Digitized by the Internet Archive
in 2007 with funding from
Microsoft Corporation

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

CONTENTS

PAGE

CITATION ON THE WORK OF CHARLES J. KUNZ, HERBERT E. GOLDBERG, AND CHARLES E. IVES*

GLENN E. MATTHEWS**

The Journal Award for 1945 has been made to Charles J. Kunz, Herbert E. Goldberg, and Charles E. Ives. Appropriate certificates were presented to them by President D. E. Hyndman on the evening of October 16, 1945, at the dinner-dance held during the Fifty-Eighth Semi-Annual Technical Conference of the Society. This award is given annually for the most outstanding paper originally published in the JOURNAL of the Society during the preceding calendar year. The title of the paper designated for this award is "Improvement in Illumination Efficiency of Motion Picture Printers," published in the May 1944 issue. The paper describes the application of condenser and reflector systems for 2 typical printers with which increased illumination efficiency is obtainable.

The three authors are members of the staff of the Kodak Research Laboratories. Charles E. Ives was born in Rochester, New York, and attended schools in that city. He has taken specialized training in the extension courses of the University of Rochester in the fields of chemistry, physics, mathematics, optics, and languages. Mr. Ives joined the Eastman Kodak Company in 1919 and worked from that date until 1940 mainly on the problems of motion picture laboratory operation. He carried out useful studies in several fields of motion picture engineering related to film processing, instrument design, printing, surface treatment of film and analysis of defects, tinting and toning, storage of film, and other related subjects.

Mr. Ives' experience was also used to plan the organization and arrangements of the film developing department. In 1940, he became a supervisor in the photographic chemistry department and has

---

continued work on specialized problems related to the progress of
the war.   During the 26 years of association with the Kodak Re-
search Laboratories, he has published 25 papers in the *Transactions*
and JOURNAL of this Society.   He also served on several committees
and assisted in the editing of the *Transactions*.

Mr. Ives lives in an unusual 3-level modern home in Huntington
Hills near Rochester and claims as his hobbies sailing, hiking, and
listening to good music.

FIG. 1.   D. E. Hyndman (right), President of the Society, presents the
1945 Journal Award to, left to right, Herbert E. Goldberg, Charles J. Kunz, and
Charles E. Ives, co-authors of the paper, "Improvement in Illumination Effi-
ciency of Motion Picture Printers."

The second author, Herbert E. Goldberg, was born in Leipzig,
Germany, and was educated in France.   He received the degree
Licencie és Sciences (B.Sc.) at the Sorbonne (University of Paris)
in 1935.   Subsequently, he continued his training in Paris and ob-
tained degrees in optical and electrical engineering at the Institut
d'Optique and the École Sup. d'électricité, respectively.   Mr. Gold-
berg joined the Eastman Kodak Company in November, 1937, and
has worked since that date as a research engineer in electronics in
the physics department.   Throughout the war he carried on special
work in this field.   He collaborated in the preparation of an unusual

article on "The Science of Color" published in *Life* for July 3, 1944. In private life, Mr. Goldberg is a great enthusiast for hiking and has spent many delightful hours on the Adirondack trails.

The third of this trio of authors, Charles J. Kunz, was born in Rochester, New York. He graduated from Villanova College in 1933 with the degree of Bachelor of Science in Chemical Engineering. After a year spent as a staff chemist with the American Chemical Products Company in Rochester, New York, he joined the film developing department of the Eastman Kodak Company. His work in this department has consisted in the design of special developing equipment, effects of agitation in motion picture developers, and the standardization and handling of photographic materials during processing operations. The results of some of these investigations have been published in several papers in the JOURNAL. Mr. Kunz enjoys photography and gardening as hobbies.

INTERMODULATION DISTORTION OF LOW FREQUENCIES IN SOUND FILM RECORDING

FRED G. ALBIN*

Summary.—*Variable-density sound film recording is subject to intermodulation distortion in the low-frequency band which extends from the lower limit of the audible spectrum toward zero, but not to zero frequency. This distortion is the result of the "Bromide Drag" phenomenon and is in the nature of exorbitant gamma. Corrections may be made for gamma at any point in this exorbitant range, but only at the sacrifice of correct gamma for other frequencies.*

The popular intermodulation method of distortion analysis uses 60 cps as a low-frequency component, which frequency lies in the exorbitant band. The data obtained thereby are representative of the exorbitant conditions and are misleading if they are taken to represent the entire recorded frequency spectrum.

The delta-db method of distortion analysis gives data representative of conditions in which the low-frequency component is zero frequency. The analysis shows, however, that the data are also representative of frequencies above the exorbitant band and, therefore, represent the general recorded frequency spectrum except for the exorbitant band.

Optimum processing specifications should be based upon data representing both conditions—outside the exorbitant band, as indicated by the delta-db method (zero frequency), and inside the band, as indicated by the intermodulation method using several frequencies around 60 cps.

Either method may be used alone for processing control data after all conditions have been determined and are known to remain constant. Practice has substantiated the merits of the principles expounded here.

"BROMIDE DRAG" PHENOMENON

Variable-density sound film processing, like processing of action photographic film, is subject to nonuniformity as the result of the release of the products of the reaction of the developer as it reduces the silver halide. The accumulation of these reaction products tends to retard the reaction by attenuating the concentration of the developing reagents, and by a definite depressing effect on the reaction itself. This accumulation of reaction products streaks downward across a photographic plate in a still processing bath, and the effects are known as "Mackie" lines. In machine development, where the

---

* Radio Corporation of America, RCA Victor Division, Indianapolis, Ind.

film is pulled longitudinally through the developing bath, the accumulation of reaction products is "dragged" to a trailing position from where it diffused from the emulsion. The accumulation of reaction products is considered as consisting effectively of bromide ions. Thus, the effect of this phenomenon is known as the "Bromide Drag Effect."

The bromide drag effects, always present to a more or less serious degree, are influenced very extensively by the processing technique. The more important factors in the processing technique are the degree of developer solution agitation relative to the lineal velocity of the film through the developer solution, and the slope of the gamma-versus-time curve at the point employed. In other words, minimum bromide drag effect is realized when the agitation of the developer solution is greatest, and when the gamma of development system nears its "infinity," or saturation; thereupon, the developing time produces a negligible increase of gamma.

An easy demonstration[1] of the presence of bromide drag can be given by means of a sample of film prepared in the following manner: A mask is prepared to cover rectangularly shaped areas of the film. These rectangular areas have a dimension in the direction longitudinal with the film ranging from $1/16$ in. upward, and are widely spaced in this direction. The unmasked area of the film is exposed with a medium value of exposure which, when developed to a gamma lower than its infinity, will have a density lying approximately at the point on the H and D curve where the slope is the greatest. A second and larger exposure is made by using a second mask which will allow exposures only of a series of rectangularly shaped areas similar in sizes and spacing to the first series. The second series is remotely spaced from the first series, but lies in the same field of medium exposure, and is heavily exposed. A third exposure about one-tenth as great as the medium exposure is given to the entire unmasked film.

This sample of film is now developed by a developing machine, fixed, washed, and dried. The resulting sample consists of a field of medium density upon which are tablets of both small and large density. Inspection will reveal that the density surrounding these tablets is not uniform with the density in the field remotely located from these tablets. (See Fig. 1.) As the film passes through the developer solution, and the reduction of the silver salt takes place by the reducing action of the developer, by-products of the chemical reaction which consist effectively of bromide ions are released. The

concentration of the bromide ions is in proportion to the amount of silver reduced, and, consequently, to the density of the image. In the field of uniform exposure the bromide concentration can be considered as uniform, but surrounding the tablets of greater exposure there will be an increased concentration of bromide. This cloud of concentrated bromide will be dragged by the motion of the film through the developer, so that it trails behind the image of greater exposure. Consequently, in the area following this image will be an
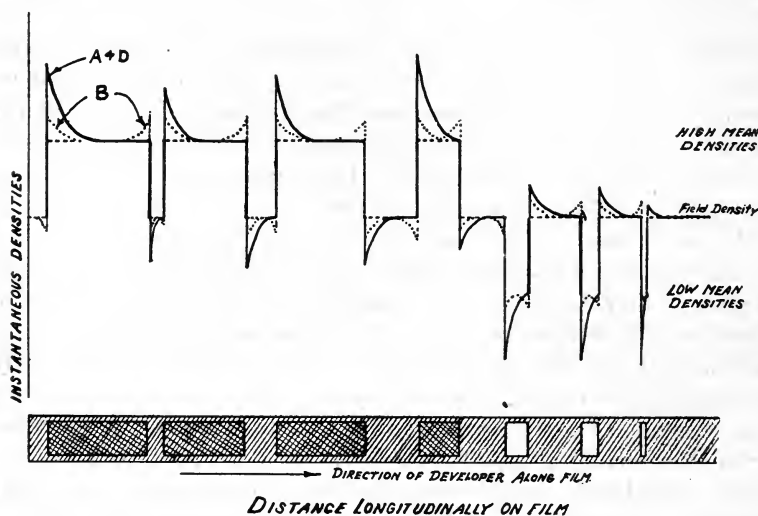
Fig. 1. Densities measured along film as a result of bromide drag in development. Exposures consist of tablets of each, high and low exposure, in a field of uniform medium exposure.

area of reduced development where the concentrated bromide ions have retarded the development, the results being lower density.

The same action as described results in the opposite effect in the area trailing the tablets of low exposure. In this instance, the area trailing the tablet of low exposure has bromide concentration lower than the average, which results in accelerated development in the region immediately following the tablet of low exposure. The tail may not necessarily be directly behind the tablet in line with the film travel. But it will be in a direction from the tablet determined by the resultant velocity of the developer relative to the film, determined by the film motion, and the prevailing motion of the developer

owing to externally created agitation. The result of this bromide drag action is effectively to increase the contrast wherein there is a greater difference in density than normal between the tablet density and the ·density of the field immediately adjacent thereto. As stated previously, this bromide drag is always present and the length of the tail following the tablet is inversely dependent upon the degree of agitation of the developer at the surface of the film.

WAVE DISTORTION

Now let us consider what occurs in the case in which we have, instead of isolated tablets, a repeated function in the form of a low-frequency wave. Such a wave on film consists of a succession of dark half-waves and light half-waves. As shown above, a dark half-wave is followed by a light tail and a light half-wave by a dark tail. If the length of a half-wave corresponds approximately to the length of the tail, a dark tail coincides with the following dark half-wave and a light tail coincides with the following light half-wave. Thus, the bromide drag has the effect of reinforcing the amplitude of the wave in a manner similar to increase in gamma. If the length of the half-wave is very great relative to the length of this tail, the tail coincides with only a small portion of the following half-wave, and the average increase in contrast for the sine wave diminishes accordingly. Likewise, if the length of the wave is very short compared with the length of the tail, the tail coincides with both light and dark halves of the cycle, and no reinforcement occurs because there is no increase in contrast between the dark and light halves of the cycle.

Experimental data to prove the foregoing theory were obtained by setting up apparatus wherein a variable-density recording machine was used in the conventional manner for sound recording so far as exposing intensity, mean exposure, type of film and processing conditions were concerned. The apparatus was set up in a manner similar to that described later in this paper as "Variable Frequency Intermodulation Setup." Recordings were made of intermodulation test signals with the low-frequency component at discrete values between zero and 200 cps.

Three such identical sets of recordings were made for processing at 3 different film laboratories, A, B, and C:

(A)   Laboratory A used a processing machine with below-normal turbulence of the developer solution.

(B)   Laboratory B used a spray type of turbulence wherein the developer was

applied to the top ends of the loops of film as the film passed over the top rollers in the tank.   The height of developer in the tank was considerably below the tops of the loops.   The developer consequently had a motion whereby it ran down both sides of the loop from the top.   Thus, as the film passed through the machine, the direction of the developer was first one way, then the opposite, along the film.

(C)   Laboratory C used relatively vigorous agitation together with a developer formula which required a relatively long time of development, thus operating at a point of low-slope on the time-gamma curve.   In other previous recordings, the speech and music quality of this processing was judged the best available.

(D)   Typical commercial laboratory on a par with A.

After processing and printing, the intermodulation recordings were reproduced through a review room reproducing system which in-
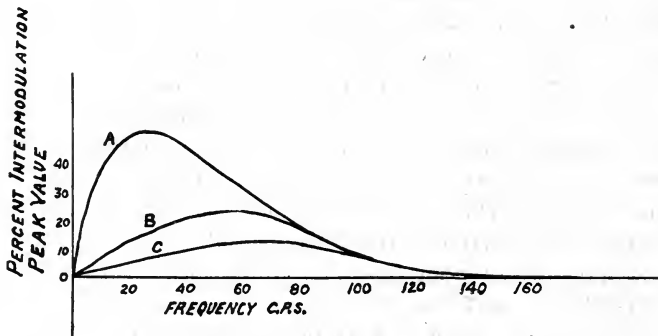
FIG. 2.   Intermodulation versus frequency of low-frequency component: A from film processed by laboratory A; B from film processed by laboratory B; C from film processed by laboratory C.

cluded a 1000-cps high-pass filter especially for this occasion.   The levels were read by means of a special volume indicator consisting of a high-speed galvanometer wherein the displacement was linear with the instantaneous amplitude of the distorted wave.   The variations of 1000-cps amplitude were taken as the data for computing distortion.   By this arrangement, true peak values of distortion irrespective of frequency and wave-form were obtained, using Formula 1.

Intermodulation apparatus in current use usually employs an indicating meter of the copper-oxide rectifier type which gives a reading approximately proportional to the average value of the distortion wave.   The distortion wave is seldom sinusoidal.   Certain equipments in current use employ a vacuum tube voltmeter circuit for the level meter which circuit has a response more nearly proportional to

the peak value of the distortion wave.   Under identical conditions of distortion, the type employing the copper-oxide rectifier type meter gives the lowest indication of distortion, the vacuum tube voltmeter type gives the next greater, and the delta-db or the high-speed oscillograph indicator type both indicating the maximum or the peak value of distortion.   The differences between these indicator values for the same sample of distortion are very large, which account for the fact that Fig. 2 displays a case of 50 per cent distortion, which would read in the order of 12 per cent by the more familiar copper-oxide rectifier type indicator.   Fortunately, as the distortion is lessened, the readings of the 3 types of meters converge, all reaching zero distortion simultaneously.   Furthermore, since it is more important to determine the conditions for minimum distortion, the absolute distortion value is unimportant except for record purposes.

The conclusions to be derived from the data obtained as illustrated by Fig. 2 are that the measured intermodulation distortion is a function of the frequency of the low-frequency component present.

An early method of determining optimum film processing is popularly known as the Delta-db Test.[2]   This test is a special intermodulation test wherein the low-frequency component is zero frequency.   It consists of the recording of a 1000-cps tone of low amplitude two or more times, using a different value of d-c bias each time.   This test has enjoyed popular favor for the following reasons:

(1)   It was the first over-all dynamic check of film processing in use.

(2)   The test can be applied without any special apparatus other than that which is part of the regular recording system, namely, a test oscillator to produce the high-frequency signal, and a bias current supply with a key for *on* and *off*, or polarity reversing.

(3)   The test can be reproduced through a standard theater or review room reproducing system with no special apparatus other than an ordinary volume indicator such as is used for usual level measurements.

(4)   The test indicates the peak value of distortion for the particular exposure excursion that corresponds to the amplitude of the low-frequency component. In this case, double amplitude of the low-frequency component is represented by the difference between the bias exposure and the unbiased exposure, or between any 2 bias exposure values which may be chosen.

(5)   A series of readings of peak distortion versus amplitude may be obtained by simply choosing a series of bias current values at which the exposures are made:

(a)   From any 2 readings taken with 2 values of bias, the effective over-all gamma, over the latitude defined by these 2 negative exposure values resulting from the 2 values of bias, may be computed very readily.   (See Formula 2.)

(b)   The toe or shoulder characteristic of either negative or positive may be de-

termined from 2 delta-db readings, one of which lies on the mid range of exposure, and the other of which lies on either the toe or shoulder. The effective over-all gamma for this region, when calculated, is a measure of the slope of the toe or shoulder. Corrections as desired may be made by shifting the mean density, thereby shifting the density range employed for recording either on or off the toe or shoulder as conditions require.

Investigation as to the causes of film distortion discloses the following possible contributors:

(1) Recording amplifier and system—nonlinear characteristics.
(2) Recording modulator device—nonlinear characteristics.
(3) Film latent image spread of negative.
(4) Negative gamma:
    (a) Average value.
    (b) The instantaneous variation of nonlinearity of H and D curve.
(5) Bromide drag or Eberhardt effect on negative.
(6) Printer distortion.
(7) Latent image spread of positive.
(8) Positive gamma:
    (a) Average value.
    (b) Instantaneous variation or nonlinearity of H and D curve.
(9) Bromide drag on positive.
(10) Reproducer contrast coefficient.
(11) Photoelectric cell—nonlinearity.
(12) Reproducing amplifier and system–nonlinearity characteristics.

Items *1, 2, 4, 8, 10, 11,* and *12* may be considered as having nonlinear characteristics independent of the frequency of the low-frequency component of the intermodulation test. The remainder can be proved to introduce distortion with magnitude dependent upon the frequency.

The 2 items which are probably the contributors of the greatest distortion dependent upon frequency are items *5* and *9,* and the figures given show that the magnitude of this distortion is considerable. The remainder of the discussion will be confined largely to these 2 items. It might be mentioned that the existence of these 12 sources of possible distortion justifies the intermodulation method of distortion measurement and makes inadequate any static method of checking of film processing.

Another interesting sidelight is that any one of the 12 contributing sources measured alone might indicate a distortion higher than the aggregate of the twelve. This would indicate that there is a very decisive compensating effect present. Some of these sources are very obvious and well known to film technique. For example, it is com-

mon knowledge that small variations of negative gamma (item *4a*) can be compensated for completely by proper adjustment of positive gamma (item *8a*).   It also happens that items *10* and *11* have effects very similar to items *4a* and *8a*, so that the nonlinearity of the aggregate of these four may readily be canceled out.

RECORDING PRACTICE

In recording practice for motion pictures, the frequency spectrum lies between 50 cps and 8000 cps, these limits being established by appropriate high-pass and low-pass filters.   The attenuation by the high-pass filter for frequencies below 50 cps is very large, hence the signal energy below this cutoff point is negligible.   However, the action of ground noise-reduction facilities is to impress upon the film exposing illumination a modulating frequency equivalent to the envelope frequency, which frequency extends down to zero.   In view of this condition, the effect of the low-frequency component lying in the band between zero and 60 cps might very well be considered.

As all frequencies ranging from zero cps upward are encountered in recording practice, the question arises as to what frequency should be used for testing intermodulation distortion.

The intermodulation test which is in popular use employs a single low frequency of 60 cps for the low-frequency component, which frequency lies definitely within the range of exorbitant gamma.   The results obtained thereby are representative of conditions at the one frequency only and not of the average conditions for the recording spectrum.   It would seem probable that the preferred frequency would not lie in the range from 30 to 60 cps, which frequencies lie near the region of maximum distortion for a typical laboratory, (*A* or *D*).   Neither would it seem logical to choose a frequency above 100 cps.   It would, of course, be very desirable to improve the film processing technique so that the distortion, as illustrated by Fig. 2, could all be held to very low values; in such a case the choice of frequency would be unimportant.

It is apparent that the delta-db test is also inadequate for providing the information as to conditions within the frequency band where the bromide drag effect is prevalent and the gamma is exorbitant.   In the present state of the art, the curves for laboratories *A* and *D* represent typical conditions and although not desirable, do prevail, and a choice of test frequency must not be made arbitrarily.   There is no choice but to explore the low-frequency region to determine the

conditions prevailing, and strive to obtain a compromise for optimum over-all processing conditions.

VARIABLE FREQUENCY INTERMODULATION SETUP

Signals of frequencies much lower than 50 cps cannot be passed satisfactorily by the speech transmission circuits. The ground noise-reduction circuits will pass signals of frequency extending down to zero cycles, and may be used as a means of communicating low-frequency modulations to the film. An amplitude-modulated 1000-cps signal may be generated at the input of the ground noise-reduction amplifier by beating together 2 signals of frequencies that differ by the amount of the low frequency required. The ground-noise rectifier system acts as a detector to produce the required low frequency, which is then applied to the shutter, valve, or other device, normally used as a mean exposure control for noise-reduction purposes.

A suggested equipment setup is outlined as follows:

(1) Set up the recording system in the normal manner with noise-reduction facilities. Set the exposing lamp intensity so that the exposure range with full modulator excursion lies within the linear latitude of the film.

(a) Full modulator excursion will be referred to as 100 per cent modulation,[3] with peaks extending to zero and 100 per cent exposure.

(b) The mean (unbiased) exposure is 50 per cent.

(c) "Bias" mean exposure, for noise reduction, is referred to by its ratio to the unbiased exposure. Noise-reduction decibels are 20 times the common logarithm of the ratio of unbiased-to-bias exposures.

(2) Adjust the system to allow a minimum of 6-db "reverse bias."[4] This means that as the input level to the ground noise-reduction amplifier is increased, the mean exposure will increase linearly until at least 100 per cent is reached.

(3) Set the bias for 4.7-db noise reduction.

(4) Set the gain of the ground noise-reduction amplifier for 12-db margin.

(5) Introduce a signal of 1000 cps into the system with a level of −16 db relative to 100 per cent modulation.

(6) Introduce a second signal into the input of the ground noise-reduction amplifier (but not into the recording amplifier) in a manner which adds the amplitude of the second signal to the first. The amplitudes of the first and second signals at the point where they are added must be equal if the specified bias and levels are used. The wave-form of the low-beat frequency would be more sinusoidal if these 2 signals were widely different, requiring new bias and level values. The frequency of the second signal shall be variable from the same frequency as the first (1000 cps) to 200 cps greater.

(7) The wave filter normally incorporated in the ground noise-control apparatus would effectively limit the low-frequency component to a frequency below 30 cps. Therefore, it is necessary to replace this filter with one with a higher cutoff frequency. It is important to retain a filter with cutoff frequency below

1000 cps so as to eliminate the 1000-cps signal. The cutoff frequency of this filter should preferably be not greater than an octave above the low frequency so as to remove the sidebands and leave only the fundamental sine wave of low frequency. Thus, the wave produced by beating the 2 signals need not necessarily be sinusoidol.

The above described setup will apply to the film an intermodulation test consisting of a 1000-cps signal superimposed on a low-frequency signal of 12-db higher amplitude. The peak excursions of the complex wave lie between the limits of 10 per cent and 90 per cent exposure, which is as great an excursion as should be used for intermodulation tests. The low-frequency signal may be varied in frequency at will between zero and 200 cps, for initial tests of new processing conditions. Afterward, the range may be narrowed down, eventually resolving to a single frequency, such as zero or 60 cps which can be obtained more readily. If the relationship between characteristics may be safely assumed to remain fixed, any point may be chosen as a control point for the routine checking of processing. Recordings are made at discrete low-frequency values from zero to 200 cps.

The resulting recordings are processed and printed in the normal manner and reproduced in a standard sound reproducing system. The output levels of the recordings made with extremely low frequencies may be read on a standard high-speed rectifier-type volume indicator, no special analyzer, filter, *etc.*, being required. The reproducer amplifier system will not pass frequencies much below 30 cps and it therefore acts as though a high-pass filter were included. Conditions free from distortion will give a steady reading on the meter, since the meter reads the unmodulated 1000-cps tone. The amplitude of the excursion of the meter is a measure of the intermodulation distortion.

Formulas 1 and 2 may be used to compute the harmonic distortion and effective over-all gamma, respectively, where R_1 and R_2 are the minimum and maximum meter readings, in decibels, of the fluctuating meter readings.

Where R_1 = VI reading (db) at exposure E_1
      R_2 = VI reading (db) at exposure E_2

Per Cent Harmonic Distortion (peak value) = antilog $\dfrac{R_2 - R_1}{20} \times 100$ per cent   (1)

Effective Over-all Gamma = $1 - \dfrac{R_2 - R_1}{20 \log_{10} \dfrac{E_2}{E_1}}$ (2)

If the suggested setup values were used:

$$\frac{E_2}{E_1} = \frac{90}{10} = 9 \text{ and } 20 \log 9 = 19.1 \text{ db.}$$

In determining effective over-all gamma,[5] it is important to identify R_1 and R_2 with respect to E_1 and E_2. Here the advantage of the use of zero frequency is obvious, wherein E_1 and E_2 are recorded in a prechosen sequence and R_1 and R_2 are read in the same sequence.

When the low frequency is near to, or higher than, the resonance frequency of the indicating meter, the readings are not reliable. For these higher frequencies, a cathode-ray oscilloscope together with a 500-cps high-pass filter may be used as an indicator to replace the rectifier-type meter. The resulting wave will be a 1000-cps wave modulated in amplitude in accordance with the magnitude of the distortion. The amplitudes may be scaled from the cathode-ray oscilloscope image, and the distortion computed therefrom.

CHOICE OF CONTROL FREQUENCY

That component of intermodulation distortion which results from improper contrast or gamma can be canceled completely; for instance, by proper choice of negative gamma. Thus, processing conditions may be chosen to result in minimum distortion at any arbitrarily chosen low frequency. It would seem logical to choose conditions which will reduce the average distortion to minimum, under which the greatest departure from the minimum would be reduced.

By extensive listening test, wherein the processing was regulated to give minimum distortion at the points lying between the distortion zero cps and 60 cps, it has been determined that the optimum condition has been obtained lying approximately midway between zero and 60 cps. Such a frequency is odd, and cannot be obtained as readily as zero or 60 cps are now obtained with existent facilities. Instead of choosing such a frequency for routine checking at processing, it is perfectly practical to make the measurement at either zero or 60 cps, and interpolate the data for the case represented by this intermediate frequency. This practice is now being followed by certain Hollywood studios. As pointed out earlier in this discussion, the distortion evident at 60 cps as compared with zero cps, is equivalent to the distortion resulting from excessive contrast or gamma. With this condition known, it is perfectly practical to make the measurement at zero cps, but with an over-all gamma slightly lower than optimum for the

frequency.   This correction is in the order of 10 per cent.   Also, it is perfectly practical to make the measurement at 60 cps and use an over-all gamma slightly higher (10 per cent) than the optimum for this frequency.   This technique has been followed in practice with good results.   (See Figure 3.)
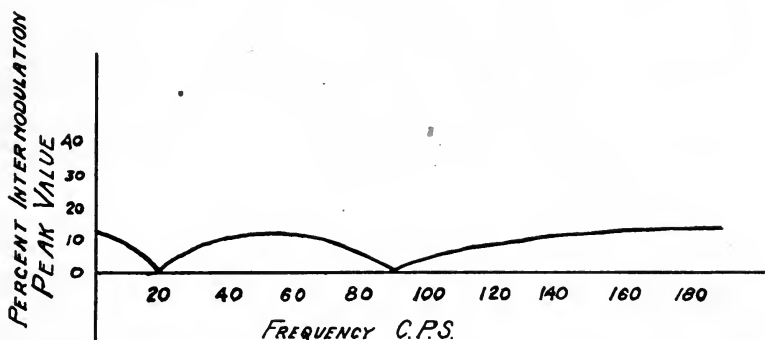
FIG. 3.   Intermodulation versus frequency of low-frequency component: Film from laboratory *B;* process adjusted for lowest average intermodulation distortion.

REFERENCES

[1] LESHING, M., INGMAN, T., AND PIER, K.: "Reduction of Development Sprocket Hole Modulation," *J. Soc. Mot. Pict. Eng.*, **XXXVI**, 5 (May, 1941), p. 475.

[2] ALBIN, F. G.: "A Dynamic Check on the Processing of Film for Sound Records," *J. Soc. Mot. Pict. Eng.*, **XXV**, 2 (Aug., 1935), p. 161.

[3] The reference to 80, 100, or any percentage modulation of the light modulator has little significance.   Reference to per cent modulation of variable-density film has no significance at all.   If a modulator such as a light valve, deflected penumbra, or glow lamp, has fixed average intensity, the modulation may be then stated definitely in terms of percentages of complete or 100 per cent modulation.   In this case, 100 per cent modulation is that level at which the amplitude of the wave is equal to the average or mean value of light intensity in which case the excursion of light intensity extends from zero to double the mean.

The use of bias (for ground noise reduction) and reverse bias (for level range extension) has complicated this concept.   However, for a reference point, some arbitrarily chosen mean value of light intensity is established, and the percentage modulation is referred to this.   The use of this mean value and 100 per cent modulation thereof imposes upon the film an excursion of exposure which the film may accommodate with reasonably low distortion.   This is the customary procedure in studio recording practice.   The percentage modulation values referred to herein are so reckoned.

[4] Hansen, E. H., and Faulkner, C. W.: "Mechanical Reversed-Bias Light-Valve Recording," *J. Soc. Mot. Pict. Eng.*, **XXVI**, 2 (Feb., 1936), p. 117.

[5] The over-all effective gamma determined in this manner is the gamma of a simple curve,

$$T_\mathrm{p} = KE_n{}^\gamma$$

having only a single value of gamma, which curve includes the 2 points used for the computation of gamma. Generally, film characteristics as used in practice involve not only the straight portion of the H and D curve, but the toe and shoulder as well. The positive film H and D toe region is extensively used in variable-density sound recording. The curve involving both the straight line and toe portions requires multiple values of gamma for expression. To express such a curve in terms of gamma, and to take delta-db data to compute gamma, requires that the curve be scanned in short increments. The gamma for each increment as defined by 2 exposure values should be calculated by use of Formula 2.

In practice it has been learned that the over-all effective gamma should not exceed unity to any appreciable extent in any portion of the film characteristic curve. Gamma in excess of unity is equivalent to expansion, and is particularly deterimental to speech intelligibility. Compression in the same degree is acceptable. Thus, if low and medium level recordings, made with ground noise reduction, are confined to the straight portion of the H and D curve (which portion has an over-all effective gamma of unity or only slightly higher), the higher level recordings will extend into the region of the toe of the positive H and D curve where the gamma is lower and some compression is encountered. This is the preferred condition of variable-density recording technique.

For routine checking, 3 delta-db control points are required; the first at bias value of exposure, the second at unbias, and the third at reverse bias. The gamma as computed from the first two should lie between unity and 5 per cent greater. The gamma as computed from the second and third should lie between unity and 10 per cent less than unity.

The ability to check these 2 ranges separately is a unique advantage enjoyed by the delta-db test over the intermodulation test. For this paper, the term "Effective Over-all Gamma" has been adopted to represent the exponent of the over-all response curve, which is plotted with the current in the modulator as the abscissa and the photocell output current as ordinates. Effective over-all gamma thus includes all factors in the system which affect contrast or linearity, and is the figure which must be reduced to unity for linear performance of the system. The use of the term gamma in this manner has aroused some criticism, but the criticism is based upon academic rather than practical considerations.

A SYSTEM OF LENS STOP CALIBRATION BY TRANSMISSION*

EMMANUEL BERLANT**

Summary.—An apparatus is described for the measurement of relative transmission of photographic objectives, consisting of a controlled light source, condensing system, lens mount, integrating sphere, photo cell, and meter. Transmission characteristics of 100 typical objectives are presented, together with a proposed standard method of calibration that will reconcile present practice and equipment with future problems involving low reflectance coatings and objectives designed with high index glasses.

With the increasing accuracy of exposure required by color photography and closely controlled monochromatic photography, interest in illumination characteristics of lenses has increased to the point where need for a system that would eliminate transmission variation from lens to lens has become manifest. Any system proposed for general adoption must be based upon:

(a) A standard of calibration reproducible from a mathematical premise,

(b) Correlation to current calibration practice, to avoid disturbance of film speed data and enable use of the new system with exposure meters and exposure data now in existence, and

(c) Correlation to geometrical aperture ratio calibration, to permit use of depth of field tables, and other pertinent data based upon geometrical aperture ratios.

It is well known[1] that the illumination of an image is indicated by the formula

$$E = kB \sin^2 \theta$$

wherein B = brightness of object plane

θ = angle formed by edge ray and axial ray of lens

k = transmission loss factor

The geometrical ratio of focal length to entrance pupil now used as a method of calibration fails to take into account variation of the

---

loss factor k.   This loss factor not only varies from design to design, but from lens to lens of the same design and manufacture.   Further consideration must be given to the angle of coverage involving lenses of different focal length.   For detailed consideration of the importance and extent of illumination variance resulting from this cause alone, reference is made to G. Slussareff[2] and F. Benford.[3]

A photographic objective of large aperture also shows a marked deviation from the theoretical relationship existing between various geometrical apertures, owing to the change of surface reflection losses with the change of angular presentation of various zones of the lens. The extent of this deviation will be indicated in another part of this paper.
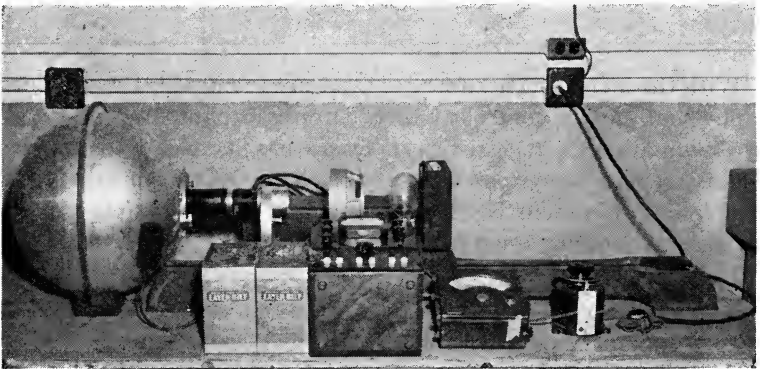
FIG. 1.   View of apparatus.

Photometric methods of calibration may be used to integrate these phenomena and permit the matching of transmission values of various lenses of various focal length, with provision for the best balance of axial zone to edge zone levels of illumination commensurate with good practice.

A method of photometric calibration described by D. B. Clark and G. Laube[4] involved the selection of a lens which is arbitrarily denominated as having a certain effective stop value wide open, based upon its geometrical ratio of focal length to effective aperture.   Light from a diffuse plane surface is passed through the lens, and limited by an academy aperture in the focal plane of the lens.   The lens is then calibrated by decreasing the illumination by an amount in ac-

cordance with the theoretical mathematical progression of f/stop transmission by closing the diaphragm, and marking the indicated position of the diaphragm ring.

This method results in a consistant progression of integrated illumination value, and other lenses may be matched to this standard. However, it is obvious this method suffers from the necessity of reference to the arbitrary standard selected, and is therefore not feasible of extension beyond reach of the standard lens, except by the use of secondary standards, always an objectionable technique. A method described by E. W. Silvertooth[5] is based upon measurement of axial intensity, and uses as a basis of calibration an arbitrary aperture selected to correspond to the focal length of the lens being calibrated, and making an arbitrary allowance for losses to be expected within the system. While this method permits reconstruction of the standard selected, it requires creation of a new standard for each focal length, and makes no provision for extra axial illumination characteristics.

It was decided that any standard proffered by this laboratory would have to be based upon a method of absolute transmission, and the problem was attacked from that direction.

Extensive use was made of work on transmission losses of optical systems as described by D. B. McRae, and the apparatus used was developed as an extension of that used in his investigation of transmission losses (Fig. 1).

A 1000-w projection lamp was coupled to a voltage controlled line, and a beam of light condensed upon an opal glass masked by an academy aperture. The light from this aperture was admitted into an integrating sphere, and measured by a vacuum photocell and precision microammeter (Fig. 2).

The lens to be measured is placed into a turret-type mount bored out to receive several different types of lens mounts, with a proper registration depth to the plane of the aperture (Fig. 3). The light passed through the lens is then admitted into the integrating sphere, where it is measured as a proportion of the total flux at the aperture.

One hundred lenses of the highest quality, of all focal lengths from 35-mm to 165-mm, were measured in this apparatus, and the results plotted as given in Fig. 4. The ordinate is the f/stop as calibrated by the manufacturer, and abscissa is the transmission of the lens in terms of thousandths of unity of aperture flux, as measured by the described apparatus.
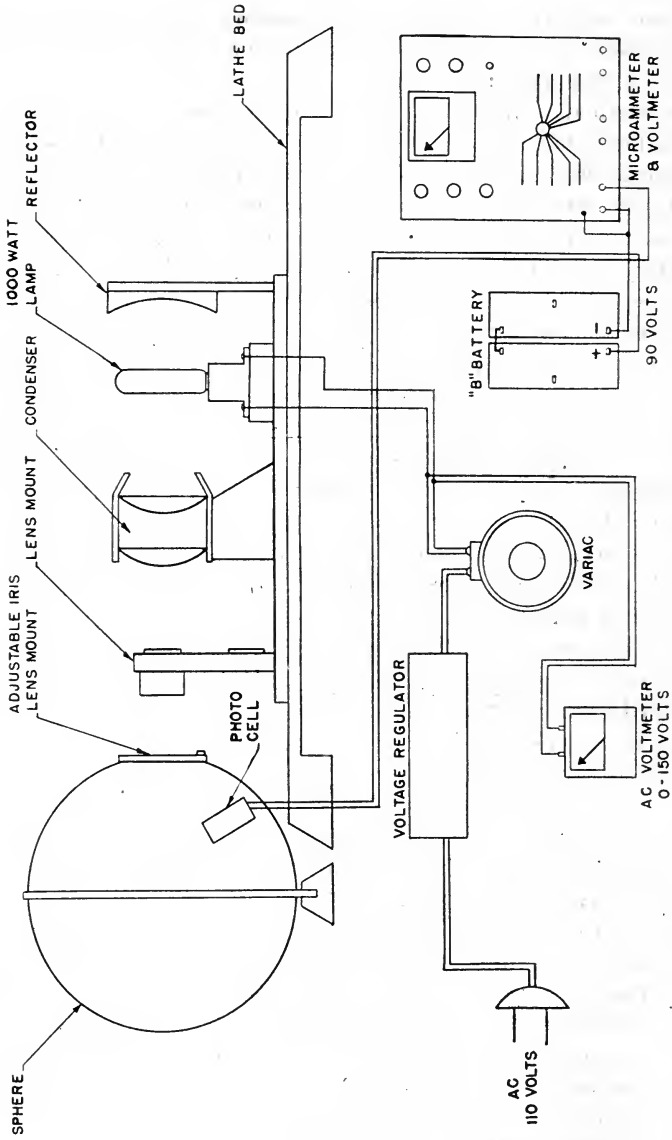
FIG. 2.   Lens transmission integrator.

Of immediate note is the wide spread of transmission values for various lenses of the same calibrated f/stop. This is not because of a difference in focal length alone, as may be verified by reference to Table 1, wherein lenses of short focal length are seen to have equal and higher transmission values than lenses of longer focal length. Some of these lenses showing extreme values for a given calibration were checked by the Steinheil method[6] to verify their geometrical ratio of focal length to aperture, and were found to be of good commercial accuracy.

The average transmission value for each group of f/stops is indicated in Fig. 4 as "Mathematical Average." It is of interest to note that a $\sqrt{2}$ progression from the smaller f/stops toward the larger f/stops indicates a failure of the geometrical aperture ratio calibration method, owing to the progressively greater surface reflection losses for outer zones of lenses of larger relative aperture and accords with observations on the subject made by L. C. Martin.[7]

A. C. Hardy and F. H. Perrin,[8] in their discussion of the photometry of optical systems, note that

FIG. 3.   Turret-type lens mount.

a photographic objective should transmit about one per cent of the object brightness at f/8. This point has been indicated in Fig. 4. Measurements with this apparatus indicate an average transmission of one per cent for f/4.7. A line based upon a slope angle of $\sqrt{2}$ progression drawn through this point is offered as a basis for photometric transmission calibration. This standard is in accordance with actual use, and will not require revision of film speeds now in use, nor will it obsolete exposure meters now in use. Tables of exposure based upon published data are also valid for use with this system.

It is advocated that lenses be marked with the geometrical f/stop value in its usual place upon the manufacturer's identification ring, and the diaphragm setting ring be calibrated in accordance with the
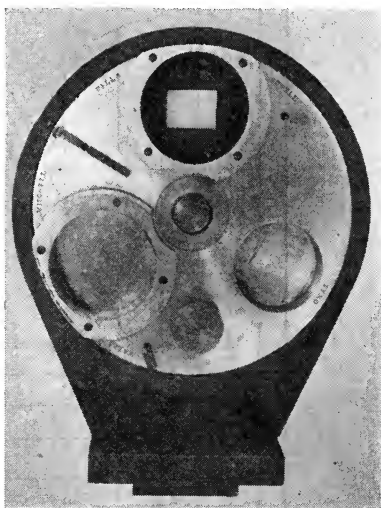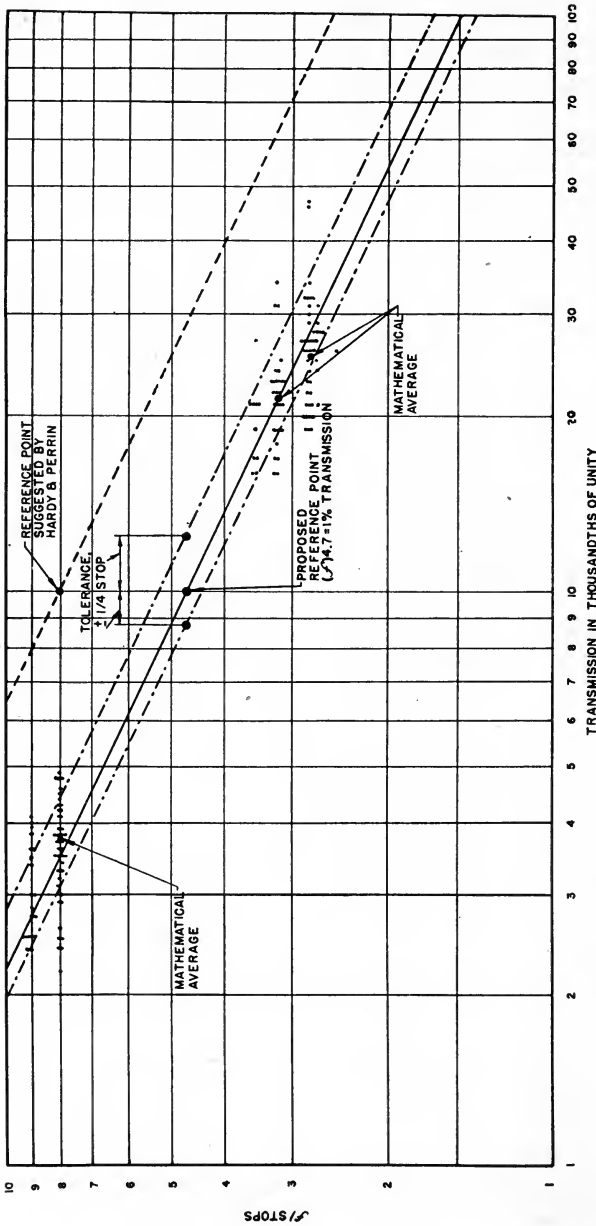
FIG. 4.   Transmission characteristics of 100 photographic objectives of good quality.

t/stop, or transmission value, shown in Fig. 5. This value is based upon a $\sqrt{2}$ progression through the point one per cent of transmission equals t/4.7. This indication of the relationship existing between transmission value, or t/stop, and focal length to effective aperture ratio, or f/stop, will function as a basis for a correction factor in using tables of depth of field, *etc.*, where greater than normal accuracy is required.

TABLE 1

Transmission in Thousandths of Unity for Calibrated f/Stops

Lens No.*	Mfr.	Focal Length in Mm	f/2.8	f/8
1	A	100.0	24.8	3.5
2	B	75.0	45.7	7.6
3	B	75.0	32.4	4.8
4	B	75.0	31.9	5.6
5	C	75.0	26.7	4.2
6	C	75.0	25.7	3.2
7	C	75.0	20.9	2.5
8	A	75.0	25.2	2.9
9	A	75.0	26.7	3.7
10	C	52.0	26.7	3.0
11	C	52.0	27.6	4.5
12	B	50.0	31.9	4.6
13	B	50.0	26.7	3.8
14	C	47.0	19.0	2.9
15	D	41.0	20.0	4.8
16	A	40.0	19.5	2.4
17	B	37.5	23.8	4.1
18	A	35.0	29.0	5.4
19	A	35.0	22.8	3.1
20	A	35.0	21.7	3.9

* These 20 lenses are selected at random from 100 lenses measured.

The validity of this approach is verified by the measurement of lenses calibrated by Technicolor to an arbitrary standard, which paralleled this standard within slightly more than $^1/_4$-t/stop, and measurement of a lens calibrated by Twentieth Century-Fox to an arbitrary standard, which fell wholly within the $^1/_4$-stop tolerance advocated for accuracy of calibration.

In summation, it is believed that adoption of this t/stop system will permit universal calibration of lenses, coated or uncoated, in a manner that will enable their use with current emulsion speed values and exposure meter equipment, with a minimum of mental adjust-
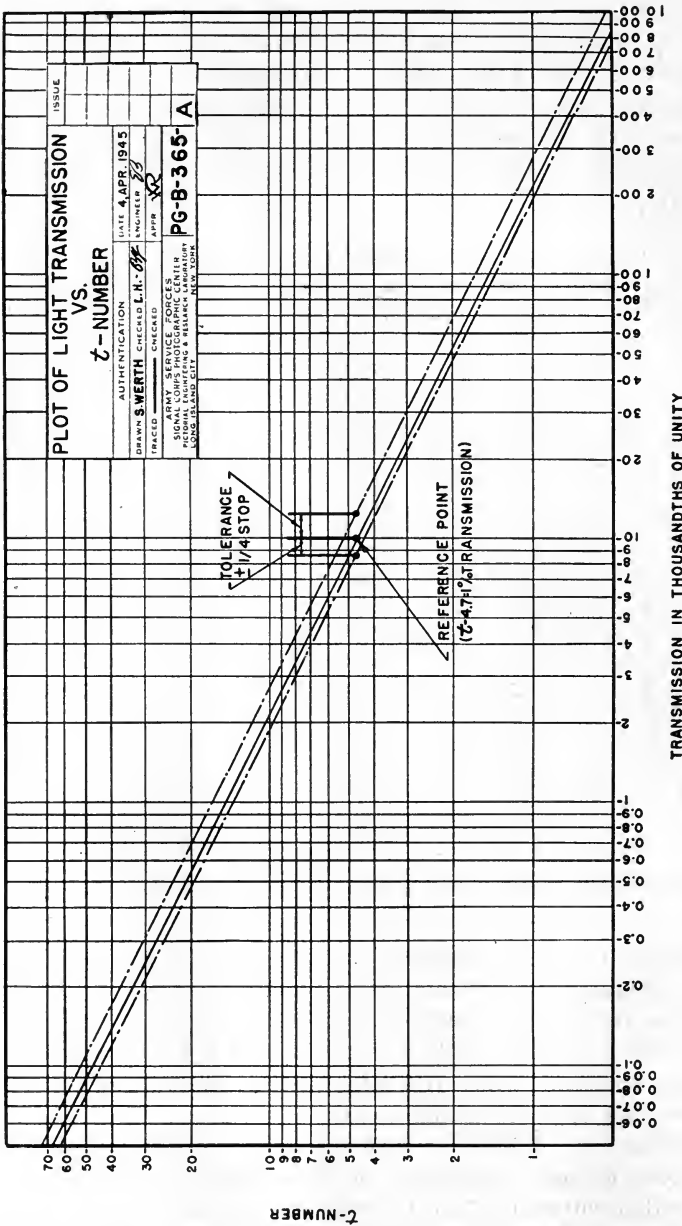
FIG. 5. Suggested basis of transmission calibration.

ment, and a maximum of exposure accuracy. It eliminates confusion relative to allowance for exposure in the case of coated objectives, yet retains a basis for computing accurately optical relationships based upon f/stop values.

In the case of objectives intended for use other than with motion picture apertures, it is suggested the plate size to be covered be used as a limiting aperture, in order to establish an optimum exposure value for all parts of the negative.

I wish to express appreciation to the personnel of the Pictorial Engineering and Research Laboratory Division of the Signal Corps Photographic Center, New York, for their participation in the preparation of this paper.

REFERENCES

[1] McRAE, D. B.: "The Measurement of Transmission and Contrast in Optical Systems," *J. Opt. Soc. Am.*, **33**, 4 (Apr., 1943), p. 229.

[2] SLUSSAREFF, G.: "Brightness of the Image Formed by Wide-Angle Objectives," *J. Phys. U.S.S.R.*, (1941), p. 537.

[3] BENFORD, F.: "Illumination in the Focal Plane," *J. Opt. Soc. Am.*, (May, 1941), p. 362.

[4] CLARK, D. B., AND LAUBE, G.: "Twentieth Century Camera and Accessories," *J. Soc. Mot. Pict. Eng.*, **XXXVI**, 1 (Jan., 1941), p. 50.

[5] SILVERTOOTH, E. W.: "Stop Calibration of Photographic Objectives," *J. Soc. Mot. Pict. Eng.*, **XXXIV**, 2 (Aug., 1942), p. 119.

[6] LOCKETT, A.: "Camera Lenses," Isaac Pitman & Sons, Ltd. (London), 1938, p. 46.

[7] MARTIN, L. C.: "An Introduction to Applied Optics," Isaac Pitman & Sons, Ltd. (London), 1932, p. 206.

[8] HARDY, A. C., AND PERRIN, F. H.: "Principles of Optics," McGraw-Hill Book Co. (New York), 1932, ch. 19.

ARMY FILM DISTRIBUTION AND EXHIBITION *

ROBERT A. KISSACK, JR.**

Summary.—The U. S. Army has become the largest distributor of motion pictures in the world. This paper describes the system of exchanges which handled distribution and reviews the contributions made by motion pictures to the war effort.

The success of the Army film program is in large measure attributable to the cooperation given by the motion picture industry and the motion picture engineers.

The Army has become the largest distributor of motion pictures in the world. This should not be a challenging statement to make even here in the capital of the motion picture industry, because it has been with the cooperation of the motion picture industry that Army film distribution and exhibition is so world wide in scope.

Army film work is the responsibility of the Army Pictorial Service whose primary mission is the production and distribution of motion pictures, film strips, and still pictures.

Army Pictorial Service motion picture production includes all training films authorized by the Army Service Forces and the Army Ground Forces and all orientation, information, and education films required by the Army. Industrial incentive, historical, and campaign films are produced at the direction of the Bureau of Public Relations, while certain special and foreign language films are produced for the General Staff.

Since the Army Pictorial Service produces films at the direction of other War Department agencies, no completed picture may be released without the approval of the initiating agency. The requirements of such agency also determine the method and extent of distribution of completed motion pictures, while the number of prints distributed for showings within the Service Commands and Theaters of Operation is based on the requirements of the respective Commanding Generals.

Many completed pictures are intended for release outside the

Army. Some are shown to workers in war plants throughout the country and are released with the approval of the Bureau of Public Relations. Other pictures intended for general public information and civilian morale are released through the War Activities Committee of the motion picture industry.

When the war started the accent was on training, and the job of film distribution was to cooperate in that huge task of starting to train an army by the quick and efficient visual aids methods of training films and film strips. First a system of film exchanges, or film libraries, was organized throughout the Service Commands of this country, a system which included 10 central exchanges and over 200 subexchanges. Personnel were trained and assigned to these libraries as visual aids coordinators, and procedures for film distribution, projection, and film exchange operation were standardized and incorporated in Army supply procedures. Military instructors were assisted by traveling teams of visual aids experts, and by catalogs and publicity material on new films. Research studies were instituted which provided highly important operating statistics on projection equipment and print utilization.

As the Army went overseas, similar training film exchanges were set up in all overseas theaters. Meanwhile, the Overseas Motion Picture Service was handling the distribution of 16-mm prints of entertainment films contributed by the motion picture industry for free showing to U. S. troops overseas. Today, the film libraries and the film and equipment exchanges form a coordinated distribution network over the entire globe serving the Armed Forces with a wide variety of films.

For example, each week a special version of the latest combat footage received from all fighting fronts is rushed to the General Staff, to the Commanding Generals of every overseas theater, and to the Commanding Generals of the Service Commands.

Each week prints of a film called *Combat Bulletin* are circulated overseas and domestically as a military newsreel, a factual document of great interest to officers and troops of all services.

To instruct troops in the strategy and tactics of warfare there are the Training Films and Film Bulletins, released on the average of one every week. Each of these must be considered a separate case, distribution and print allocation depending upon a specified audience, upon troop strength and dispersion, and upon "play-off" time. Some special technical films are limited to only a dozen prints, others of

general nature, such as military courtesy or personal health, where required showings are directed by the Army, may be sent to many posts, camps, and stations for repeated showings to all military personnel. Distribution of the Surgeon General's reconditioning films has become increasingly important of late and has required the establishment of new subexchanges in hospitals throughout the country.

There are Information and Education films which were distributed to troops overseas long before VE Day and were held in film exchanges throughout the world for that victorious moment—films which are now being shown to troops to explain demobilization and redeployment plans and also the Army's training program for return to civilian life.

The industry's gift of entertainment film to the troops overseas has proved to be, as everyone knows, one of the finest morale factors of this war. Three complete programs are sent out each week to 21 overseas exchanges. Reports of audience reaction are regularly obtained and guide a selection board in the choice of pictures that most soldiers, sailors, and marines like the most. There have even been overseas world premières—gala performances in the fox-hole circuits before release of the pictures back home.

Thus, the type of film subject, the type of audience, and other variable factors, determine the best distribution policy. Some films are planned for circuiting throughout many installations and to large audiences, some are sent to exchanges for spot-booking to specific users, and some permanently allocated for recurrent needs. Whenever possible, rebookings and second-run circuits, such as programs for transports and hospital ships, are utilized. Wherever feasible, mutual print loans are accomplished among the Navy, the Air Forces, and the Army. Always the criterion is: the fewest prints that will do the job adequately. Well aware of the vast footage requirements of the Armed Forces, the Army has a natural desire to utilize available footage allocation as efficiently as possible. With the complete statistical information reported monthly by all central exchanges and libraries, requests for initial distribution of new subjects and for reordered prints are viewed searchingly in the light of utilization reports. The result of these efforts has been a huge conservation of motion picture raw stock.

Army Pictorial Service also provides projectors as well as films. Although it does not exhibit pictures to the troops, part of its function is to serve as a clearing house for information on equipment allocation

and use. In the early days there were not enough projectors to go around. Many and all models were pressed into use. The problem was particularly critical overseas where conditions were so rugged that projectors took an awful beating. Damp humid climates, extremes of heat and cold, rain, sand and dust, continuous operation, and terrible transportation difficulties were too much for equipment designed for home use. Replacement parts were not only scarce, they were often unavailable.

Yankee ingenuity was the only thing that made it possible for the show to go on. Equipment was cannibalized, new projectors and amplifiers assembled from parts of many others. Public address equipment was hooked into projector sound systems. Tail-light bulbs from jeeps became almost standard exciter-lamp replacements. To furnish a brilliant picture and adequate sound for large audiences a 35-mm arc projector was completely dismembered, remodeled, and combined with a 16-mm machine.

Meanwhile, motion picture engineers came to the rescue. Projection models and parts were standardized. Design was made sturdier for operation and for transportation under extreme conditions. Equipment was fungus-proofed. Standardized replacement parts began rolling off the line. Today the Army projector situation is in pretty fair shape. Yet much still needs to be done to increase the quantity, the quality, and the suitability of 16-mm projection equipment for changing needs.

The distribution and use of films produced by Army Pictorial Service has contributed to many phases of the war effort:

(1) Orienting troops in the background and causes of the war;

(2) Instructing troops in the strategy and tactics of warfare;

(3) Fostering morale by information and entertainment films;

(4) Study of current operations by the Army high command for future planning;

(5) Research and analysis of American and enemy equipment for improvement of equipment supplied to our troops;

(6) Reconditioning convalescent soldiers and counseling men ready for discharge from the Army;

(7) Informing the general public in the United States of the progress of the war;

(8) Providing civilian workers with pictorial evidence of the Army's production requirements.

In conclusion it must be repeated that the success of this program is in large measure attributable to the invaluable help and cooperation of the motion picture industry and the motion picture engineers of this country.

AN ANALYSIS OF THE COMPARISON OF BEAM POWER AND TRIODE TUBES USED IN POWER AMPLIFIERS FOR DRIVING LOUDSPEAKERS*

JOHN K. HILLIARD**

Summary.—*This paper is a description of a study of 2 types of output power tubes used to drive loudspeakers. Since the introduction of beam power tubes several years ago, engineers have not been in agreement that they gave comparable results to the low impedance triode type tubes. The comparison was made on 15 and 40 amplifiers. The results indicate how both types of tubes can be made equivalent and intermodulation curves on all amplifiers are shown. Signal-to-noise ratios are also given.*

Several years ago when the beam power tube was introduced, designers began using this tube because of its high power output, high power sensitivity, and high efficiency. These outstanding features, however, caused several important disadvantages, the most important of all being its apparent high distortion when working into a loudspeaker. This distortion was reduced considerably, however, by the application of negative feedback.

Comparisons with low-impedance triode tubes led to a widespread belief among a large group of engineers that the beam power tube could not compete in high-quality reproduction with the triode.

This skepticism about the use of the beam power tube was apparently justified in a great many cases and as a result, tests were conducted to determine if the 2 types of tubes could give comparable results.

The desire to use the beam power tube instead of the triode arose because of the advantages of high efficiency, high sensitivity, and an indirect heater cathode which gives less hum than the high power filamentary-type triode.

Since the intermodulation method[1] of testing amplifiers appears to have the best correlation with actual listening tests, it was used for testing the 2 types of tubes.

---

* Presented May 14, 1945, at the Technical Conference in Hollywood.
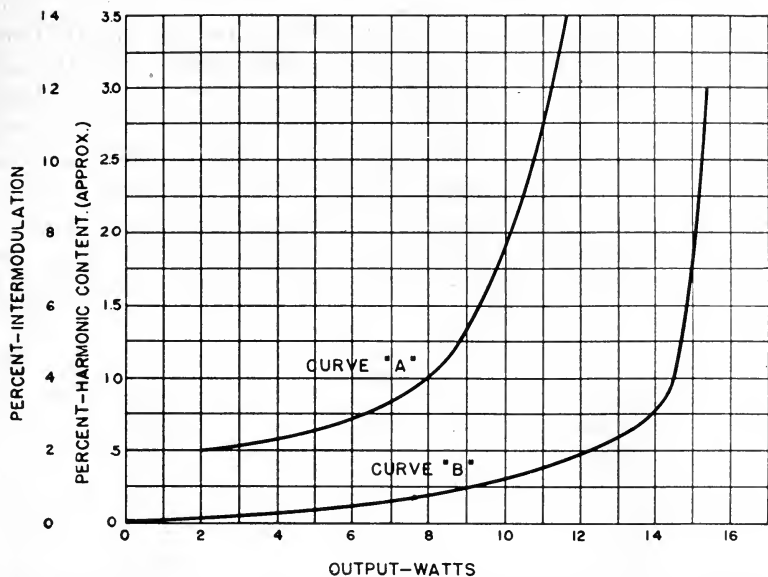
** Altec Lansing Corporation, Hollywood.

FIG. 1.   Curve *A—2A3* triode amplifier; Curve *B—6L6* beam power amplifier.
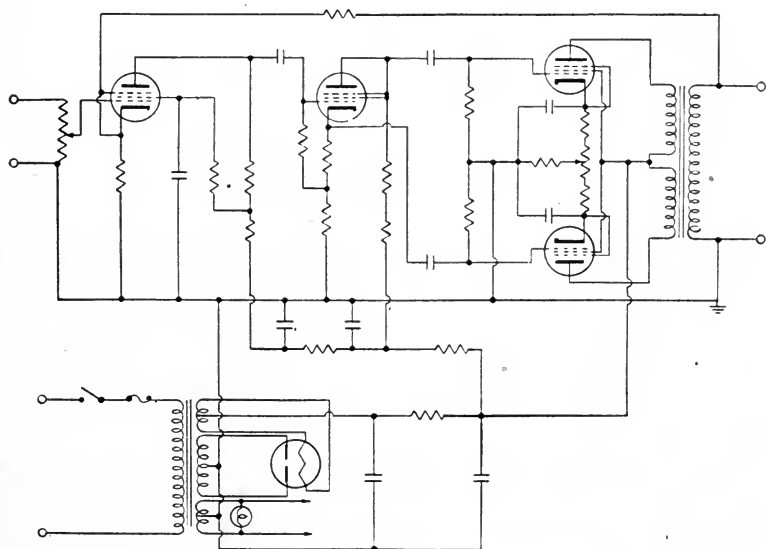

FIG. 2.   Beam power 15-w amplifier.

Early work on this comparison indicated that the output trans-
former seemed to be the limiting factor. This resulted from the fact
that with the use of feedback from the secondary winding, a large
phase shift took place at both the very low and very high frequencies,
causing "motor-boating" and supersonic high frequency singing.
This unstability was minimized in those cases by reducing the feed-
back in various ways. However, a comparatively large amount of
feedback is required so that the output impedance will be low. An-
other practice which caused severe distortion was the fallacy of using
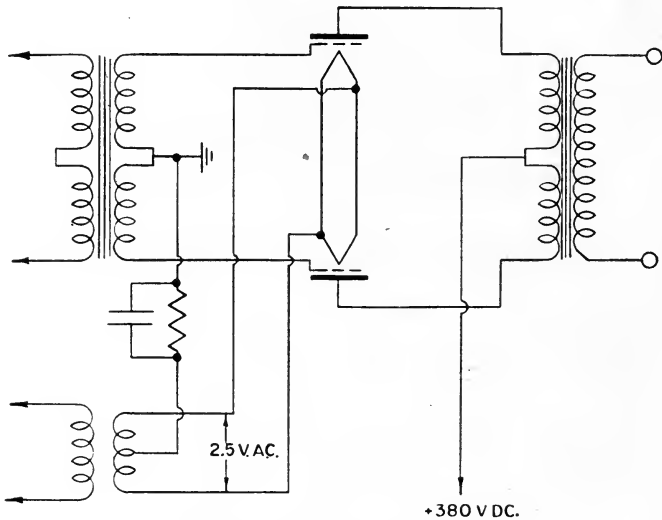
FIG. 3.   *2A3PP* 10-w amplifier.

negative feedback to correct the over-all frequency characteristics,
and other circuit deficiencies such as excessive shunt capacity and
small coupling condensers.

The result of this practice was that little or no feedback was avail-
able at the very low and very high frequencies, and accordingly the
output impedance varied over a large ratio throughout the frequency
band being transmitted.

To overcome these objections an amplifier was constructed for the
test which had the required frequency and power capacity without
feedback.

This was accomplished by designing an output transformer, having

a very high self impedance, accurate balance between windings, a high coefficient of coupling to reduce leakage, and a very low distributed capacity. Care was taken to determine that sufficient driver power to the grid of the tubes was available. With these conditions fulfilled intermodulation tests were made. These tests indicate that the distortion could be reduced to an insignificant degree up to a point very near the theoretical overload point.
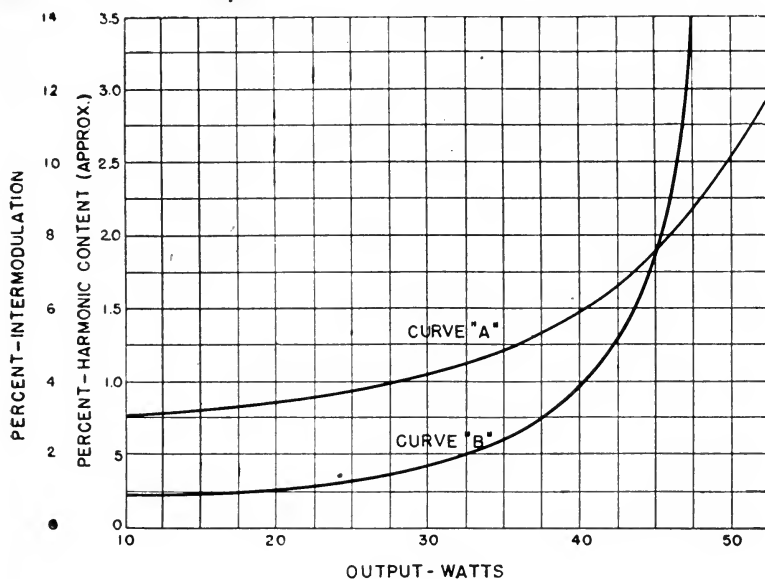
FIG. 4.   Curve *A*—*PP-845* tubes;   Curve *B*—*PP-807* tubes.

A comparison test was then set up and a critical listening group was invited to determine the difference, if any, between the beam and triode type of amplifiers.

High-quality direct wire monitor facilities from networks, best available studio film, and disk records and special sound effects were used as the source of program material.

One set of tests had a *6L6* push-pull amplifier in comparison with a *2A3* triode amplifier for which the measured intermodulation products are shown in Fig. 1. The intermodulation test signals consist of 60 and 1000 cycles. The 1000-cycle signal is transmitted 12 db below the 60-cycle signal.

Fig. 2 shows the schematic circuit of the 15-w *6L6* beam power tube.

Fig. 3 shows the push-pull *2A3* amplifier.

The second test had an amplifier using a pair of *807* tubes in comparison with a pair of *845* tubes, and their respective intermodulation products are shown in Fig. 4.

Both the intermodulation products and total harmonics are plotted. The approximate relation between the intermodulation products and the total harmonics is such that the intermodulation products are approximately 4 times the total harmonics.
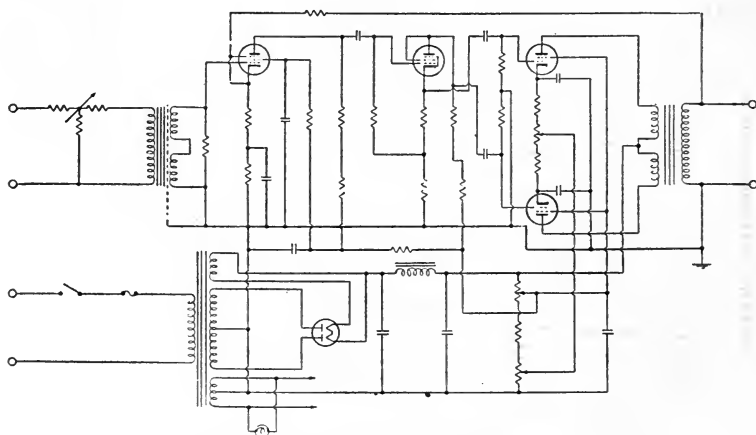
FIG. 5.   Beam power, 40-w amplifier.

Fig. 5 shows the push-pull *807* beam power tube schematic.

Fig. 6 shows the *87*-type 50-w triode amplifier schematic.

The feedback and output transformers were so designed that the measured output impedance was identical for both the beam power and triode amplifiers.   These amplifiers were compared on a 2-way loudspeaker system[2] designed for high-quality, high-power reproduction.

The listening group was unanimous that the beam power tube amplifiers were at least equal to the triodes and some observers favored the beam power tubes slightly over the triode type of amplifiers.

The reason for favoring the beam power tubes may have been a result of the output hum being approximately 15 db lower for the same

net gain and because the intermodulation curves indicate the lower intermodulation products in the average power range.

It is well to bear in mind the fact that equalization in the feedback circuit to modify the frequency characteristic of an amplifier, changes the output impedance. This changing impedance with frequency can be a very undesirable condition when the amplifier is driving a
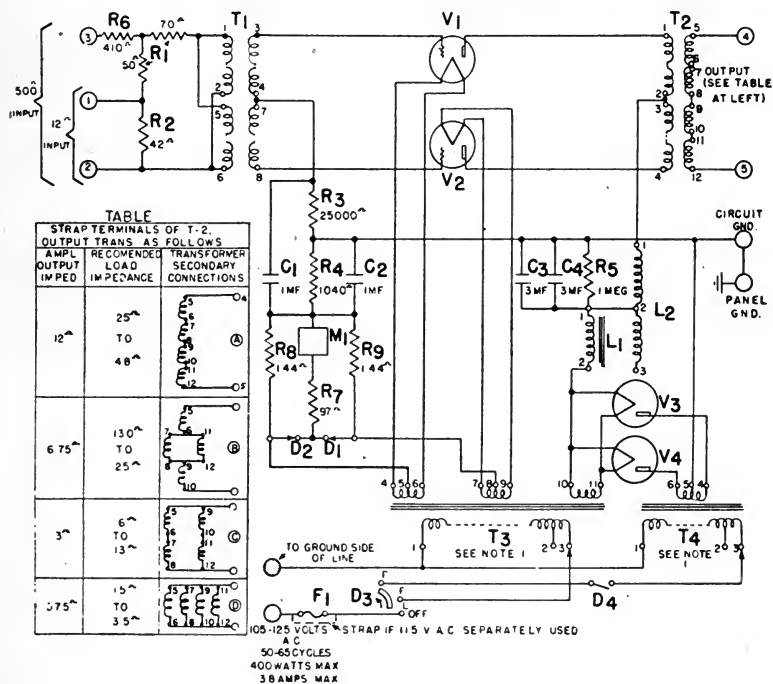
FIG. 6.   *87-E* amplifier.

loudspeaker since the damping of the speaker depends to a degree upon the load impedance of the amplifier.

The results of these tests can be summarized as follows:

(1) Beam power tubes can deliver the same audio power as triodes with the same or less distortion.

(2) A high over-all power efficiency can be obtained using relatively low plate voltages and inexpensive tubes.

(3) The circuit of the beam power tubes need not be complicated.

(4) The signal-to-noise ratio is improved.

(5)   Intermodulation method of testing compares favorably with the listening tests.

(6)   Excellent output transformers are required.

REFERENCES

[1] HILLIARD, J. K.: "Distortion Tests by the Intermodulation Method," *Proc. I.R.E.*, **29**, 12 (Dec., 1941), p. 614.

[2] ACADEMY OF MOTION PICTURE ARTS AND SCIENCES: "Motion Picture Sound Engineering," D. Van Nostrand & Co. (New York), 1938, p. 97.

PUSH-PULL FREQUENCY MODULATED CIRCUIT AND ITS APPLICATION TO VIBRATORY SYSTEMS*

ALEXIS BADMAIEFF**

Summary.—*The purpose of this paper is to describe a new push-pull frequency modulated circuit in which the push-pull action is accomplished by varying the resonant frequencies of both the oscillator and the discriminator in opposite phase relation to each other. Modulation of the oscillator and discriminator is achieved through the use of 2 capacitors with a common plate and arranged in a push-pull circuit. Thus, if the common plate is the moving element of a vibratory system, this circuit can be used for measuring vibrations or for monitoring purposes.*

One of the applications of the push-pull FM circuit is to calibrate recording heads while cutting phonograph records. Using this calibrator, it is possible to measure, without mechanical or inductive coupling, the actual frequency response of the cutting head under normal load, and to observe the input-output characteristics as well as the amount of distortion. It is also possible to use it for monitoring while recording.

1—BASIC PUSH-PULL FREQUENCY MODULATED CIRCUIT

Considerable interest is being shown in the development of frequency modulated circuits in which the oscillator and the discriminator are combined in one unit. This type of circuit can be used to convert mechanical vibrations to electrical voltage variations and is applicable to measuring instruments, pickup devices, and other forms of transducers.[1] The purpose of this paper is to discuss a new type of FM circuit in which the advantages of push-pull action are utilized.

In a single-ended FM circuit,[1] when used in conjunction with a very small capacitor as the frequency controlling element, a nonlinear relation exists between the condenser plates spacing and the frequency which the condenser controls. The magnitude of nonlinearity depends on the ratio between the spacing of the plates and the amount of variation of that spacing when the plates are vibrated mechanically. To illustrate, consider an LC circuit, in which one condenser plate is moved away from the other plate during tuning. Progressively increased separation has less effect on the resonant frequency because

---

the latter varies approximately as the square root of the distance of separation. This means that a nonlinear relation between the frequency and the displacement results in even harmonic distortion. It is well known that by combining the voltages from 2 similar nonlinear components in any push-pull system, the distortion can be greatly reduced, since the even harmonic components are practically eliminated.
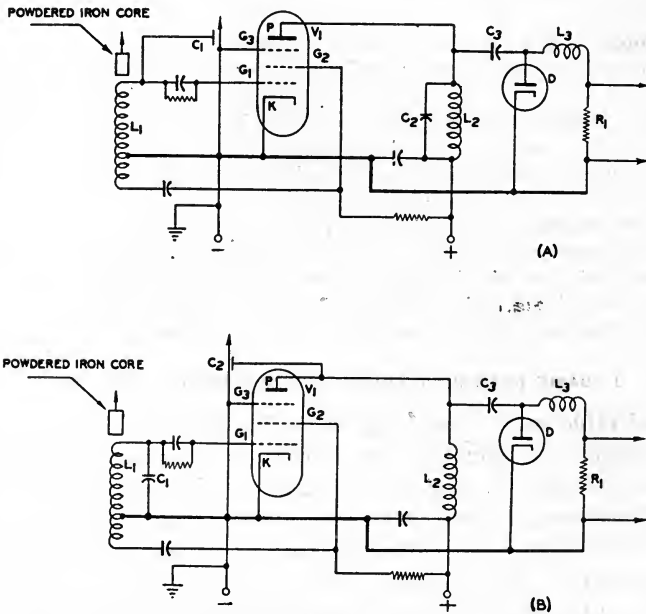
FIG. 1. (A) Modulated oscillator FM circuit. (B) Modulated discriminator FM circuit.

The distortion owing to the nonlinear relation between condenser spacing and frequency, however, can be canceled in a single-sided FM circuit by a complementary distortion in the discriminator circuit. This is not easy to attain, however, because the ratio of the spacing and the change of that spacing, which produces a given distortion, must match inversely the complementary nonlinear slope of the discriminator curve. This condition can only be satisfied when the distortion produced by the condenser plates does not exceed the complementary nonlinear action of the discriminator. This indicates that the change in condenser plate spacing must be small in

comparison with the average spacing (in the order of 5 per cent).   To meet this requirement, and to produce the swing in frequency necessary to attain an appreciable amount of output, comparatively large plate area must be used.   If, however, the plates are made small in comparison and their movement is large (in the order of 30 per cent) to secure a usable output, the second harmonic distortion produced is then quite large, and was measured to be about 17 per cent in one instance.   This large amount of second harmonic content is too great to be canceled by the complementary nonlinear discriminator curve,
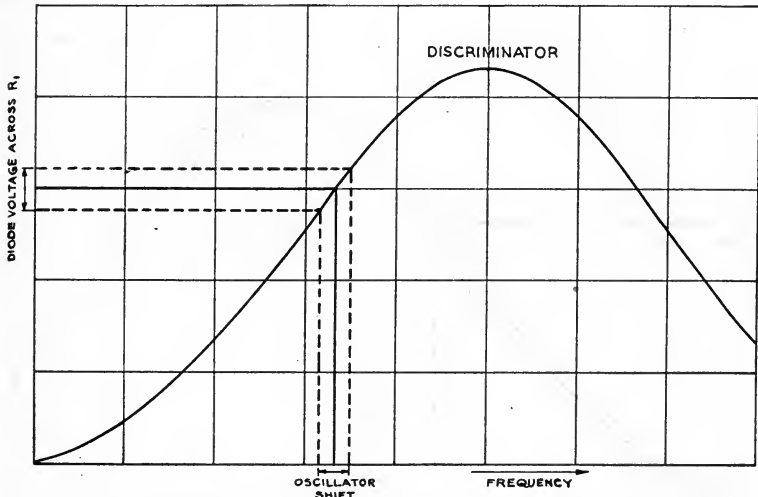
FIG. 2.   Graphical representation of the modulated oscillator FM action.

except very close to the resonance point, where the range is limited and adjustment is critical, or far off resonance where the sensitivity is low, as shown later in this paper under Section 2.

Another consideration is that, in a single-sided FM circuit, only one side of the movable plate is active.   The other is inactive since it is not faced by another plate.   In the push-pull FM circuit, both sides of the common center plate are active, since each side forms one plate of 2 condensers.   This fact reduces the effective size of the movable plate to a half of what is necessary in the case of a single-ended circuit.   Further reduction in size is attained by a larger movement in a small spacing, as mentioned before, which produces an adequate frequency swing by using 30 per cent of the spacing for the

total maximum movement. These 2 factors can be advantageously employed in designing a translating device having a minimum mass and therefore contributing to a minimum mechanical impedance.

A typical single-ended FM circuit in its elementary form is illustrated in Fig. 1A. A pentode (V_1) with its cathode (K), grid (G_1), and screen (G_2) is combined with the tuned circuit (L_1) and a variable condenser (C_1) to form an oscillatory circuit electron-coupled[2] to the plate (P) and electrostatically shielded by grid (G_3) (which is normally the suppressor element of the tube). The oscillatory energy from the plate is applied to a circuit which consists of another
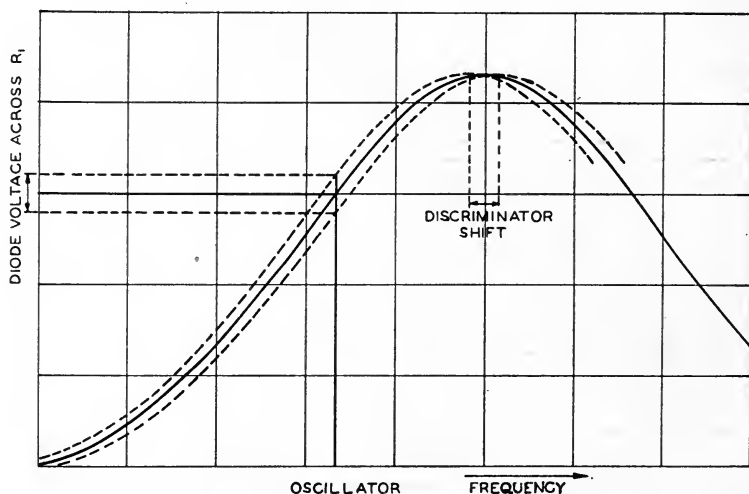
FIG. 3. Graphical representation of the modulated discriminator FM action.

tuned coil (L_2) and condenser (C_2). This circuit is slightly off resonance relative to the mean frequency of the oscillator and forms the discriminator part of the FM system. The condenser (C_1) across the oscillator coil (L_1) is the controlling element of the FM circuit. The output from the discriminator tuned inductance is coupled through a condenser (C_3) and rectified by a diode (D), after which it is filtered of its *rf* component by a choke (L_3) and appears as a varying voltage across the diode load resistor (R_1). The function of this system is graphically represented in Fig. 2, in which the oscillator mean frequency is positioned close to the discriminator's resonant peak. The dotted lines represent the variation of the oscillator frequency

and its equivalent change in the voltage amplitude of the output of the rectifier and filter circuits.

Suppose the circuit just described were again used, but instead of modulating the oscillator, the discriminator were modulated by shunting a variable condenser across the resonant coil (L_2). As illustrated in Fig. 1B, the frequency of the resonant peak of the discriminator would move back and forth along the frequency axis. The output voltage of the discriminator would be identical to that produced in the case in which the oscillator frequency was modulated.
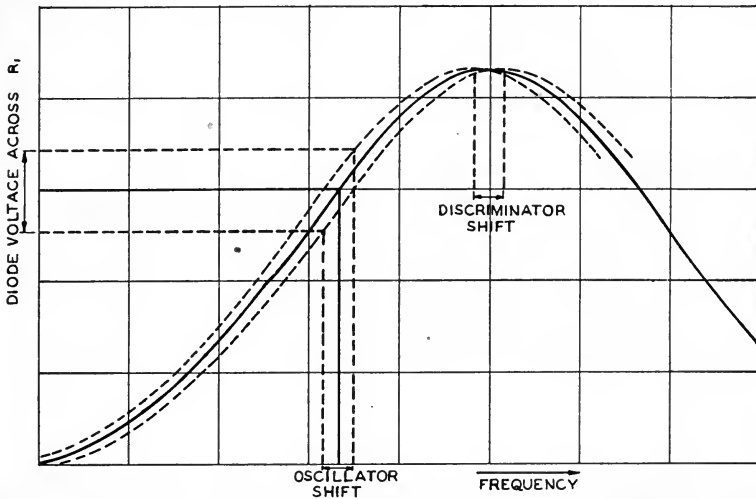
FIG. 4.   Graphical representation of both oscillator and discriminator combined modulations in the push-pull FM system.

The oscillator frequency will still cover the same part of the discriminator peak as before.   This is graphically illustrated in Fig. 3 in which the dotted lines represent the displacement of the discriminator's resonant peak.   If we combine both methods of modulation in the same circuit in such a manner that the oscillator frequency shifts in the opposite direction to the discriminator's resonant frequency, the voltage output from the discriminator would be twice as great as would be the case if only one of the factors had been varied through the same frequency range.   If, for instance, the oscillator frequency moved down along the frequency axis at the same time the discriminator resonant peak moved up, the relative shift along the frequency axis would be doubled, producing twice the amplitude in

the discriminator voltage output. This is illustrated in Fig. 4. Since both modulations have to be in opposite phase to produce the push-pull action, and since a simple controlling factor is a capacity change in the 2 tuned circuits, the push-pull FM circuit is particularly adapted to the use of 2 capacitors arranged for push-pull action.

The combining of 2 frequency modulations is accomplished by employing a small condenser, one side of which is connected across the oscillator coil and the other across the discriminator coil. The common center plate is grounded. If the center grounded plate is moved in either one of 2 directions, the frequency shifts of the oscilla-
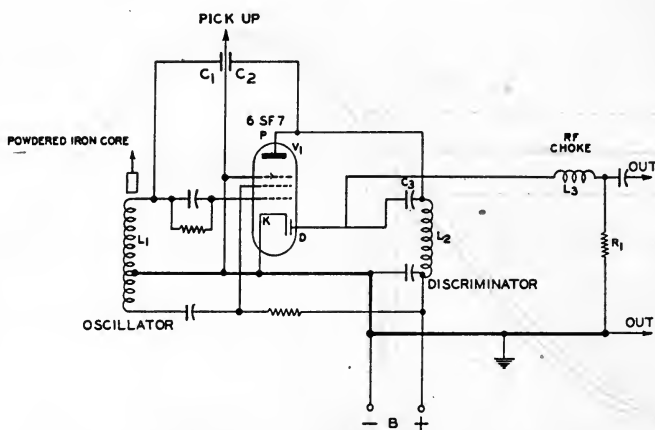
FIG. 5. Push-pull FM circuit combining both the oscillator and discriminator modulations.

tor and the discriminator circuits will be in opposite directions to each other resulting in push-pull action. Such a circuit is shown in Fig. 5. In this circuit, coil (L_1) and one half of the push-pull condenser (C_1), together with the grid, cathode, and screen of the pentode-diode tube, such as a 6SF7 (V_1), form the oscillator, and the coil (L_2), the other half of the push-pull condenser (C_2), and the plate of the tube form the discriminator circuit. These 2 circuits are electron-coupled, and shielded from each other within the tube by its suppressor which is grounded. The output is then rectified and filtered by the diode in the same tube, and the choke (L_3).

It should be mentioned, at this point, that the push-pull feature applies only to the action of the variable capacities. No claim is made to any cancellation of distortion because of the nonlinearity in

the discriminator characteristic. Maintaining low distortion in the discriminator circuit depends upon the relatively small range of frequency change. The full benefit of the push-pull action in reducing distortion will not be realized unless the 2 parts of the system are closely balanced with respect to each other. To realize this, inductances of the coils must be alike and the mechanical construction of both sides of the push-pull capacities must be alike so as to give substantially equal capacity, equally varied in opposite phase.

The balance between the 2 modulated tuned circuits was checked by modulating the oscillator and the discriminator separately, and noting the outputs in each case. This was done by substituting an equivalent fixed capacitor for the discriminator side of the push-pull capacitor and with a constant modulation applied mechanically to
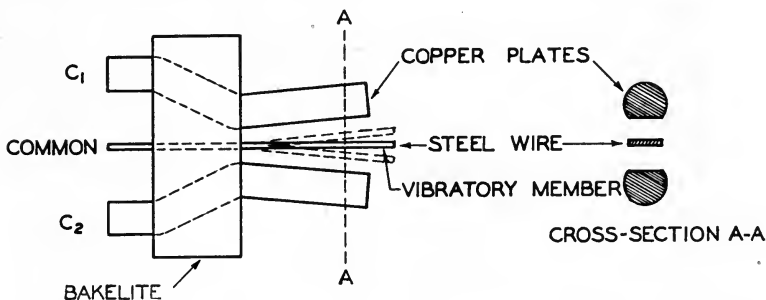
FIG. 6.   One form of push-pull FM transducer.

the oscillator part of the push-pull capacitor, the output was then noted. When substituting a fixed condenser of equal value in the oscillator circuit and modulating the discriminator, the output was found to be of the same amplitude as in the case when the oscillator was modulated. In other words, both circuits were designed to produce equal output voltage variations.

In each case, however, the exact oscillator center frequency position on the discriminator curve was noted, and the fixed substituted capacity adjusted so that the position was the same. This is important, since if the position were to change, a different amount of diode voltage would be developed for a given modulation, depending on the slope of the discriminator curve in the section used for discrimination. This position was noted by observing a microammeter connected between ground and the diode load resistor. The reading then was highest at the peak and proportional to the position of the oscillator

center frequency on the discriminator curve.	By thus observing the reading, the position and the side of the discriminator curve can be duplicated in each case.

Since the output voltage of the 2 sides of a push-pull system are additive, only half the voltage is required from each side of the system and, therefore, only half the frequency change to produce it.	It is, therefore, evident that the vibratory member is capable of producing a large voltage amplitude with a relatively small capacity, resulting in a very small unit.
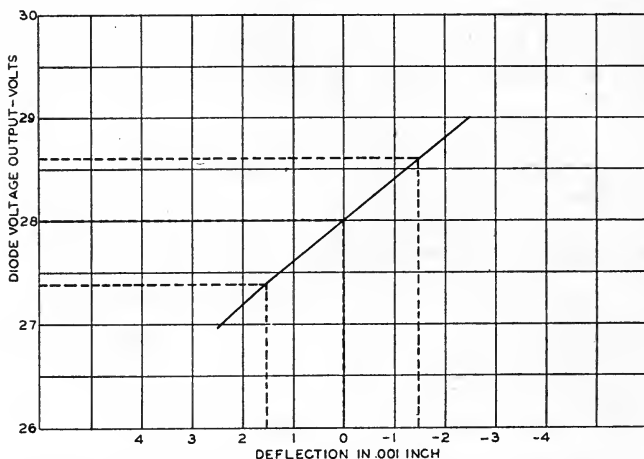
FIG. 7.	Linearity of the push-pull FM system (distortion).

2—OPERATION

The push-pull FM circuit, built and tested, included a push-pull condenser as its controlling element.	This condenser consisted of a steel wire $1/8$ in. long, 20 mils wide, and 8 mils thick, on each side of which is a plate of similar dimensions and spaced about 5 mils from the center movable plate as illustrated in Fig. 6.	The movable steel wire, which is the common grounded element of the push-pull condenser, is clamped at one end.	Its free end can be attached to any mechanical system whose vibrations are to be measured, as, for instance, the stylus tip engaged in the groove of a phonograph record. The rigidity of this wire is low, being in the order of 1.4×10^6 dynes per centimeter.	The 2 outside plates as previously described are connected; one across the oscillator coil, and the other across the

discriminator coil, with the center movable plate grounded. Using the circuit as described, the diode voltage was measured by a sensitive voltmeter and a curve plotted of the diode voltage versus the deflection of the center condenser plate. This curve is shown in Fig. 7. It should be noted that throughout most of its length this curve is practically linear. The total harmonic content represented by the curvature between the 2 dotted lines, A and B, amounts to less than one per cent. The curvature above that is caused by the non-
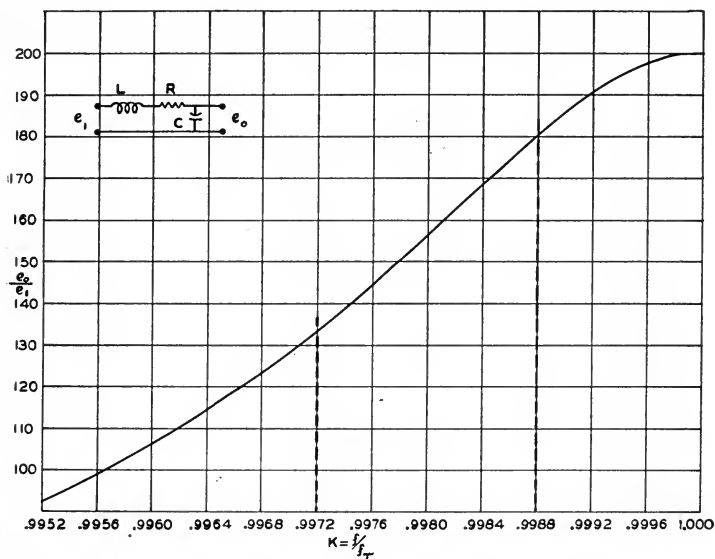
FIG. 8.   One side of the discriminator resonance curve.

linearity of the discriminator resonance slope. When the Q of the discriminator coil is in the order of 200 (which is easy to attain at frequencies of 40 megacycles), and the mechanical vibration applied to the tip of the wire is ± 1 mil, the output from the diode rectifier, as measured across the diode load resistance R_1, will be in the order of -30 db (reference 0.006 w).

The only nonlinear factor in this circuit is the discriminator resonance peak, one side of which is used as the slope against which the frequency modulation is changed to amplitude variations of the carrier. The calculated linearity of that slope is represented in Fig 8, and is based on the formula[3]

$$\frac{e_0}{e_1} = \left[(1 - K^2)^2 + 2.5 \times 10^{-5} K^2 \right]^{-1/2}$$

as taken from an equivalent circuit shown in Fig. 8 where L and C are the inductance and capacity of the resonant circuit and R is the loss and therefore the limiting Q factor. K stands for the ratio of the oscillator frequency to the resonant frequency of the discriminator ($K = f/f_r$).   When the distortion is thus computed, the following table represents the per cent of second harmonic distortion as compared to the frequency swing, relative gain, and the mean frequency of the point on the resonance curve against which the carrier is sweeping.

K	Second Harmonic in Per Cent of Fundamental, ± 45 KC	Relative Gain
0.980	2.94	25.3
0.982	3.26	28.0
0.984	3.67	31.5
0.986	4.20	36.0
0.988	4.90	41.9
0.990	5.88	48.8
0.992	6.9	60.0
0.994	8.0	77.5
0.9968	6.5	123.0
0.9976	3.2	144.5
0.9980	Less than 0.5	156.0
0.9981	Less than 0.5	160.0
0.9988	12.5	180.0

The curve is practically straight from $K = 0.9972$ to 0.9988. Thus a discriminator will cause negligible distortion if the total range of modulation is restricted to 80 kc for a 40-megacycle carrier.   This is also the portion of the characteristic which provides maximum output.   The range actually used covered 30 kc in each push-pull component, thereby effectively covering 60 kc on the discriminator curve.

The push-pull FM circuit presents a new tool which can be applied to any mechanical translating or measuring device.   As an example, in translating the mechanical vibration of a reed it is possible to place the 2 outside plates of the push-pull condenser on each side of the reed, having the reed act as the center grounded plate.   In that case large amplitudes can be translated with minimum distortion without adding anything to the reed itself.

3—PUSH-PULL FM CUTTER CALIBRATOR

During recent years as the art of disk recording has become refined, a number of improvements were made in the recording head. Several ways were devised to measure the ability of the cutting head
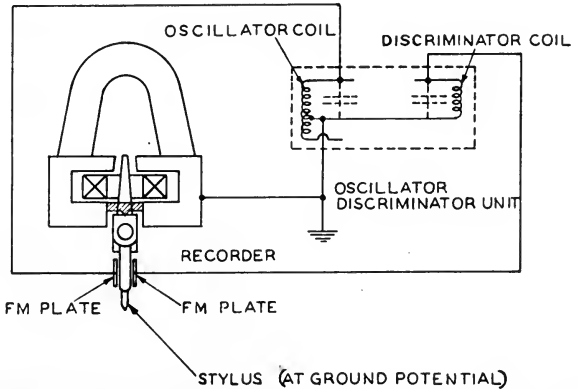
FIG. 9.   Arrangement of the FM calibrator adapted to a recorder head.

to reproduce faithfully the sounds engraved on a disk.[4]   The most important of these measurements is the frequency response of the head after compensation.   This type of measurement is made in several ways.   One of the best-known and widely used direct methods
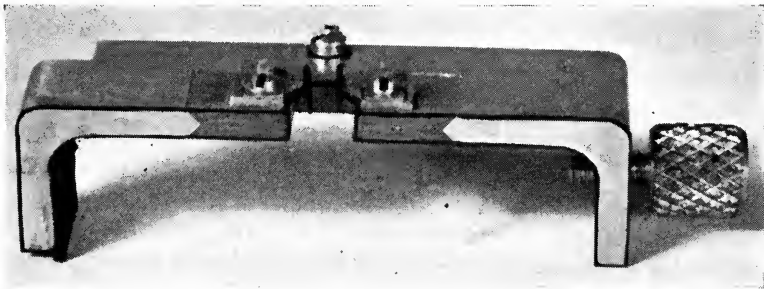
FIG. 10.   Push-pull FM plate assembly.

is by the light pattern.   As is generally known, this method consists of recording several frequencies on a disk and comparing their amplitudes with the aid of reflection of light.   This method is fairly accurate when certain precautions are taken and is really a true indica-

tion of the performance of the head, since the head is actually engaged in cutting a disk that represents the normal load on the stylus.

Another method which has been widely used consists in measuring the amplitude of the stylus vibrating freely in air by means of a microscope which has been precalibrated to measure small distances. In this method it is very difficult, however, to obtain accurate results, since in some cases the amplitude of the vibrations is extremely small. By substituting a photoelectric cell for the human eye it is possible to improve the accuracy to a large extent. Such optical cutter calibrators have been in use for years. Since the measurements are taken
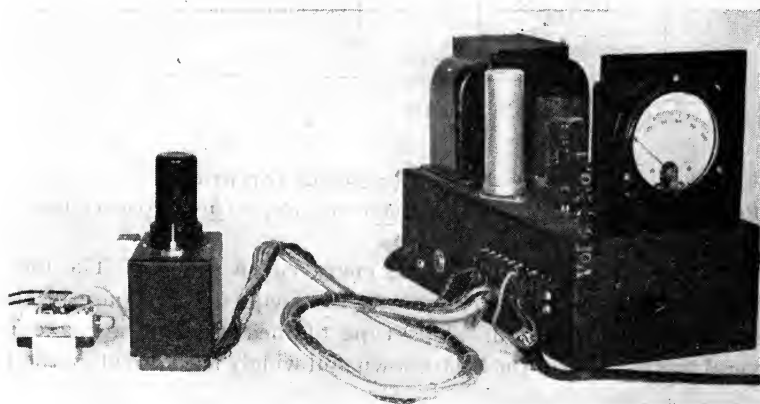
FIG. 11.   Component parts of a complete FM calibrator for recording heads.

in air, it is assumed that the difference in the measurements is small when compared to such made while the head is actually cutting a record.

The problem of being able to calibrate the recorder under actual cutting conditions still remained, however, and it was not until the push-pull FM circuit was developed that a solution to the problem was realized. A device was needed which could be attached to the recorder without requiring much space or adding any mass to the moving system, as well as one which would not couple electrically to the driving coil of the recording head, and of course one which would not interfere with the cutting action of the stylus.

The push-pull FM system meets these requirements very nicely. However, it is practically essential to use the push-pull circuit, be-

cause the distortion would be too high if only one side of the stylus were used as one of the plates of a condenser, owing to the low ratio of the capacitor plate spacing and the large variation of the spacing. As illustrated in Fig. 9, 2 small plates, one on each side of the stylus shank, insulated from each other and from the recorder, are spaced a few thousandths of an inch from the stylus.   Since neither mass nor rigidity is added to the moving system, no change in its action can occur.   Two flexible leads from these plates and another lead from the cutter mechanism are connected to the oscillator discriminator unit mounted on the carriage and located as close to the cutter head as feasible.   The oscillator-discriminator unit is of the same type as
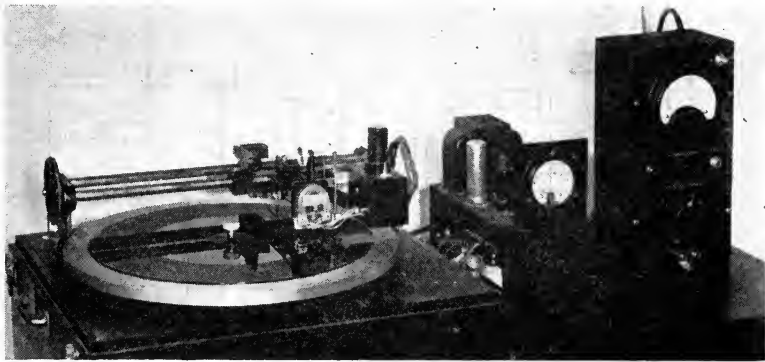
FIG. 12.   The FM calibrator in operation.

described in Section 1. The variation of the capacitance, between the 2 plates and the stylus, because of its motion, changes the oscillator frequency and varies the tuning of the discriminator in accordance with the method of operation described in Section 2.   The audio output of the oscillator-discriminator unit, since it also contains a diode, is transferred to another unit containing an amplifier and a power supply.   The output from this amplifier is then either measured with the aid of a tube voltmeter, or is further amplified for listening or other purposes by using a suitable transformer located between the amplifier tube, which has a high-impedance output, and a conventional amplifier of 500 ohms input impedance.

The push-pull FM plates are mounted on the bottom side of the cutter in such a way that in combination with the cutting stylus they form a small push-pull condenser.   As shown in Fig. 10, this assem-

bled bakelite plate on which the 2 FM plates are mounted fits on the under side of the cutter and replaces the cover plate.   This assembly is again shown separately in Fig. 11.   The FM plates are, of course, adjustable so as to provide any width of gap to accommodate any cutting styli or for unusual circumstances where a wide gap is necessary.   Normally, however, the FM plates are spaced 0.01 in. away from the stylus for frequency response measurements and 0.015 in. for distortion measurements at the lower frequencies.   This spacing is ample for any modulation and yet provides more than ample output.
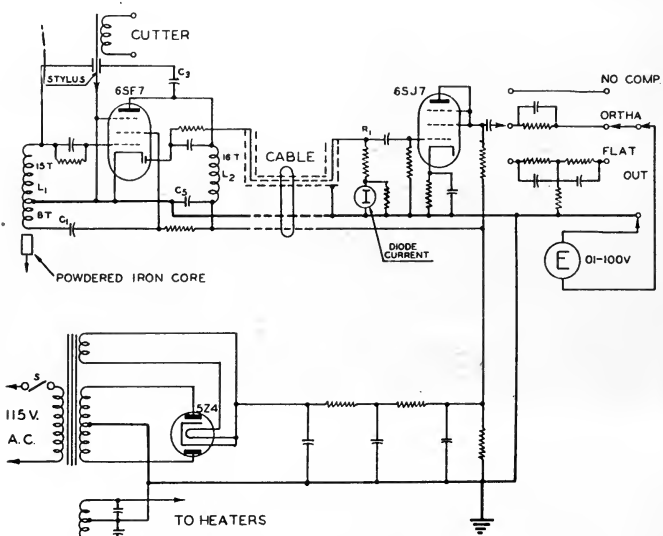
FIG. 13.   Schematic of the push-pull FM calibrator.

For calibration during the cutting of a record, the cutter is mounted in the usual way.   The oscillator-discriminator unit is mounted immediately beside the cutter (see Fig. 12).   The FM plates are connected to the oscillator and discriminator circuits by means of two 0.004-in. diameter steel wires covered with vinylite insulation.   The ground wire between the 2 units is of the same material.   The complete schematic diagram of the calibrator is shown in Fig. 13.

The output of the oscillator-discriminator unit is fed to an amplifier, which is on the same chassis with the power supply.   It consists of a conventional circuit using the 6SJ7 triode connected.   From there

the signal passes through a 3-position switch which selects the "flat compensator," the "orthacoustic," or the "no compensation" circuits. These positions can be used for different purposes as follows: "No compensation" is used for measurements with a vacuum tube voltmeter, for frequency response tests, and input versus output curves. "Flat" response can be used for monitoring on disks requiring that type of response; however, the important function of this position is for intermodulation tests.   "Orthacoustic" can also be used for monitoring while the record is being cut, and is designed for that purpose.

To obtain consistent readings, it is important to have the oscillator tuned to the same frequency relative to the optimum point of operation of the discriminator circuit.   To accomplish this, a meter is provided in the diode circuit.   The oscillator circuit is tuned for maximum diode current and is then backed down, in the same direction each time, to 70 per cent of the peak current.

The use of this instrument and results of measurements are completely covered in the paper by H. E. Roys entitled "Experience with an FM Calibrator for Disk Recording Heads."[5]

REFERENCES

[1] BEERS, G. L., AND SINNETT, C. M.: "Some Recent Developments in Record Reproducing Systems," *J. Soc. Mot. Pict. Eng.*, XL, 4 (Apr., 1943), p. 222.

[2] TERMAN, F. E.: "Radio Engineering," McGraw-Hill (New York), 1937, p. 360; Dow, J. B.: "A Recent Development in Vacuum Tube Oscillator Circuits," *Proc. I. R. E.*, 19 (Dec., 1931), p. 2095.

[3] LANDON, V. D., AND McILWAIN, K.: "Pender's and McIlwain's Electrical Engineers' Handbook (Electric Communication and Electronics)," John Wiley and Sons (New York), 3d Ed., p. 7.

[4] FINK, D. G.: "Electronic's Engineering Manual," McGraw-Hill (New York), p. 240.

[5] ROYS, H. E.: "Experience with an FM Calibrator for Disk Recording Heads," *J. Soc. Mot. Pict. Eng.*, 44, 6 (June, 1945), p. 461.

A DISCUSSION OF THE ACOUSTICAL PROPERTIES OF FIBERGLAS*

WILLIS M. REES AND ROBERT B. TAYLOR**

Summary.—*The wide range and controllable properties of Fiberglas thermal insulating materials when used as absorbents of airborne sounds are discussed. Tables of sound absorption coefficients are given for 6 frequencies from 128 to 4096 cps and for 24 different combinations, weights, and thicknesses of materials. Curves are shown analyzing the relative absorption at different frequencies of the different materials based on density, thickness, and fiber size.*

Sound isolation blankets made of a newly developed superfine glass fiber show remarkable acoustical efficiency when used for aircraft sound insulations. Their potential application to other uses when materials and research facilities are available is discussed. Some data are also given evaluating the influence of surface treatments and enclosing materials and methods.

The paper is a compilation and analysis of available data but does not represent a complete evaluation since much further work is needed as a result of properties discovered in war applications.

During the 10 years prior to the war, glass products in fibrous form, known as Fiberglas, were being developed from those of broom-straw diameters to those of microscopic fineness. With each refinement in manufacturing processes and development of finer fibered products, entirely new groups of products and applications for them came into being.

The original type of large diameter fibers are used in air filters and aeration mats. The next group of products of much smaller fiber diameter are known as wool products and are used for thermal insulation and sound absorption. Smaller diameter fibers were developed having microscopic fineness and great length. These became textile materials which are used for electrical insulations, for fireproof fabrics and draperies, for plastic reinforcements, and a host of other applications. The most recent development is down-like fiber of submicroscopic fineness which is made into incombustible aircraft blankets with exceptional heat and sound insulating proper-

---

ties, combined with extremely low weight. About 8 standard fibers are being produced ranging in diameter from 0.008 in. for aeration products down to 0.00022 in. for textiles, and 0.00005 in. for the new aircraft blankets. Basic characteristics of various fibers are shown in Figs. 1 and 2.

During the prewar period acoustical tests were made at Riverbank Laboratories of various Fiberglas wool products. Some of the test results are here made public for the first time. Our wish is to give you a preliminary report, or a preview of what we believe may lie
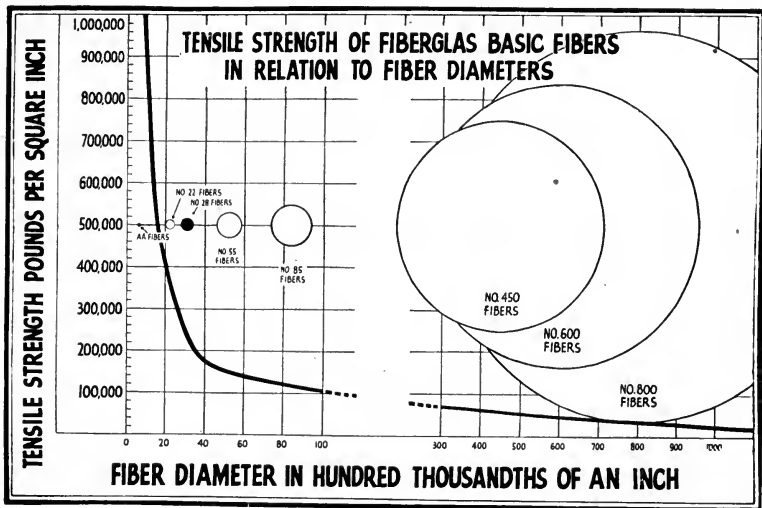
FIG. 1.

ahead in the acoustical development of Fiberglas materials based on a critical analysis of these data and further tests which have been made in the Fiberglas Research Laboratories. However, it should be pointed out that there are not enough data on which to base any scientific conclusions. The data are considered merely as a guide to point the direction for further study and research.

The plain white insulating wool form of Fiberglas is known as "*TW-F* Wool." It is manufactured to a natural density of $1\frac{1}{2}$ lb per cu ft but because of its resilience it may be compressed to greater density. It is thus possible to use the material in a wide range of densities and thicknesses. The same material, when bound with a thermosetting resin, forms a series of preformed products known as

TABLE 1

Sound Absorption Coefficients of Fiberglas Products

(From tests made at Riverbank Laboratories by methods prescribed by the Acoustical Materials Association)

Insulating Wool—Type TW-F

Thickness (In.)	Density Lb Per Cu Ft	N.R.[a]	Coefficients						Fiberglas[b] Lb Per Sq Ft	Test No.	Facing[c]	Mounting[d]
			128	256	512	1024	2048	4096				
1	2	.55	.24	.30	.57	.69	.70	...	.17	265	Metal Lath	4
1	3	.65	.27	.35	.68	.77	.76	.71	.25	301	Perforated Metal[1]	4
1	4	.75	.33	.45	.81	.88	.78	...	.33	264	Metal Lath	4
1	4	.70	.33	.40	.76	.91	.77	.73	.33	302	Perforated Metal[1]	4
1	6	.80	.35	.51	.89	.93	.87	...	.50	263	Metal Lath	4
1	2	.75	.38	.49	.84	.91	.76	...	.33	262	Metal Lath	4
2	3	.80	.44	.61	.96	.93	.77	.86	.50	303	Perforated Metal[1]	4
2	4	.90	.54	.68	.99	.99	.88	...	.67	266	Metal Lath	4
2	4	.90	.62	.85	.99	.99	.86	...	.67	268	Muslin	4
2	6	.90	.55	.79	.99	.99	.91	...	1.00	267	Metal Lath	4
2½	2	.80	.50	.60	.93	.90	.81	.87	.42	42-11	Metal Lath and 10 mil Bonded Mat[2]	4
2½	2	.85	.48	.59	.98	.94	.85	.78	.42	42-14	Same as above-painted[3]	4
2½	2	.85	.47	.64	.99	.99	.76	.59	.42	42-13	Metal Lath and 40-lb natural Kraft paper	4
3	2	.85	.55	.68	.95	.90	.79	.80	.50	305	Perforated Metal[1]	4
3	3	.90	.68	.78	.99	.94	.86	.80	.75	306	Perforated Metal[1]	4
3	4	.95	.69	.91	.99	.99	.91	.82	1.00	307	Perforated Metal[1]	4
PF Insulation												
1	2½	.60	.24	.32	.65	.77	.73	.81	.21	40-16	Bare	2
1	4¼	.70	.20	.41	.75	.87	.86	.82	.35	40-14	Bare	2
1	6	.75	.25	.41	.86	.94	.84	.81	.50	40-13	Bare	2
1	6	.70	.18	.33	.75	.95	.84	.77	.50	40-80	Creped Kraft paper	2
1	9	.75	.22	.46	.97	.90	.68	.52	.75	39-83	Painted	2
2	4¼	.85	.41	.60	.99	.99	.84	.85	.71	40-15	Bare	2

						Insulating Wool—Type N						
1	$1\frac{1}{2}$	.75	.26	.40	.70	.93	.88	.82	.18[4]	40-12	Glass Cloth Type Ecc-108	2
2	3	.90	.44	.75	.99	.97	.83	.86	.50	304	Perforated Metal[1]	4

Notes

[a] N.R.: Noise Reduction Coefficient. The average of the coefficients at frequencies of 256, 512, 1024, and 2048 cycles, given to the nearest 5 per cent. This average coefficient is recommended for use in comparing materials for noise-quieting purposes as in offices, banks, corridors, etc.

[b] Weight of Fiberglas only. For estimating weight of metal mesh and sewn blankets, add weight of facing materials to these figures.

[c] See notes below for description and weights of facing materials.

[d] Mounting 4 is laid on laboratory floor. Mounting 2 is nailed to 1 in. × 2 in. wood furring 12 in. on center.

[1] Perforated Metal—25 gage, 0.076-in. holes, 0.176 in. on center.
[2] Fiberglas 10 mil Bonded Mat Type 10.
[3] Spray painted with cold water paint.
[4] Weight includes glass cloth facings.

Facing or confining materials which may be used with Fiberglas products without appreciable acoustical effect upon materials covered:

Fiberglas 10 mil Bonded Mat   0.009 lb per sq ft
Expanded Metal Lath (Burial Vault Mesh)   0.278 lb per sq ft
⅜-in. Hi-rib Lath   0.444 lb per sq ft
Hexagonal Wire Mesh   0.109 lb per sq ft
Flameproofed Muslin   0.017 lb per sq ft
Kraft Paper   0.026 lb per sq ft
Glass Cloth—Ecc-108   0.011 lb per sq ft
Perforated Materials such as Metal, Hardboard, Cement Asbestos Board, Plywood, etc.

"*PF*" materials made in flexible or rigid block or board form. These can be made in predetermined thicknesses and densities, the latter ranging from $2^1/_2$ lb to 9 lb per cu ft.   They are also incombustible and chemically inert, as are all Fiberglas wool products.

Table 1 gives sound absorption data for type *TW-F* Wool in several densities and thicknesses.   All items show exceptionally high sound
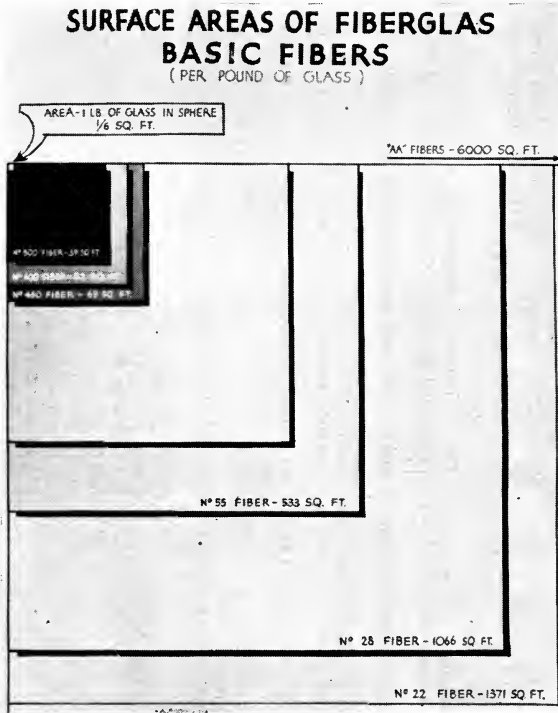
Fig. 2.

absorption at the low frequencies.   Some show coefficients at 128 cycles considerably in excess of 0.50 and even as high as 0.69.   All but one exceeds 0.25, a characteristic possessed by very few of the usual acoustical materials.

Table 1 also gives data for several *PF* densities and thicknesses. The same general acoustical characteristics of high absorption at low frequencies are evident here (as with *TW-F* type of materials) although to a lesser degree.

All of the data given in Table 1 are from tests made by the River-bank Laboratories by methods prescribed by the Acoustical Materials Association.

Fig. 3 shows the apparent effect of thickness and density upon absorption values of *TW-F* Wool. In a material one inch thick, the absorption at all frequencies increases with little change in the shape of the curve as the density increases. As no tests have been made for densities over 6 lb, it is not apparent what the optimum density would

TW-F WOOL – THICKNESS vs DENSITY
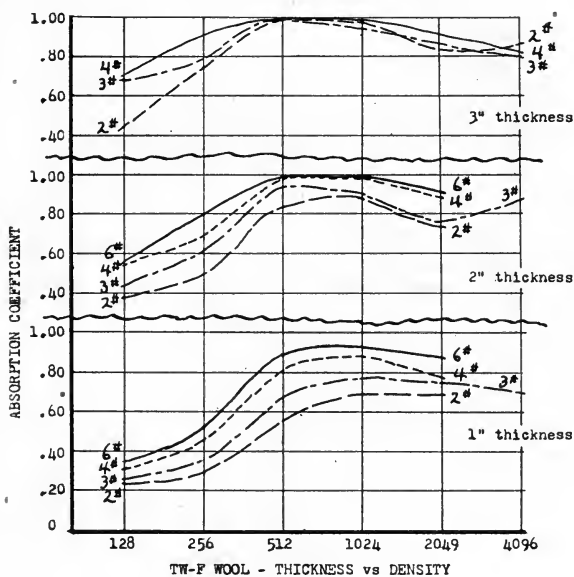
FIG. 3.

be for one-inch material. The 2-in. thickness curves show increased absorption at all frequencies with little advantage of 6-lb material over 4-lb material at middle and high frequencies. In the 3-in. thickness curves it would appear that density is of little consequence for frequencies of 512 and up, although higher densities improve low-frequency values.

These curves also show that an engineer who is concerned with the economics of an acoustical installation has a considerable choice of materials. If he is concerned only with higher frequencies, a 2-lb density material 3 in. thick is just as good as double the amount of material in a 4-lb density 3-in. thickness.

Although the data are not complete enough to make positive assertions, it would appear that for all practical applications of 2-in. or 3-in. thickness that a 4-lb density of *TW-F* Wool is optimum density. In the 3-in. thickness, further tests may show that greater than 4-lb densities will increase low-frequency values giving a high flat curve. This appears to be a logical deduction from curves shown and indicates a possible course of investigation.

TW-F WOOL — WEIGHT vs THICKNESS
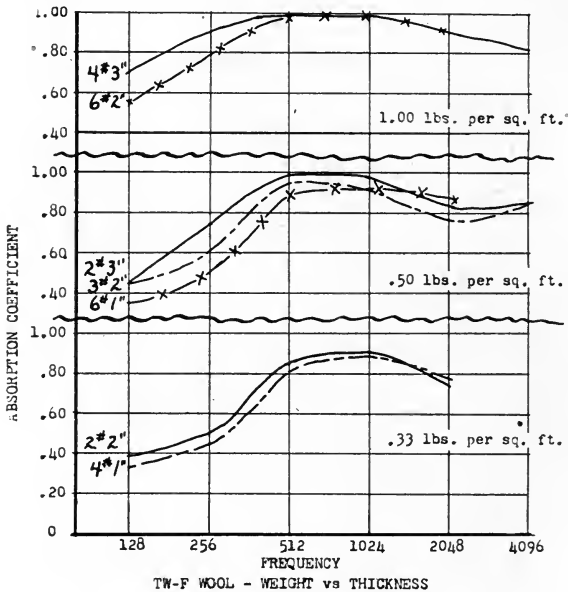
Fig. 4.

It has been said that friction of pulsating air molecules against the walls of the interstices of porous materials dissipates sound energy into heat.   It is in this way that most absorption is provided.   Fig. 2 shows that there is a great increase in the square foot surface area of a pound of Fiberglas as the fiber diameter decreases.   Because surface area within a given weight of Fiberglas is related to the diameter of the fibers, research may show that acoustical values are functions of the fiber diameter.   Test work in a war research sound laboratory indicates that this may be true.

In a fibrous product such as Fiberglas *TW-F* Wool, it is conceivable that within reasonable limitations this frictional loss would be a func-

tion of the surface area of the fibers which make up the material.
If such a supposition were true, it might be just as reasonable to be-
lieve that a given square foot weight of material with given surface
area of fiber would have about the same acoustical value whether it
was applied thick or thin, dense or light.   If surface area is what
does the trick, pounds of a given type of fiber and not thickness or
density should be the controlling factor.

In Fig. 4 are plotted the few data available to show the effect of
applying a given weight of *TW-F* Wool in several thicknesses and
densities.   Admittedly, there are insufficient data to permit positive

APPARENT EFFECT OF SURFACE FILMS
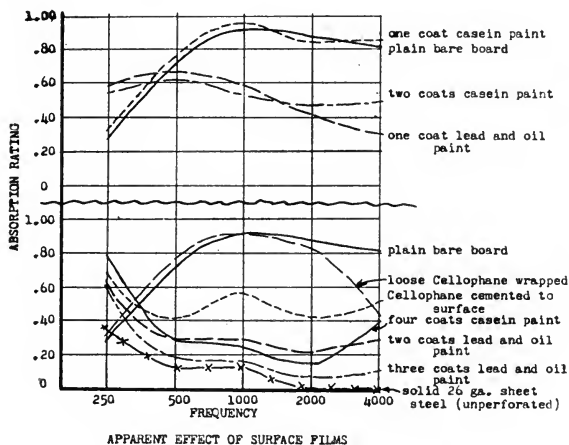
Fig. 5.

conclusions.   But there is surprisingly little difference for variations
in the density and thickness of application of a given square foot
weight of material.   It does appear, however, that if an acoustical
engineer were given a choice of thicknesses in which to install a given
weight of material, the results would favor the greater thickness.

To study the effect of surface treatments on a Fiberglas board prod-
uct of the *PF* type, acoustical tests were made in the Fiberglas Re-
search Laboratories.   These tests were made by the tube method,
measuring sound attenuation in a concrete tube lined with the ma-
terial under test.   The term "Absorption Rating" is used in presenting
these data rather than "Absorption Coefficient" because the informa-
tion given provides comparative data only and is not intended for

direct comparison with data obtained by the reverberation chamber method.

Fig. 5 shows the apparent effect of various surface films on a Fiberglas board. The curve for bare board is typical of many materials. The upper set of curves shows that one coat of casein paint has no appreciable affect on the absorption. But with either 2 coats of casein paint or one coat of lead and oil, strange things happen. The curve is completely altered, both surfaces giving substantially the same characteristics. The test with 2 coats of casein in particular gives an extremely flat curve.

In the lower set of curves in Fig. 5, the effect of additional paint coats is shown. Two and 3 coats of lead and oil, and 4 coats of casein all show very similar curves. Cellophane cemented to the board surface and even solid unperforated 26-gage sheet steel surfacings show similar curves. A loose Cellophane wrapping shows little change in the curve from the bare board except for a reduction at 4000 cycles.

Interpretation of the curves in Fig. 5 is not as simple or obvious as those for TW-F Wool in Figs. 3 and 4. Fiberglas board is fairly rigid but has some springiness or compressibility. A film which sealed the surface could also be subject to diaphragmatic action owing to resilience of the board. It is believed that the heavy paint films and cemented Cellophane have one thing in common; namely, that they seal the surface porosity but still permit a movement and dissipation of sound energy owing to resilience of the board. It is believed that the single lead and oil paint coat and the double casein coat have similar curves because of similarity of restricted surface porosity, possibly as a single characteristic or in combination with the property of resilience. In any event, the curve for 2 coats of casein paint is one of extreme flatness which might be of great value for certain critical applications if it could be designed into a product.

What effect varying degrees of resilience in Fiberglas boards might have on the absorption curves with sealed surfaces is a question. But resilience might be another controllable factor in the design of an acoustical product, although this characteristic in Fiberglas board is less subject to complete control than some of the other traits discussed.

Fig. 6 shows the effect of perforated metal facings with different percentages of open area. With a high percentage of open area, such as 18 per cent, there appears to be little effect upon the absorption

curve except for slight reduction at 4000 cycles.   As the percentage
of open area is reduced, high frequency values decrease and low fre-
quency values increase.   Reducing the percentage of open area seems
to sharpen the peak of the curve and move the peak to lower fre-
quencies.

No study will be complete, however, until the relationship between
acoustical effect upon absorbents covered and hole size and spacing
for various open areas is investigated.   It will also be important to
study the effect of various types of perforated surfaces over materials
of varying characteristics.

During analysis of the acoustical data on Fiberglas materials and
limited research findings, one fact stands out: Fiberglas materials

APPARENT EFFECT OF PERCENTAGE OPEN AREA
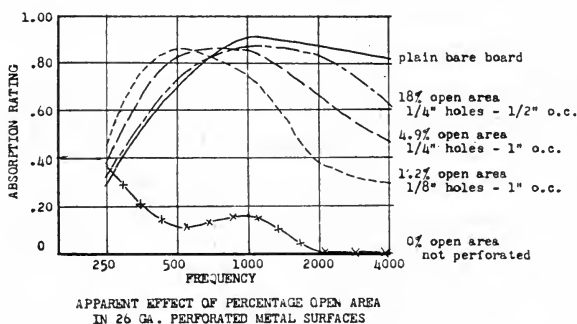IN 26 GA. PERFORATED METAL SURFACES

FIG. 6.

provide a group of incombustible products apparently subject to
more complete control than has ever before been possible in acoustical
materials.   With control of thickness, density, fiber diameter, and
surface area per unit of volume or weight; with possible control of
resilience, porosity of surface films, combinations with perforated
surfaces; and with control of methods of mounting and assembling
materials in actual use, the conclusion is warranted that research men
can find in Fiberglas materials the means of conducting basic research
into the physics of sound absorption.

Through research there may be developed some day products
that will more closely meet the requirements of the motion picture,
radio, and television industries. As more is learned about the needs
of these industries and of the acoustical characteristics of Fiberglas
materials and the methods of using them, the availability of ma-
terials to meet specific requirements may become a reality.

There are other acoustical applications for Fiberglas materials than as sound absorbents. Fiberglas Bonded Mat is used as a covering material over either TW-F or PF types of products. It is a porous, meshed sheet formed by bonding together long glass fibers. It is made in thicknesses from 0.010 in. to 0.050 in. The 0.010-in. thickness is usually used as an acoustical facing as it offers desired characteristics at minimum cost. It may be sprayed with casein paint without apparently affecting sound transparency.

So far as is known glass cloth draperies have not been tested for their acoustical absorbing values. However, some of the lighter weight cloths have been used as facings on sewn blankets with a Fiberglas wool filler. The high acoustical value for such blankets would indicate sound transparency for the cloth, permitting its rather free use over sound absorbents.

During the war the speed, power, and size of all types of aircraft have been tremendously increased. These changes have resulted in more difficult sound control problems and have rendered inadequate the types of acoustical treatment previously used.

A great deal of money and effort was expended by the National Defense Research Committee at Cruft Laboratory, Harvard University, to develop improved types of aircraft acoustical materials and treatments. Since this work was primarily directed at the aircraft field, low weight was an important design consideration. Also it was recognized early in the program that it would be impossible to develop a light-weight structure offering much attenuation to the very low frequencies, so the evaluation work was principally confined to the frequency range of 1650–9100 cycles per sec. This is the portion of the audio spectrum in which noise interferes most with aural communication.

This research effort has resulted in the development of several very efficient structures for the above frequency range. Coinciding with this structure research, 2 new types of Fiberglas were developed: XM-PF and XAA-PF. Both materials are admirably suited to such light-weight applications, possess extremely good acoustical properties, and have the additional advantages of inherent fireproofness and low moisture absorption.

Type XM-PF blankets are approximately equal to Kapok acoustically when compared on a weight basis. Type XAA-PF is a superior grade Fiberglas product and will do an equally good acoustical job at weights $\frac{1}{3}$ to $\frac{1}{2}$ that required with Kapok. Using this ma-

terial, blanket weights of $2^1/_2$ oz per sq ft will satisfactorily insulate multimotored heavy bombers.   Such a blanket is so light one has a difficult time realizing its acoustical efficiency.

The full details of these new acoustical treatments are still restricted.   However, they should find many applications in the postwar period in mobile equipment, portable sound studios, light-weight sound isolating blankets, *etc.*

Fiberglas research men are convinced that with proper engineering and use of principles that have been incorporated in aircraft design, important contributions will be made some day to other industries having problems of noise control that must be solved by isolation of airborne sounds.

A THREE-BAND VARIABLE EQUALIZER*

L. D. GRIGNON**

Summary.—A recently designed variable equalizer providing suppression and emphasis in 3 frequency bands, adjustable by means of 3 controls, and based on a different philosophy, is described. The principle features include, (1) zero insertion loss, (2) small change in apparent insertion loss as equalization is varied, and (3) more pronounced effects for equivalent changes in equalization.

Since the commercialization of sound motion pictures, the technician has been designing, modifying, or discarding equalizer networks having various frequency characteristics and configurations to such a prodigious extent that a list of the literature would be exceedingly lengthy. Let it be sufficient to note that the most recent information on the subject was presented by Miller and Kimball,[1] which described a system of networks so designed as to cover the frequency spectrum in discrete bands and with sufficient flexibility as to provide a great variety of choices to the user. This paper describes another system of corrective networks based on a differing philosophy with the end result achieved in an unusual manner.

The variety of corrective networks in use results from the equally great number, and the extent, of the required corrections encountered over a period of time and to the difficulty of adequately and rapidly analyzing undesirable features in the signal being recorded or reproduced. We must, therefore, decide how far we wish to go in providing the corrective devices and what frequency characteristics are to be used; particularly, if the desire is to minimize the total number of units to be supplied. The bases for the specifications of the device to be described are as follows:

(1) The majority of the desired corrections exist in either the low or high ends of the present-day frequency range or both simultaneously.

(2) Intelligibility must be maintained at all times, therefore, a means must be provided to emphasize the mid-spectrum frequencies. Conversely, suppression

---

of the same band can frequently be used to make harshness more tolerable, provided intelligibility is not degraded.

(3) The number of units shall be kept to a minimum and still provide the greatest amount of correction.

Accepting the above fundamentals as design features, the complete specifications can be written as follows:

(1) Low- and high-end emphasis or suppression shall be in discrete steps and achieved by a shelf effect, arranged to shift the frequency of one-half loss or gain further toward the extremes of the signal band or nearer the mid-frequencies, thereby affecting the normal circuit characteristics only to the extent required by
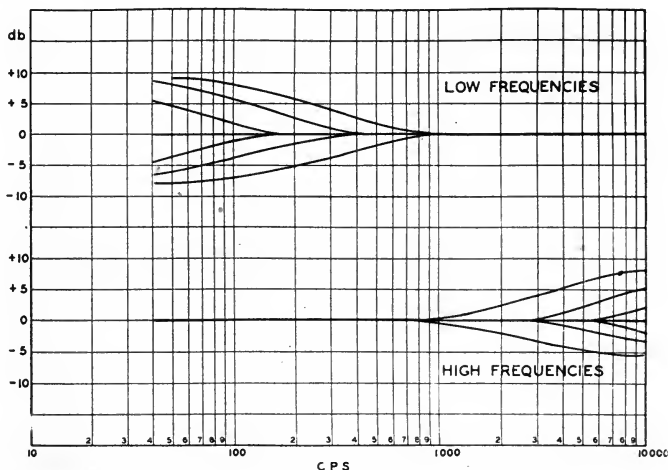

Fig. 1.   Low- and high-end equalization specifications.

the necessary correction.   (This differs from the usual manner in which only the slopes of the characteristic are changed, the "hinge" frequency remaining fixed.) Maximum suppression shall be approximately 6 db, maximum emphasis approximately 8 db, and change between steps approximately 1 db, measured at 100 cps and 7000 cps.   Fig. 1 gives these requirements in more detail.

(2) Mid-frequency correction shall have a maximum at 2750 cps in an amount equal to 5 db suppression, or emphasis, in steps not exceeding $1/2$ db (Fig. 2).

(3) The insertion loss of the system of networks shall not exceed ± 1 db at normal settings.

(4) Suppression, at any of the 3 bands, shall be introduced by rotating a control in a counterclockwise direction from a normal setting and emphasis shall be applied by rotating the *same* control from the *same* normal setting in a clockwise direction.   In either case, suppression or emphasis is made progressively greater as the control is manipulated further from the normal.

(5)   As suppression or emphasis is introduced into any of the 3 frequency bands, the insertion loss at 1000 cps shall not vary more than ± 1 db.

(6)   Dial stops, which are readily adjustable, shall be provided on each control to permit pre-setting, or to provide limits.

(7)   The complete system shall be constructed on a portable plug-in basis.

The above specifications assure the condition that the system may be inserted into a circuit without affecting normal transmission, manipulations, or usage and that volume corrections need not necessarily be made simultaneously as equalization is introduced.   Under some circumstances, particularly when low-end corrections are applied,
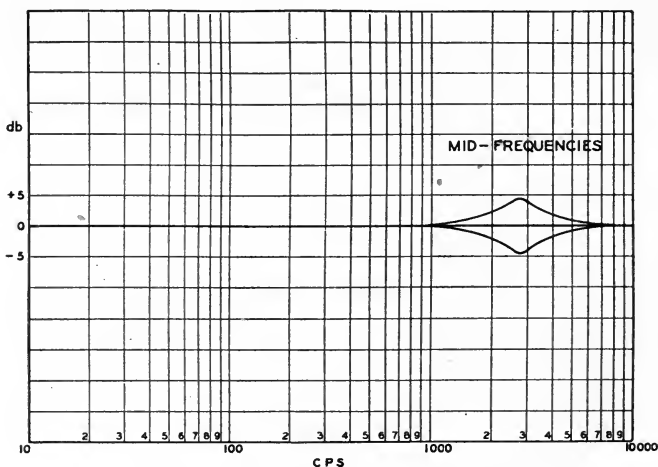

FIG. 2.   Mid-frequency specifications.

there will be an apparent level change which this specification does not consider.   A portable type of construction was selected since it is not proposed to build any final systems until certain special items of apparatus are more easily obtainable in the post-war period.   In the meantime, a small number of systems, available wherever required, are expected to serve the immediate needs.

The mid-frequency band arrangement will be described first.

MID-FREQUENCY SECTION

Two constant impedance networks are used for this control; one, a suppression network of the required shape and fixed in amount at the desired maximum; the second, an emphasis network connected

in series and variable in equalization by an amount equal to the sum of the maximum amounts of desired suppression and emphasis.   At an intermediate point in the setting of the variable attenuator associated with the variable network, the frequency characteristics of the 2 networks are inverse and the net applied frequency correction is zero.   The design parameters for the particular specifications are

F_r	$= 2750$ cps	F_r	$= 2750$ cps
b	$= \dfrac{10}{8}$	b	$= \dfrac{10}{7.5}$
Z_0	$= 500$ ohms	Z_0	$= 500$ ohms
Pad loss	$= 5$ db	Pad loss (design value)	$= 8$ db
		Pad loss (actual)	$= 0$ to 10 db
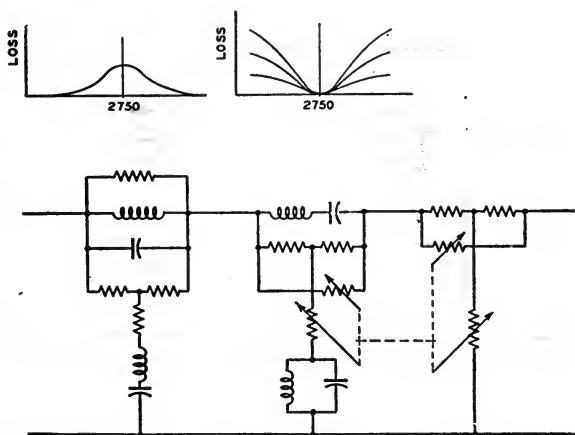
MID-FREQUENCY   EQUALIZER

FIG. 3.   Mid-frequency circuit arrangement.

In order to satisfy (5) of the specifications a second variable attenuator having a 10 db maximum was placed on the same shaft with the variable network attenuator, connected in series with the 2 networks, and mechanically arranged to maintain the total attenuator loss at 10 db.

The arrangement and circuit as described above is shown in Fig. 3.

LOW- AND HIGH-END SECTIONS

Having already introduced an insertion loss of 10 db (owing to the mid-frequency networks) it becomes necessary to use at least 10 db

of gain in order to satisfy (3) of the specifications. By providing an amplifier of greater than 10 db of gain, the remaining requirements can be realized by use of a negative feedback path. The theory of amplifier negative feedback is widely known and will not be discussed fully in this paper. Excellent references are provided by Black[2] and Terman.[3]

The fundamental equation pertaining to negative feedback is

$$\text{Net gain} = \frac{A}{1 - KA}$$

where A = voltage amplification
K = ratio of applied input feedback voltage to the output voltage.
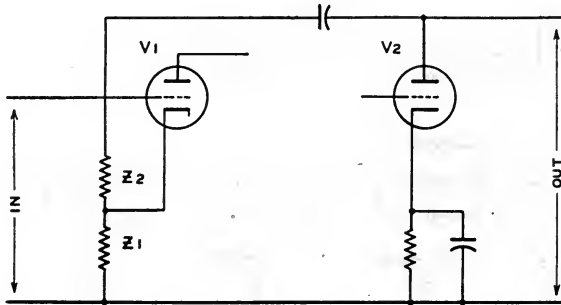

FIG. 4.   Typical 2-stage amplifier with parallel feedback.

Examination of this equation discloses that a two-fold change in factor K will provide 6 db change in gain, provided the product KA is made sufficiently large. Further, by selection of the proper value for KA the slope of the gain change can be adjusted up to a maximum of 6 db per octave. If K is caused to vary with frequency by the use of reactive elements, the phase angle around the feedback loop must be considered and the calculations for net gain become much more laborious.

Fig. 4 depicts a typical 2-stage amplifier with parallel feedback from the second plate circuit to the input cathode resistor. With fixed input and output voltages assumed, the feedback factor is determined by the ratio of Z_1 to $Z_1 + Z_2$ and if either Z_1 or Z_2, or both, are made a function of the applied frequency, the characteristic of the amplifier will vary in accordance with the given equation.

Low- and high-end suppression, or emphasis, as required in this

case can be the result of simple condenser-resistor combinations such as are shown in Fig. 5A. With a suitable choice of resistors, capacitors, over-all gain (without feedback), and feedback factor, the specified frequency characteristics can be obtained by increasing or decreasing C_1, C_2, C_3, or C_4 in discrete steps, as follows:

Low-end suppression: Decrease C_1
Low-end emphasis: Decrease C_3
High-end suppression: Increase C_4
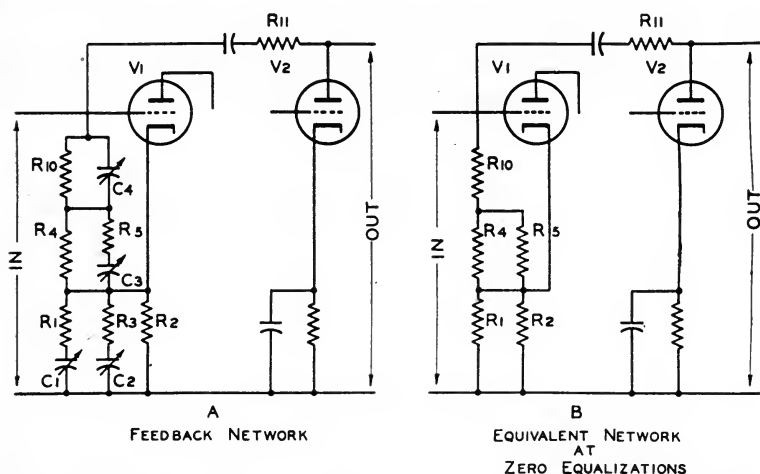High-end emphasis: Increase C_2

FIG. 5. (A) Method of connecting capacitors and resistors in feedback path, and (B) equivalent feedback path at zero equalizations.

Capacitors C_1 and C_3 are connected into the circuit with a single switch which is arranged to maintain C_1 constant in value, while C_3 is being decreased to produce low-end emphasis and, conversely, C_3 is held constant as C_1 is decreased to give low-end suppression. Capacitors C_2 and C_4 are switched in the same manner except that either is held at the minimum value while the other is increased, in steps, to obtain high-end emphasis or suppression. The approximate feedback network, for zero equalizations, is shown in Fig. 5B.

It has already been indicated that large values of KA must generally be used which can obtain by a variety of choices for the separate values of K and A. In order that the feedback path does not adversely shunt down the plate cathode branch of the output tube,

it is desirable to keep the minimum impedance of the path about twice the nominal plate impedance of the output tube. At first thought, such a relatively low impedance path may seem unduly small, but in use, the effective plate impedance is considerably lowered by the feedback factor and further is favored by the fact that as the path impedance is lowered to achieve equalizations, the plate impedance is likewise lowered. Obviously, there must be a limit and *R11* (Fig. 5) serves the purpose. Because of the foregoing facts, large values of gain are used, amounting to 50 db in this case, which is then reduced by the no equalization feedback to 30 db. The change in net gain is then from 24 db to 38 db, leaving 12 db minimum feedback to insure stability and maintenance of characteristics.

Theoretically, a 2-stage amplifier with only resistive feedback cannot oscillate even though very large values of *KA* are used. In
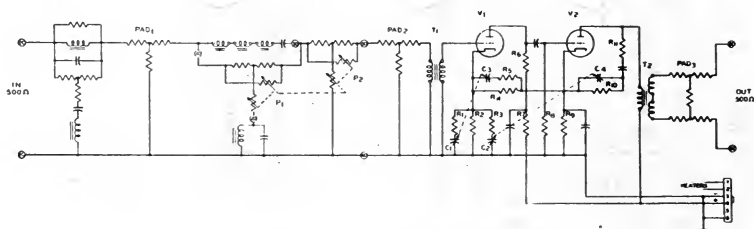

FIG. 6. Complete system, functional schematic.

practice, this is modified by phase shifts within the amplifier owing to coupling, by-pass and stray impedances so that some care must be exercised in design to minimize such effects. A satisfactory solution, when reactive elements are included in the feedback path, as in this application, results when the amplifier is flat in frequency characteristic within -2 db from 20 to 20,000 cps and no abrupt changes in gain exist. Nominally, the blocking condenser in the feedback path is made relatively large in order that appreciable changes in phase angle, or reduction of the feedback factor, occur at very low frequencies where the gain is decreasing and the stability requirements established by Black are met. The use of networks, as described, permits an appreciable reduction in the capacitances of the coupling condenser and C_3 (Fig. 5A) owing to the reverse effects of C_1 which is made smaller than might be expected to accomplish the desired result. This is a welcome circumstance since it reduces the total capacitance required and thereby saves weight, bulk, and money.

Further, proper proportioning of the capacitors maintains the feedback factor more nearly constant with frequency under those conditions where gain peaks are sometimes encountered in feedback amplifiers.

COMPLETE SYSTEM

As previously mentioned, the amplifier at zero equalizations results in a gain of 30 db which must be reduced to zero by suitable attenuators.   The system of networks is assembled as in Fig. 6 with the attenuators, 3 fixed and one variable (in the mid-frequency section),
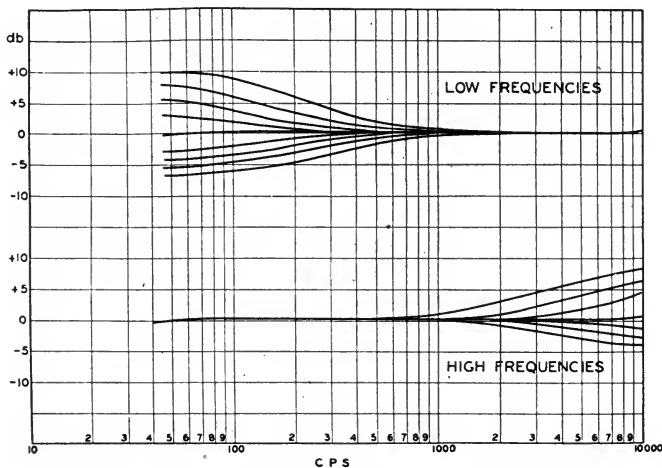

FIG. 7.   Low- and high-end equalization as obtained.

split up so as to make the input and output essentially resistive in nature.

Since the feedback network is not abnormally high in impedance the network controls can be placed in a separate unit which contains the 2 capacitor accumulator switches, the mid-frequency network attenuator with the compensating ganged attenuator, and the feedback network capacitors.   Because of the potential differences which gather on the switch contacts, some noise will be in evidence unless these difference potentials are reduced by connecting resistors between adjacent switch contacts.   These bleeder resistors can be made sufficiently low so as to materially reduce unwanted noise without seriously affecting the desired frequency characteristic introduced

by each separate network on various switch steps.   A further aid in maintaining low noise from this source is to make the attenuations between steps no greater than the specifications.   Fortunately, the amount of equalization per step, the condition for low noise, and operating desirability are compatible.

Fig. 7 shows 2 families of frequency characteristics as obtainable from the amplifier section and Fig. 8 gives the same information on the mid-frequency section.   All combinations of these curves are obtainable.   Since the mid-frequency variable network has the usual characteristic of varying frequency at the point of $1/2$ attenuator loss
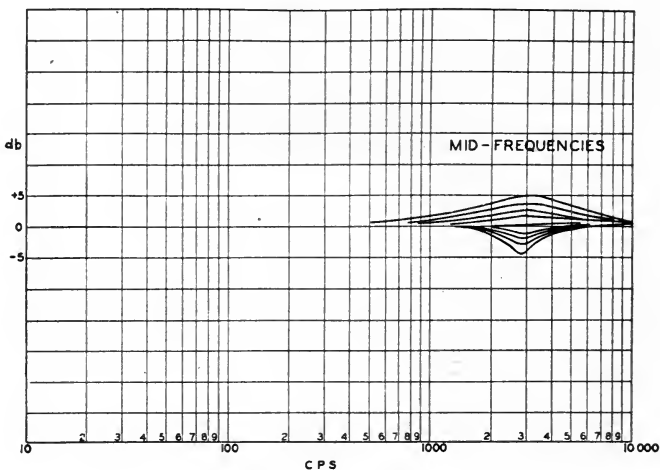
FIG. 8.   Mid-frequency characteristics as obtained.

the emphasis characteristic does not fully meet the specifications. The characteristic shown has been found satisfactory but it is planned to make this network of the "constant B" type, as described by Miller and Kimball,[1] as soon as practicable and the specification can then be fully realized.

The frequency characteristics do not change with tube replacement nor with a 10 per cent change in plate supply voltage.   The output capacity is shown in Fig. 9 for normal plate supply and for 90 per cent normal voltage; either condition being sufficient to handle the output of high level reproducers or microphones.

Total noise, measured at output of the system, is -87 db/0.001 w

which is sufficiently low to work into high gain circuits for recording or rerecording.

The dial stop arrangement consists of 2 radial arms using the shaft as centers and guided on the periphery of the dial; the lock clamps on a machined relief also on the periphery.   These arms are further provided with extended sections, which furnish accurate indexing, and pins which engage the dial pointer to provide the dial stop.
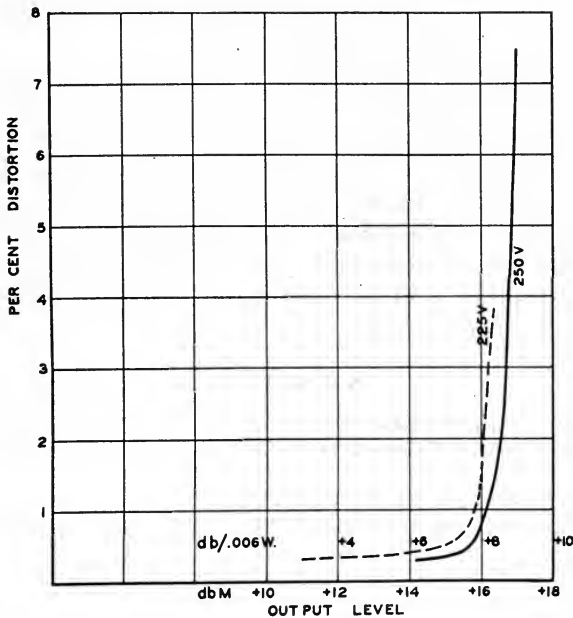
FIG. 9.   Output distortion characteristic of amplifier.

CONCLUSION

There has been some apprehension that feedback amplifiers with reactive networks in the feedback path are apt to be less stable and more susceptible to trouble than other conventional designs but experience has shown this not to be the case.   It is, of course, necessary to select suitable components to do the required job as in any other important work and, in this connection, it may be of interest to note that amplifiers designed upon the principles outlined with a frequency characteristic such as to replace a standard post-equalizer have been in service for over a year, without trouble or characteristic change, except for one instance caused by a faulty capacitor.

As further evidence of stability these post-equalizer amplifiers maintain their characteristics within $\pm\,^1/_2$ db of the required characteristic, and they are not susceptible to tube replacement.   There has also been some aversion to the use of other than constant impedance equalizers, or additional amplifiers for frequency correction purposes, which probably resulted from ill effects caused by changing impedance conditions or poor transient response; both are either reduced or eliminated in the system described, as adequately indicated by square wave and intermodulation tests.

The equalizer system described has met with such approval in rerecording work that it is proposed to use the basic design, mechanically modified to provide permanent equalizer facilities, in a new rerecording console to be built when conditions permit.   If the mid-frequency section is not needed the possible use of the amplifier section, with the available equalizations and without the fixed attenuators, should not be overlooked as a practical method of providing a variable equalizer in other recording or reproducer systems where some gain exists or is required.

REFERENCES

[1] Miller, W. C., and Kimball, H. R.: "A Rerecording Console, Associated Circuits and Constant B Equalizers," *J. Soc. Mot. Pict. Eng.*, **43,** 3 (Sept., 1944), p. 187.

[2] Black, H. S.: U. S. Patent No. 2,102,671.

[3] Terman, F. E.: "Radio Engineers' Handbook," McGraw-Hill (New York), 1943, p. 395.

PSYCHOLOGICAL AND TECHNICAL CONSIDERATIONS EMPLOYED IN THE BUCKY SOUND REPRODUCTION AND PUBLIC ADDRESS SYSTEMS*

PETER A. BUCKY**

Summary.—*Our physical senses are not capable of absolute qualitative or quantitative measurement but they indicate by comparison only. Their reaction to harmonious sounds is an emotional or artistic experience not measurable by ordinary means but definitely established as a psychological entity. Conventional theater or auditorium loudspeakers do not reproduce the emotional effect created by a "live" orchestra and it is proposed that these systems which are highly directional be replaced by another system with nondirectional characteristics in which reverberation from a multitude of separate loudspeakers replaces or even enhances the original sound picture. The physical difficulties involved in constructing such a system are bridged by the use of a radio frequency carrier for signal distribution.*

Measuring.—Measuring methods are the means of comparison and standardization. They enable any person to duplicate certain findings concerning matter or energy. Psychological perception of matter and energy takes place by means of sense organs which, however, are confined to touch (consistency, shape, surface, location), warmth, light, sound, and smell. We have no organ of perception for other energies such as, for instance, certain electromagnetic waves. Calibration of such energies can only be accomplished by converting them into other forms of energy for which we are equipped with a specific sense organ. The brain does not perceive any physical energy directly, but transformation into electrochemical action is necessary which is then conducted by the nerves to the brain. This transformation takes place in our sense organs.

Furthermore, these sense receptors are not able to differentiate exactly qualitative or quantitative perceptions. There are only a few persons who, for instance, have "absolute pitch," that means

---

they are able to recognize correctly the frequency of the sound wave to which they are subjected. We certainly can differentiate colors, but only by comparison. A white paper in a dark room illuminated by red light reflects red light only, but after some time we fail to perceive the color as such. We are able to differentiate the light intensities of various objects. We cannot differentiate the various components of white light, but we can generally recognize the individual frequencies of sound in an orchestra. The judgment of quantity is still more difficult. At night we might be blinded by a match, whereas in daylight the same match does not interfere with our vision.

This proves that we have no means to define by our perception the absolute energy and quality of light and sound. We can only compare qualities and quantities with relation to each other.

Transformations of energy do not follow straight line curves, and these curves are by no means identical in type to the different methods of transformation. In physics we can coordinate the different curves according to some absolute measuring system. But when it comes to psychological perception, the problem of measuring sensations becomes highly complex if not hopeless. These considerations lead to the conclusion that our physical make-up gives us rather limited means of analyzing psychological perception. The matter becomes still more complex in the reproduction of music as an entity in contrast to the concept of a heterogeneous aggregation of physical frequencies. Music as an art impresses the listener with emotional resonance. Besides the physical and physiological fundamentals, psychological reflections play an intricate part. It can be safely stated that the psychological response is the most important part of the entire problem of sound perception. Artistic impressions are highly individual. Therefore, a statistical average can be the only solution. As much as physical measurements might be of help, our attempts should not be dominated by them. Close cooperation of musicians, physicists, and psychologists is imperative, even more so than it was in the past.

I do not pretend to assume that these deductions are novel; in fact, they are obvious. However, our investigations, which were rather empirical physically, supported these assumptions. Since the physical fundamentals have been so well established by the meritorious work of physicists and engineers, the way is now clear for musicians and psychologists. To illustrate this viewpoint, a few

particulars should be discussed from physical, psychological, and musical viewpoints.

Directional Effect.—The directional effect allows the listener to locate the source of sound waves. There cannot be any doubt that the artistic impression of orchestral music in general does not depend on the directional effect. On the contrary, nondirectional perception of sound is ideal and will produce a harmonious and mellow sound quality. The directional effect must be comparatively greater when the sound waves travel directly from the source to the ear of the listener without reflections or reverberations. That means that in an enclosed space the directional effect will be less noticeable. Illusion is interfered with if the directional sound comes from a different direction than light impressions. Therefore loudspeakers in motion picture theaters are usually placed near the screen.

According to our experiments, nondirectional, that means evenly distributed sound, does not interfere with illusion. The instruments in an orchestra, especially the wind instruments, are seated in a linear order to dampen the directional effect and this indicates the fact that an overemphasized directional effect is not desirable. There is a great difference between the individual instruments. Brass instruments, for instance, are built to project the sound waves in a beam; whereas the majority of the other instruments produce unfocused spherically progressing sound waves. The sound of wind instruments is mainly reflected by the vertical walls, whereas the ceiling plays the greater part with most of the other instruments. If we consider the quantitative proportion of direct and reflected sound striking our ear, we see that there is a great difference between the wind instruments and the other instruments. However, we cannot assume that the wind instruments give a superior artistic effect. On the contrary, we have found that the suppressed directional effect of orchestra music and even distribution produces a rather pleasing effect—the impression of being surrounded by sound and of being relieved of the effort to focus the attention to an individual instrument which is quite often disturbing if the directional effect has not been suppressed.

Our experiences have led us to the conclusion that even distribution of sound with suppression of the directional effect represents an essential progress in the psychological artistic respect. Our opinion was confirmed by leading musicians and conductors who

called the effect startling.   We claim that traditional assumptions have to be modified.   We must not forget that the ideal arrangement and location of an orchestra would be in the center of a hall. However, the circular arrangement of the instruments would make it impossible for the conductor to give directions to the individual musicians.

A problem in itself is represented in the reproduction of speech. In this case, intelligibility is affected greatly by reverberation.   If reverberations come from comparatively long distances, the speech becomes unintelligible owing to time intervals of the sound waves. A simple solution of the problem is to use a number of low-powered loudspeakers distributed evenly over the listening area to reduce reverberation and to have the sound travel and be reflected vertically instead of horizontally in rooms or halls the height of which is shorter than the length.   However, there exists the assumption that the desired illusion is interfered with if the sound does not come direct from the stage.   This conclusion has arisen from a very peculiar coincidence.   As mentioned above, speech and human voice are emitted semispherically in a horizontal direction.   When they are generated by the ordinary type of loudspeakers, a beam is emitted (as in a brass instrument) with its specific directional effect.   If such a loudspeaker is placed in an unfamiliar location, no doubt the effect must be highly disturbing.   We have found that evenly distributed sound does not appear disturbing.   It is amazing how the listener can be misled by his imagination when there is no directional effect present.

We have an installation in a room with a piano.   When piano pieces are played over the loudspeaker system without directional effect, quite a number of listeners assume that the loudspeakers are in the piano.   This proves that an action takes place in the brain, similar to looking at a stereoscopic picture.   Psychological experience is substituted for physical facts.

Another advantage is greater apparent brilliance of the sound. Music in an unenclosed space, such as at an open air concert, appears flat owing to the lack of reverberation.   If the same waves strike the ear at imperceptible time intervals, the sound gains in brilliance and becomes "three-dimensional."   This is a well-known fact.   With our system, this effect is especially noticeable and contributes to the pleasing impression.

Installation of System.—Our system uses 3 frequency ranges

which are amplified separately.   The following rules for installation
have been arrived at from the conclusions of our psychological
experimentation:

(1)   No sound beam must be pointed directly at the listener.

(2)   The high-frequency range must be reflected from the floor by directing
the loudspeaker toward the floor.

(3)   The medium range must be reflected from the ceiling by directing the
loudspeakers toward the ceiling.

(4)   The low range must travel on and parallel to the floor.

(5)   In large rooms, an attempt should never be made to cover the entire space
by means of a single loudspeaker for the individual range.

An explanation for the resulting psychological effect, as de-
scribed above, cannot be found by physical measurement.   As we
do not know the transmission curve of sound waves into electro-
chemical nerve stimulation in the ear, we must restrict our observa-
tion to empirical experiments.   Up to now, we have not found a
means for exact physical measurement.   However, we can assume
with certainty that the psychological curve does not coincide with
the curves of the physical sound measurement apparatus.

As our system requires a multitude of loudspeakers, a rather
elaborate wiring system would be required.   We have, therefore,
developed a wireless system using a wavelength distant from
presently utilized frequencies.   Therefore, interferences are out of
the question.   The current coming from the microphone or the
pickup is connected to a radio transmitter.   The radio waves travel
over the power line in the well-known way.   Filters installed in the
fuse box prevent these frequencies from reaching undesired direc-
tions in the circuit in order not to disturb neighboring localities.
Each loudspeaker is equipped with its own receiving amplifier and
an adequate filtering system.   This arrangement has an advantage
in that all its parts may be manufactured in mass production.   No
special amplifiers have to be designed for the size of the hall to be
equipped and only the number of loudspeaker units has to be
increased.   This system is, therefore, very flexible and may over-
come comparatively easily the acoustical shortcomings of the room.

We are confident that our system proves that for real artistic
reproduction of sound, psychological and physiological factors are
at least as important as physical measurements.

TECHNICAL NEWS

The items appearing in this section were submitted December 7, 1945, by members of the Technical News Committee, who welcome and will consider items of current technical interest from any member of the Society.

Additional information concerning these items, or the equipment and processes discussed, may be obtained by communicating with the general office of the Society, Hotel Pennsylvania, New York 1, N. Y.

16-MM MAGAZINE FOR GUN CAMERAS

Eastman Kodak Company.—The Kodak 16-mm magazine as used by the Armed Forces during the recent war was designated as the *A-6*, and later the *AN-A-6* magazine. Its use in the Gun Sight Aiming Point Camera was first for gunnery training and later for the purpose of recording actual combat scoring and the criticism of combat technique.

The gun camera design was laid out around the standard commercial Kodak magazine, and when the camera was used for gunnery training only, the magazines were loaded at the factory and returned to the factory for reconditioning. It soon became very apparent that pictures taken during actual combat were also invaluable in the training program.

The Kodak magazine was designed for use in amateur cameras with spring motor drive, and for use under moderate conditions of temperature and vibration. It is loaded, unloaded, and repaired after each 50-ft run, under factory conditions by specially trained personnel. By this procedure the percentage of failure is kept to a minimum. Even when the magazine is used at high altitudes, with resulting low temperature and with the vibration of airplane motors and firing machine guns, the percentage of failures was sufficiently low to be considered satisfactory.

The expansion of the gun camera program by the Armed Forces was so extensive that it was impossible to train a sufficient number of personnel to handle the magazines properly. The Army Air Forces appealed to the Eastman Kodak Company to provide a new design of magazine which would be better suited to their facilities for loading and maintenance. The result was the later style *AN-A-6* magazine which has no sprocket film drive. The new design had

80

to be suitable for use in the same cameras and yet had to be made so as to be loaded and unloaded more readily and require much less critical handling.

The gun camera in normal use is subject to sufficient vibration to reduce the sharpness of the projected image far below that considered satisfactory for commercial use. This fact permitted a design of magazine with a lower standard of steadiness than the commercial magazine. The design finally used is one which is well above the level imposed by the military operating conditions but will not pass the photographic tests required of the sprocket type.

The sprocketless *AN-A-6* magazine utilizes the camera spline drive solely to actuate the take-up spool. The film is moved from the supply spool and through the gate by the action of the camera film claw. A spring element is introduced between the supply spool and the gate for the purpose of partially leveling-off the shock of the intermittent action of the claw against the inertia of the roll of supply film. Evidently it is this resistance of the supply roll which interferes slightly with obtaining pictures of sufficient steadiness for commercial use, and it is for this reason chiefly that the sprocketless type is recommended for gun camera use only.

TELEVISION

The most important factor in the progress of television at the present time is the Federal Communications Commission's rules for the art and the industry reaction thereto; the latter to be measured in cold dollars and cents expended in the near future. Quantity production and distribution of television receivers is a necessary part of the telecasting structure and receiver manufacturers must see hope for profit before engaging in large-scale production.

Indications are that theater television will lag broadcasting development. Apparatus is tight now, and since the movie theater is selling its regular product very successfully there appears to be little point in attempting to rush television as an added attraction.

Television Productions, Inc. (Paramount) has a building in construction on Mt. Wilson, destined for completion by the first of 1946. It will house their transmitter operating at a power of 4 kw peak, monitor equipment, living quarters, and other items.

A 500-megacycle sight-sound beam relay will transmit the television programs from existing studios on the Paramount lot in Holly-

wood to the mountain top. The equipment is expected to be in test operation during January 1946.

Klaus Landsberg, Director of Television for Paramount's television station, *W6XYZ*, brings forth the first post-war design of television control equipment. The Telemobile was designed along radically new lines by Mr. Landsberg, and constructed by his engineering staff in their Hollywood laboratory. It combines all control equipment necessary for the operation of 2 television cameras, in-
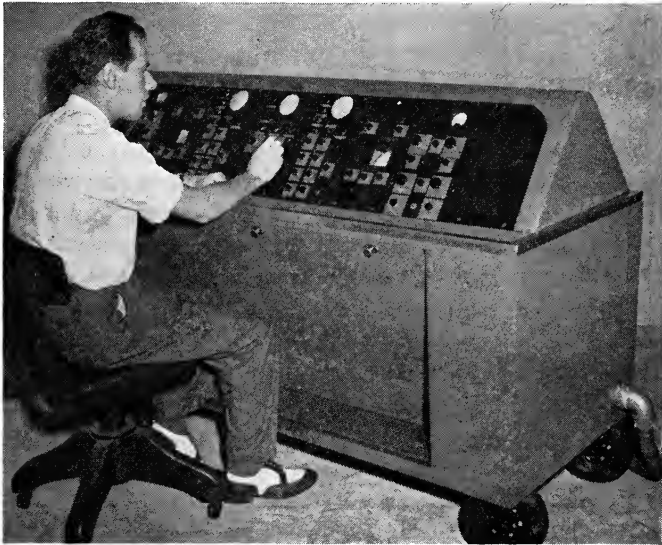

FIG. 1.   The Telemobile, a "control room on wheels," of Paramount's
Television Productions, ready for operation.

cluding the synchronizing pulse generator, sweep signal generator, power supplies, and monitoring units.

The Telemobile is a product, neither designed on the drawing board of an advertising department, nor by the research group of a manufacturer. Instead, it is a result of practical operating experience, and was evolved from DuMont's "suitcase" type of equipment, strictly out of the needs experienced by Paramount's television group during program operation. While functional design was the main consideration, and waste space was completely eliminated, the streamline design of the Telemobile establishes a new standard for eye ap-

peal. Fifteen specific advantages of this equipment are listed by Mr. Landsberg.

Earl C. Anthony, Inc., is also constructing a 2-story building on Mt. Wilson. In addition to housing television equipment, living quarters and an auxiliary Diesel power room are included.

A major studio expansion has been announced by the **Don Lee Broadcasting System.** Joining "radio row" on Vine Street in Hollywood, a $1,250,000 3-story studio building will be located on the entire block between Fountain and Homewood Avenues on Vine. A floor space of 105,000 sq ft will include 14 studios, offices and production quarters. Four theater studios with unusually large stages will be equipped for television as well as for radio broadcasting. A 150-ft tower, with elevator, will be the highest structure in Hollywood. The tower will house television and FM beam relay antennae for transmission of these programs to Mt. Wilson. Here the company has a tract of 160 acres upon which high power transmitting equipment will be located when the same is manufactured. In the meantime, operations continue on Mt. Lee overlooking Hollywood. Ground will be broken in January 1946.

PROGRESS IN THE 16-MM PROFESSIONAL FIELD

The Technical News Committee has given a great deal of consideration to national and international activities on the production, distribution, and use of 16-mm film during the immediate post-war period.

News stories have been released which indicate that circuits of 16-mm theaters are being planned for small towns in the United States, and that much of the distribution of film for the sparsely populated areas of foreign countries will be in 16-mm.

The policy of the major producers of entertainment film with respect to releasing current features on 16-mm is not clear to the Committee at this time. However, it is known that a number of independent producers are at present photographing on 16-mm film, particularly in color, for release on 16-mm film to the entertainment field. This would indicate that 16-mm entertainment film will be available wherever the market exists.

The activities of government departments in producing outstanding pictures for training and documentary purposes have firmly established 16-mm film in both the educational and industrial fields.

In the educational field there is evidence to support the opinion

that the availability of strictly training and historical subjects in 16-mm will revolutionize the teaching programs.

The successful use of animation in training and industrial films has created a great deal of interest among cartoon producers who may find a larger market in the educational and industrial fields than they now enjoy in the entertainment field.

In the equipment field much is being done toward the design and manufacture of professional 16-mm production equipment. Major improvements are being made in 16-mm color, sound, and projection.

An organization of 16-mm professional cinematographers has been formed.

While complete details of these activities are outside the scope of this news item, it is indicated from the information at hand that the subject is of international interest. It is the recommendation of the Technical News Committee that a symposium on professional 16-mm activities be planned at an early date.

SOCIETY ANNOUNCEMENTS

ATLANTIC COAST SECTION MEETING

An interesting and informative talk was given before members and guests of the Atlantic Coast Section of the Society by E. A. Bertram of DeLuxe Laboratories, New York, on "A Motion Picture Processing Laboratory and Its Relation to the Film Producer." Mr. Bertram described the organization and operation of a modern film laboratory, covering all phases of laboratory work from mixing chemicals to shipping the film. The talk was almost equal to a tour through a typical film laboratory. Mr. Bertram stressed the accurate sensitometric control and uniform development now practiced in commercial film processing laboratories.

A large audience also viewed a motion picture supplied through the Signal Corps Photographic Center. The meeting was held in the *Penn Top* of the Hotel Pennsylvania, New York.

The Chairman of the Section, C. R. Keith, thanked officers and managers of the Section for their cooperation in arranging meetings during his term of office. Mr. Keith introduced the officers and managers of the Section for terms beginning 1946, as follows:

Chairman: FRANK E. CAHILL, JR.
Secretary-Treasurer: JAMES FRANK, JR.
Managers: HERBERT BARNETT   JACK A. NORLING
           HOLLIS D. BRADBURY   W. H. OFFENHAUSER, JR.
           G. T. LORANCE   H. E. WHITE

MEMBERS LOST SERVING THEIR COUNTRY

The Society desires to compile a list of members who gave their lives while serving with the Armed Forces of their country. Such a list will include members abroad who served with Allied military forces as well as those in the services of the United States.

The general office of the Society is not always advised of deceased members, and it will be appreciated if readers of the JOURNAL will forward the name of any member known to them to have been a war casualty. Please include with names submitted the approximate date, place, and any other information available.

Your cooperation will assist the general office in obtaining a complete and accurate list for the records of the Society.

We are grieved to announce the death of Lieut. Colonel Harry B. Cuthbertson, Active member of the Society, on December 12, 1945, in Paris, France.

EMPLOYMENT SERVICE

POSITIONS OPEN

Designer and engineer experienced in optics, lighting, and microphotography, capable of designing microfilm reading equipment and products related to microfilm industry. Reply to Microstat Corporation, 18 West 48th St., New York 19, N.Y.

Design engineer, experienced in mechanics and optics of motion picture cameras, projectors, and film scanning. Give details. Reply to Mr. John H. Martin, Columbia Broadcasting System, Inc., 485 Madison Ave., New York 22, N.Y.

Position available for Optical Designer, capable of handling the calculation and correction of aberrations in photographic and projection lens systems. Junior designers or engineers will be considered. Write fully giving education, experience, and other qualifications to Director of Personnel, Bell and Howell Company, 7100 McCormick Road, Chicago 45, Ill.

POSITIONS WANTED

Sound recording engineer, 16- or 35-mm equipment, studio or location work, single or double system. Free to travel. For details write J. J. K., 354 Ninth Ave., New York 1, N.Y.

Honorably discharged veteran with 15 years' experience in all phases of motion picture production, including film editing, directing, producing. For details write F. A., 30-71 34th St., Long Island City 3, N.Y. Telephone AStoria 8-0714.

Projectionist-newsreel editor with 15 years' experience just released from service. Willing to locate anywhere. Write P. O. Box 152, Hampden Station, Baltimore 11, Maryland.

Chief Engineer of motion picture camera manufacturer now available. Special training in optics, electricity, electronics, mechanics. Experienced in all phases of manufacture of cameras, projectors, and accessories. Prefer West Coast, but not essential. Write Robert Winkler, 119 West 78th St., New York, N. Y.

Newsreel cameraman, overseas U. S. Army veteran with honorable discharge, desires position with educational or commercial organization with work-training arrangement. Will supply prints on Army work in ETO. For full references, experience, and record, write Tom J. Maloney, 406 Oak St., Ishpeming, Mich.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

| Vol 46 | FEBRUARY, 1946 | No. 2 |

CONTENTS

A WIDE ANGLE 35-MM HIGH-SPEED MOTION PICTURE CAMERA*

JOHN H. WADDELL**

Summary.—High-speed motion picture photography has played a very important part in the development of machines and working devices by providing a convenient means for analyzing the behavior of moving parts. A wide angle high-speed motion picture camera has recently been designed. The camera takes pictures at rates up to 3500 per sec and has a 40-degree field of view. This field of view allows the camera to photograph a 71-ft field when 100 ft away. The problems of design and applications of the camera are discussed.

High-speed motion picture photography has played a very important part in the development of machines and working devices by providing a convenient means for analyzing the behavior of moving parts. A wide angle high-speed motion picture camera has recently been designed to add to the photographic facilities previously available. The camera takes pictures at rates up to 3500 per sec and has a rectangular field of view 40 degrees in width. At a distance of 100 ft this gives a field 71 ft wide.

There have been described in papers before the Society of Motion Picture Engineers the 4000-picture per sec 16-mm Western Electric Company Fastax camera,[1] and the 8000-picture per sec 8-mm Western Electric Company Fastax camera.[2]

These cameras, as well as others available on the market, have a limited field of view owing to the long focal length of the lenses in relation to the width of the film. In the 16-mm Fastax camera, for example, the shortest focal length lens that can be used is 35 mm; and in order to show the action of a device moving over a considerable distance in space, it would be necessary to use a number of such cameras at a given magnification located so that their fields of view

---

would overlap.   This, of course, would be inconvenient and laborious.
The new camera herein described was designed to use a 35-mm lens,
but the film is 35 mm wide so that the field of view is much wider than
with other high-speed cameras.   Since, however, it is generally un-
necessary to cover a wide angle of view in both vertical and hori-
zontal directions, and because of certain design considerations, the
pictures provided by this camera are reduced in dimension parallel
to the length of the film as judged by conventional 35-mm film pic-
tures.   It, therefore, covers a field 12 degrees by 40 degrees.   Fig. 1
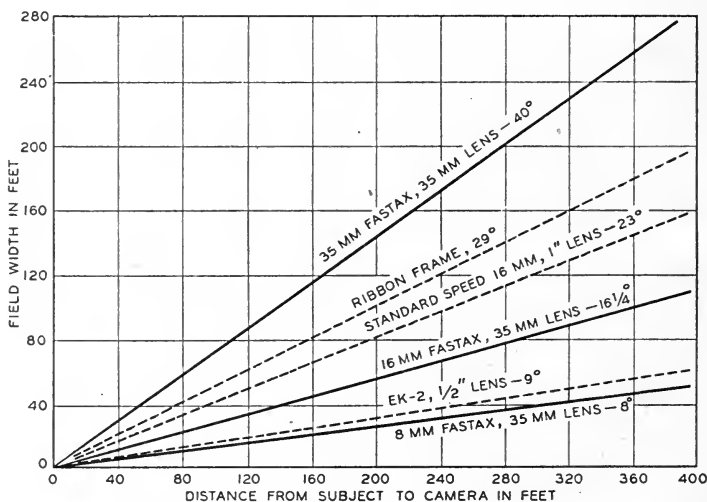
FIG. 1.   Field of view of high-speed cameras.

shows a comparison of the fields of view of a number of motion pic-
ture cameras.   Fig. 2 shows the relative photographic effect for the
16-mm Fastax and for the 35-mm wide angle Fastax; A for equal
distances from the subject and B for equal field widths.   In A it will
be noted that the subject sizes in the photograph are the same but
the field of the 35-mm camera is $2^1/_2$ times as wide as for the 16 mm.
In B note that the subject size for the 35-mm wide angle camera is
$2^1/_2$ times as large for the 35-mm camera as for the 16-mm camera.

In previous descriptions of the Western Electric Company Fastax
cameras, it has been noted that the shutter mechanism consists of a
rotating prism designed to synchronize the image with the con-
tinuously moving film.   In the 35-mm wide angle camera the same

principle is used.   The wider field in this case, however, introduced certain design problems.   The major one involves the use of a piece of glass about the same cross-sectional size as in the 16-mm camera
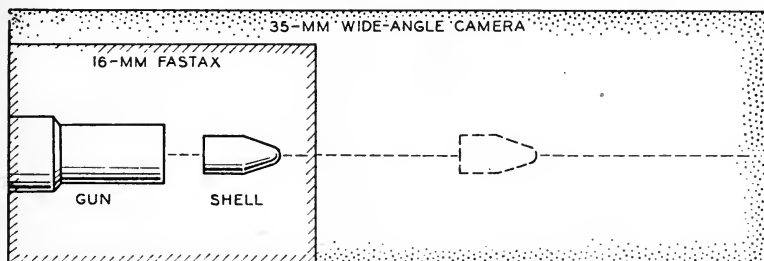
A. COMPARISON OF CAMERA FIELDS
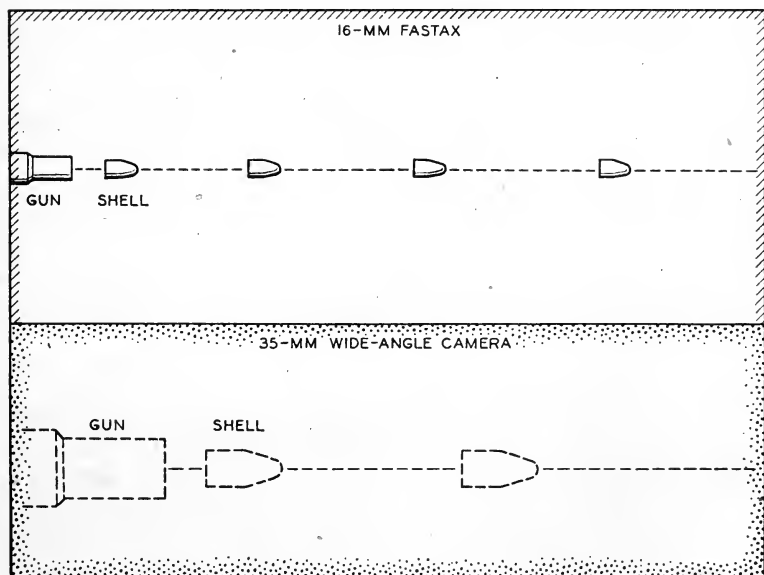
B. COMPARISON OF CAMERAS COVERING SAME HORIZONTAL FIELD

FIG. 2.   Relative photographic effects of 16-mm and 35-mm Fastax cameras.

but of such optical characteristics as to increase the speed of the image by 25 per cent in order to fulfill the synchronous requirements.

In the rotating prism type of shutter the glass must have a number of pairs of parallel faces and the thickness depends upon the index of refraction, the picture frame height, the angle of rotation in which

the picture is laid down, and the peripheral speed of the image which, as previously indicated, must be equal to the linear speed of the film. For any given set of conditions this imposes a certain minimum de-
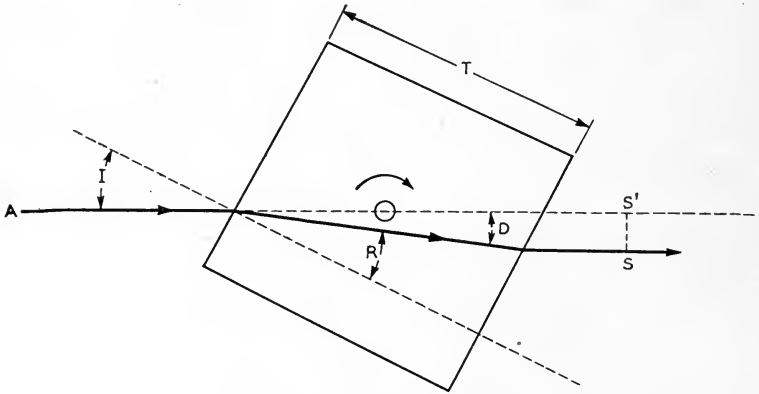
FIG. 3.   Schematic showing effect of prism rotation on ray of transmitted light.

sign dimension between the rear element of the lens and the film plane.

For example, in the 16-mm Fastax camera using glass with an index of refraction of 1.5156, the thickness of the prism is 0.551 in.   This
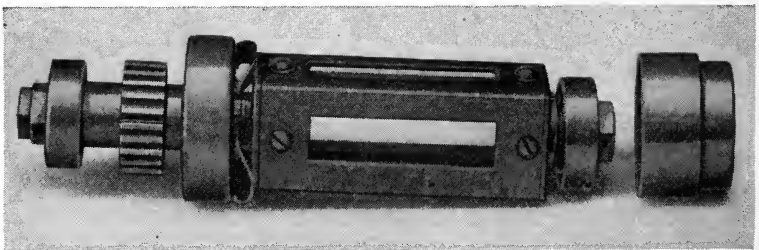
FIG. 4.   Prism shaft assembly with ball bearings.

is based on a frame height of 0.300 in.   If this kind of glass were used in a full frame 35-mm camera, the prism required for the same angle of rotation as in the 16-mm Fastax would be 1.6 in. thick.   This would mean a lens of much greater back focal length in a full frame 35-mm camera than in the 16-mm Fastax, and the field of view would

be correspondingly reduced from that of the objective sought.

The quantitative design of the prism, as illustrated in Fig. 3, is based on the following relationships:

$$\mu = \frac{\sin I}{\sin R} \tag{1}$$

$$T = SS' \frac{\cos R}{\sin D} \tag{2}$$

$$D + R = I \tag{3}$$

where

SS' is the maximum displacement of ray when passing through the prism,

I is the angle of incidence at the prism face,

R is the angle of refraction in the prism,

D is the angle of displacement of the transmitted light,

μ is the index of refraction of the prism material,

T is the prism thickness, and

AS is the trace of a ray of light through the prism.

In Table 1 pertinent data are given on the prisms used in the 16-mm and the 35-mm cameras. It is to be noted that by using a glass with a somewhat higher index of refraction a prism about the same thickness as that used in the 16-mm camera is obtained which allows the use of a relatively short back focal length lens in the new wide angle camera. The glass used is one of the rare element, high index of refraction, low dispersion glasses.

TABLE 1

	16-Mm Camera	35-Mm Camera
Diameter of Film Pitch Circle	1.910 in.	1.9074 in.
Arc Film Length on Pitch Circle Corresponding to One Frame	0.3000 in.	0.3740 in.
Angle in Degrees per Picture Frame on Sprocket	18 deg	22.5 deg
Length of Chord on Pitch Circle Corresponding to One Frame	0.2987 in.	0.3716 in.
SS'	0.03735 in.	0.04645 in.
μ	1.5156	1.7172
I	11.25 deg	11.25 deg
R	7 deg 24 min	6 deg 31 min
D	3 deg 51 min	4 deg 44 min
T	0.551 in.	0.559 in.

Another design problem in connection with the prism has to do with the mechanical support. So far only the cross-sectional size

of the prism has been considered. In the case of the 16-mm camera the prism is about 0.6 in. long and is supported in a metallic housing mounted on the end of a shaft having 2 bearings. In the 35-mm camera the prism is approximately 1.2 in. long and it was considered necessary to provide an additional bearing beyond the prism to eliminate whipping. Also, the increased length of the prism imposes increased tendencies for rupturing of the housing by the centrifugal forces in the housing itself. The latter problem was successfully
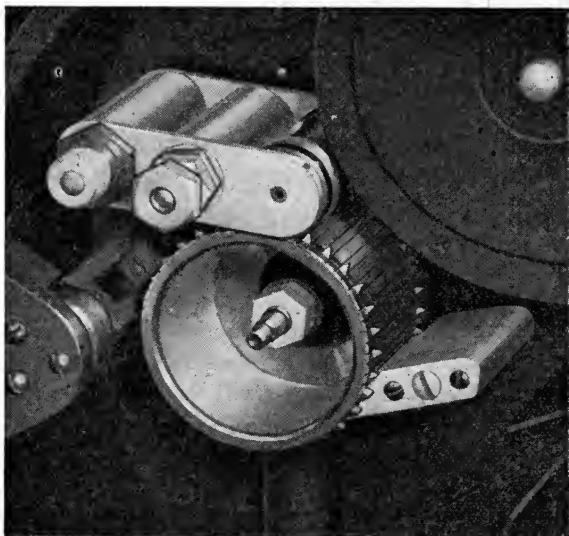
FIG. 5.   Interior view of camera showing rotating prism assembly in relation to sprocket.

overcome by more sturdy construction. Fig. 4 shows the prism and its supporting system, and Fig. 5 shows the prism assembly in the camera.

The sprocket design in the 35-mm camera is similar to that in the 16-mm camera where the pitch and rectangular shape of tooth are designed to use film of full pitch between perforations, or film that is only slightly shrunken (not more than 0.5 per cent). In order that the user can test the film, a gauge is provided on the back of the camera door. The gauge is of the "go" or "no-go" type. It consists of 2 pins for engaging the film perforations and which are located 38 perforations apart. Film having a tolerable shrinkage will fit over

the pins satisfactorily. This gauge is provided as a convenience, because the user may neglect to refrigerate or otherwise properly store film that is kept on hand for a considerable time. Fig. 6 shows what happens when excessively shrunken film is used in a camera. The pictures in this figure were part of a study made on a 35-mm camera
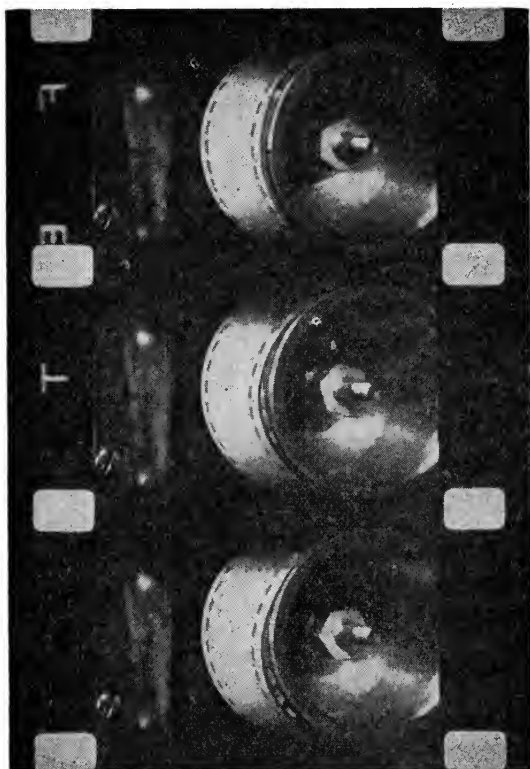
FIG. 6.   Jumping of film off sprocket at high speed caused by excessive shrinkage of film.

running at 3500 exposures per sec and using film having slightly more than one-half of one per cent shrinkage. In this study erratic skipping of frames occurred. The high-speed motion picture studies in this figure were taken with the 16-mm Fastax running at 4000 frames per sec.

Only acetate base film is recommended for use in the 35-mm camera and arrangements have been made with a supplier to provide it in

suitable lengths packed in hermetically sealed containers. This together with the use of the gauge described above insures against trouble caused by shrinkage.

Two view-finders are provided for use on the camera. One is a peep sight view-finder for use with the 35-mm lens when focused at infinity, and is intended as a convenient means for rapidly checking the field of view. The other finder is of the reflex type and fits into the bayonet socket mount on the front of the camera. When so used the 35-mm objective lens is removed from the camera and is inserted in the finder socket. This lens is provided with 2 focusing scales.
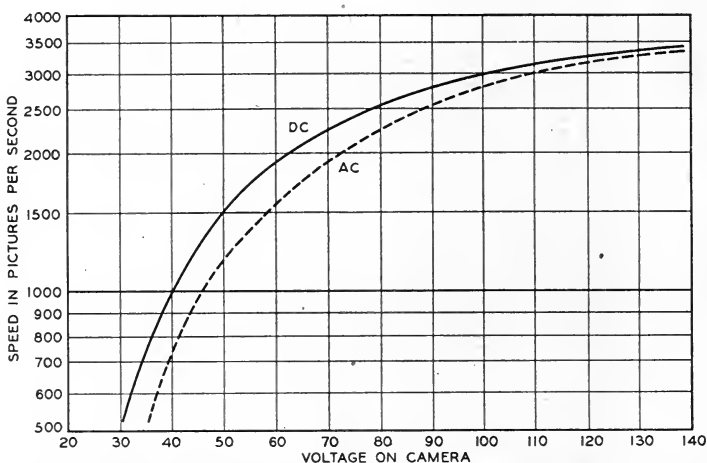
FIG. 7.   Speed in pictures per second versus voltage on motors in 35-mm Fastax camera.

The red scale used with the view-finder corrects for the difference in distances between subject and finder screen and subject and film plane. This scale is accordingly to be used only when working with the finder. The finder is provided with a 7-power magnifier as an aid in focusing. When the camera setup has been made the finder is removed and the lens replaced in the camera bayonet socket. In this case the white focusing scale is used and the lens is adjusted to the setting previously obtained on the red scale.

The $f/2$ 35-mm lens is a standard component of the camera. There are also available an $f/2$ 2-in. lens, an $f/3.5$ 105-mm lens, an $f/4.5$ 150-mm lens, and an $f/4.5$ 254-mm lens. All of these lenses are fitted with bayonet mounts and can be used with the reflex finder.
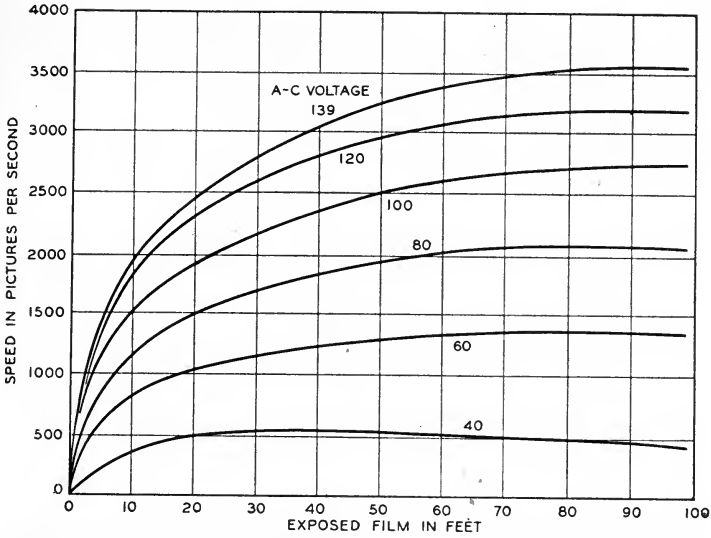
FIG. 8.   Speed *versus* footage of exposed film at various a-c voltages.
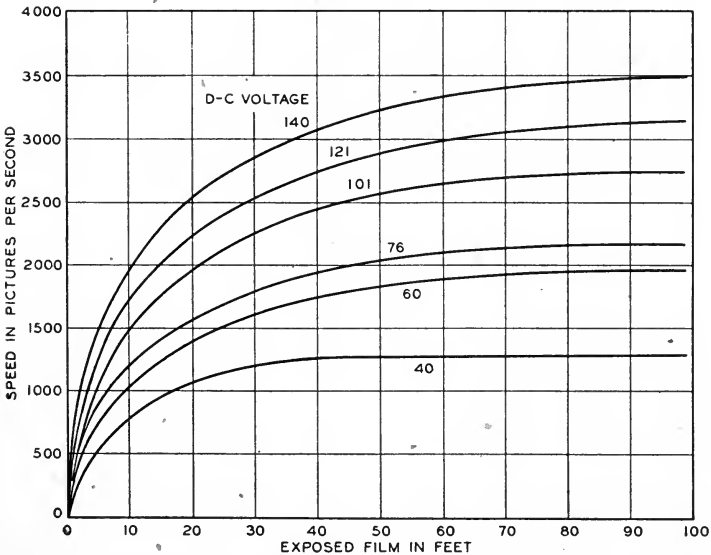
FIG. 9.   Speed *versus* footage of exposed film at various d-c voltages.

All lenses are coated. It has been found by experience that an effective increase in aperture of approximately 2 stops is obtained by using coated lenses, as compared with uncoated lenses, owing to the reduction of internal reflections in the lens and the resulting higher transmission. Also the elimination of flare in the coated lenses facilitates the photography of incandescent subjects.
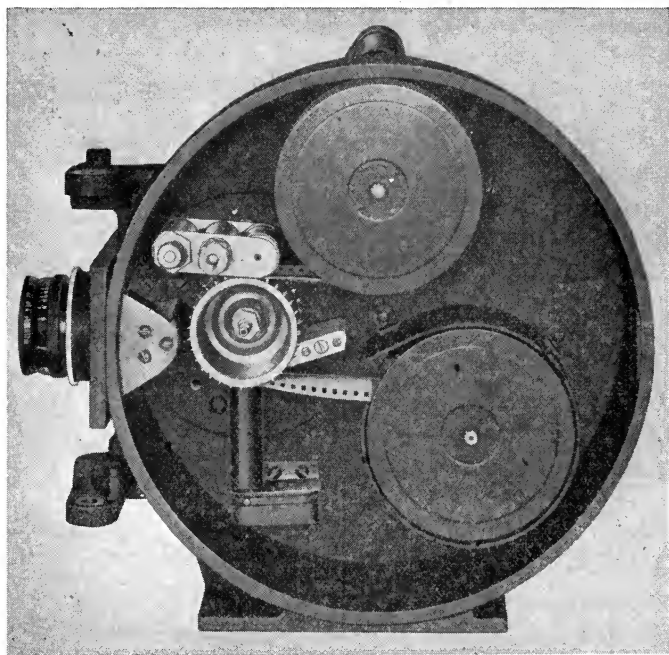
FIG. 10.   Internal view of 35-mm Fastax camera.

The motor equipment in the 35-mm Fastax is the same as that used on the other Fastax cameras; namely, two 120-v, $1/4$-hp universal motors. One motor is coupled to the film driving sprocket while the second motor is coupled to the film take-up spindle. The dynamic characteristics of the motors under load conditions are somewhat different in the wide angle camera from previously published data for the 8- and 16-mm Fastax cameras. The voltage versus speed characteristic in pictures per second for the 35-mm camera is shown in Fig. 7 for both a-c and d-c power. The speed characteristics at various voltages are shown in Figs. 8 and 9. The

values shown for voltage are voltages at the motors read immediately before the camera was started and are somewhat greater than the values actually existing when the motors are operating.

A further feature in the design of the 35-mm wide angle camera is a flashing argon lamp timer which can be actuated from an oscillator furnishing a minimum of 120 v rms. The plug for the lamp is
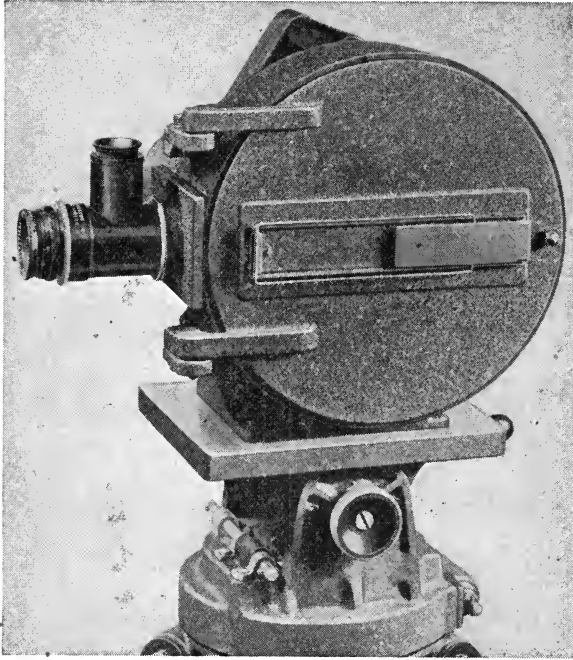
FIG. 11.   Thirty-five millimeter Fastax camera with re-
flex view-finder.

mounted on the back of the camera under the driving motor. When using a 60-cycle voltage source the lamp provides 120 flashes per sec and, therefore, the markings on the film are 0.0083 sec from the beginning of one mark to the beginning of the next. With a suitable oscillator to give 100 or 1000 flashes per sec greater convenience in reading the film is afforded.

The camera has been designed to withstand reasonably rough usage. For instance, it can be used in studies where blast pressures are many times greater than those that can be tolerated by man.

It is light in weight (about 35 lb) and can be used in any position that insures proper positioning of the film reels on their supporting spindles.   Since the camera can be operated on both a-c and d-c, it can be conveniently used in air-borne and mobile equipment, indoors and out, providing suitable power is available.
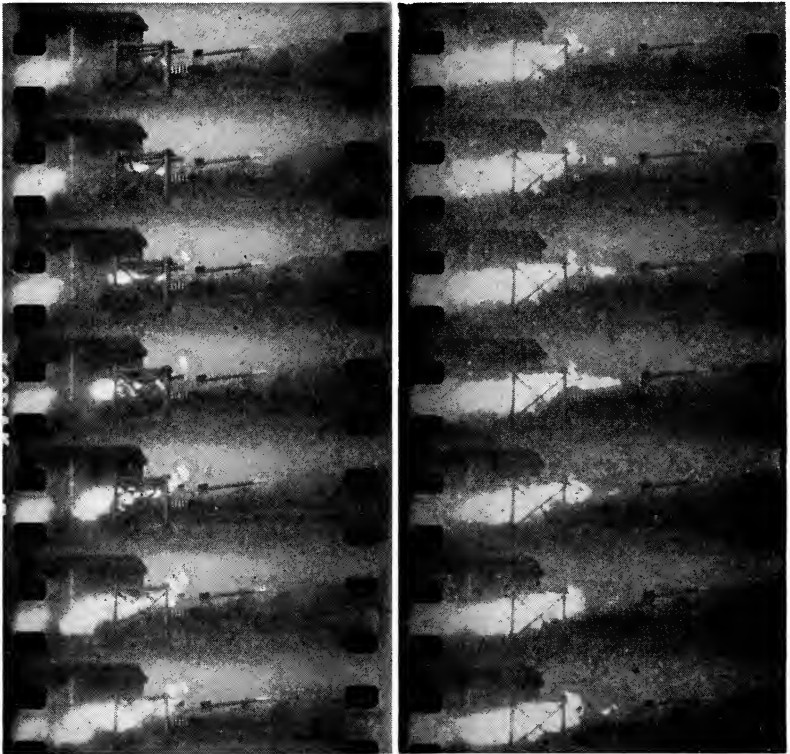
Fig. 12.   High-speed pictures of rocket being launched; 3500 pictures per sec.

Fig. 10 shows the completed camera with the door removed, and Fig. 11, the camera with the reflex view-finder in place.

The new camera has proved extremely useful in ballistic studies. Satisfactory photography in direct sunlight at $f/3.5$ at a speed of 3500 pictures per sec is possible.   It is, of course, necessary to exercise care in judging the sunlight.   For example, in Central United States and on the Eastern Seaboard, conditions for taking pictures at 3500

per sec exist from approximately April to September, while in Arizona, California, and Florida suitable pictures are obtainable all year around at this speed. In fact, with an optical system equivalent to that of the 35-mm camera sunlit pictures have been obtained in Florida when the subject was 8 ft under water and when the speed was as high as 4000 per sec.

Fig. 12 shows several strips of pictures of a rocket launching taken at the rate of 3500 per sec in sunlight. The rocket was traveling
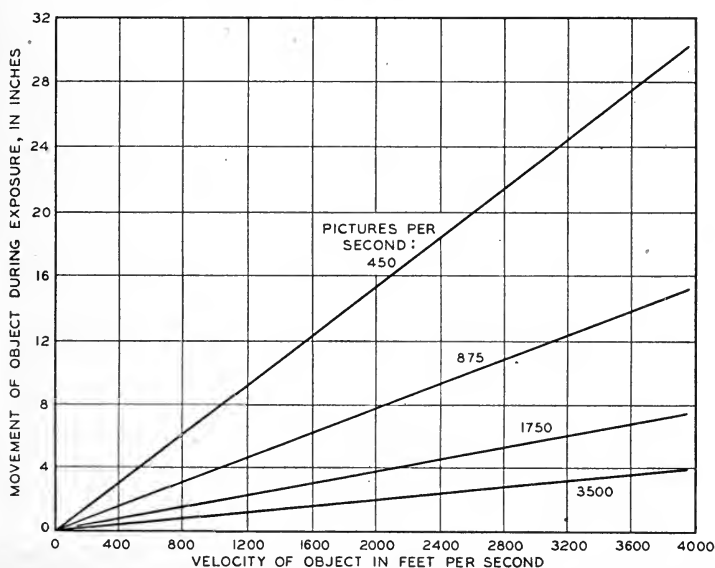
FIG. 13.   Displacement of moving object during exposure at various velocities.

approximately 1000 ft per sec in the picture. In some cases it has been found helpful to be able to adjust the speed of the camera in relation to the speed of the subject being photographed. This can be readily accomplished by means of a variable transformer, when using a-c power, and by means of a variable resistor or variable battery when using d-c power. Fig. 13 shows the displacement of a moving object during the time of one exposure when photographing at various camera speeds, the displacement being plotted against velocity of the object. Fig. 14 gives the displacement of the image on the film per exposure when the object, moving at various speeds, is photographed at 3500 pictures per sec with lenses of various focal

lengths.   In the latter case the camera is assumed to be directed at
right angles to the line of motion of the object and located at a distance of 100 ft.
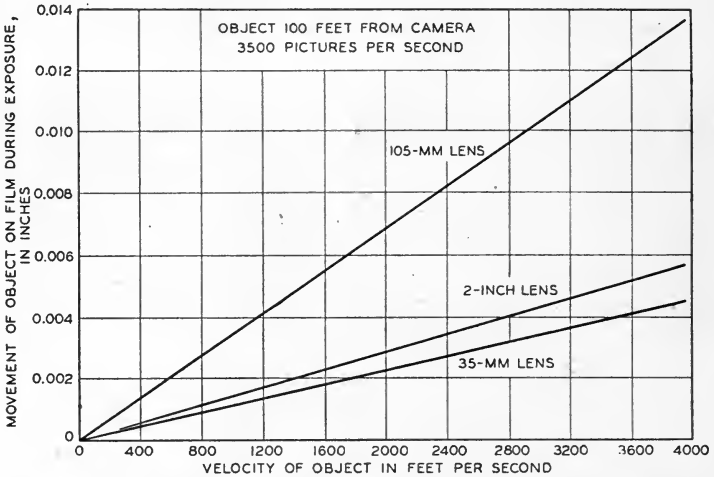
FIG. 14.   Displacement of image on film per exposure for various
velocities of object.   Photographed at 3500 pictures per sec with lenses
of various focal lengths.

In addition to the more conventional applications, the 35-mm
camera has been used for recording high-speed oscillographic traces.
For such purposes a camera without a prism is used and the lens
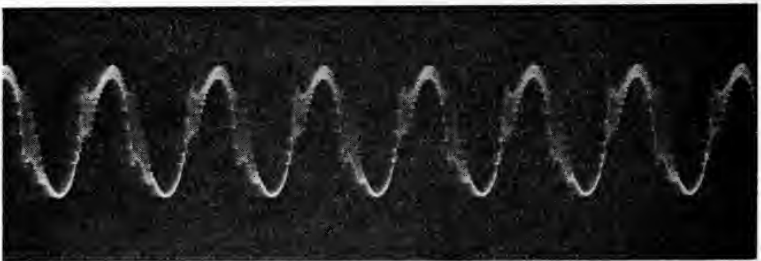
FIG. 15.   Photograph of 200-kc voltage superimposed on 5000-cycle voltage
as shown on an oscilloscope.   Film speed at 120 ft per sec.

plate is corrected to compensate for the resulting difference in back
focal distance.   By these means complete wave traces have been
taken of alternating potentials up to 200 kc in frequency and at film

speeds up to 120 ft per sec.   With such pictures in a film viewer, time measurements are possible to an accuracy of less than one microsecond.   Fig. 15 shows the trace of a 200-kc voltage superimposed on a 5000-cycle voltage.

As already indicated, pictures made with the 35-mm wide angle camera described have proved very helpful in the analysis of many kinds of problems.   Because the pictures do not correspond to the conventional 35-mm picture frame height, it is not convenient to view them on a screen by use of a conventional 35-mm projector.   Instead, a modification of a standard silent projector is used.   The 16-tooth sprockets are replaced by 8-tooth sprockets and the aperture plate is modified to correspond with the reduced picture height.   Provisions have been made whereby such projectors can be obtained on the market by purchasers of the new camera.

As indicated above, the wide angle Fastax camera offers a variety of possible applications.   Specific examples that may be cited include:

(1) The firing of a gun.
(2) Computation of pressure time curves.
(3) The behavior of shells in flight.
(4) The launching of rockets.
(5) Impact of the projectile.
(6) The landing and take-off of planes on carriers.
(7) The launching of planes by catapult.
(8) The behavior of planes in flight.
(9) Wind tunnel studies.
(10) Flight of buzz bombs.
(11) The dropping of aerial bombs and their effects at explosion.
(12) The vibration of plane parts.
(13) Propeller actions.
(14) Tow tank studies.
(15) The launching of torpedoes.
(16) Studies of cavitation under water.
(17) Studies of locomotive driving wheels in motion.
(18) Automobiles on proving grounds.
(19) Spring and transmission studies.
(20) The effect of combustion in fire boxes.
(21) The spray ejection of fuels.

The wide angle Fastax camera is being manufactured and sold by the Western Electric Company, Inc., as an aid in the research and development program of America.

making available materials and supplies used in this camera and for their fine cooperation during its development.

REFERENCES

[1] HERRIOTT, W.: "High-Speed Motion Picture Photography Applied to Design of Telephone Apparatus," *J. Soc. Mot. Pict. Eng.*, **XXX**, 1 (Jan., 1938), p. 30.

[2] SMITH, H. J.: "8000 Pictures per Second," *J. Soc. Mot. Pict. Eng.*, **45**, 3 (Sept., 1945), p. 171.

DISCUSSION

QUESTION: What type of projector is used to view the pictures taken by this camera?

MR. WADDELL: This is a standard silent projector in which the sprockets have been changed from the normal 16-tooth to 8-tooth sprockets and by modifying the aperture plate to one-half the normal height, and the pictures being projected at 16 frames per sec.

QUESTION: I would like to know why the checkerboard background is not as sharp as the projectile.

MR. WADDELL: In the first place, the checkerboard which you saw was back twice as far as the barrel of the gun. Now you will notice that the barrel of the gun was reasonably sharp. It is granted that there is a slight amount of dispersion on the edges, but for all practical purposes that is negligible. But, if you study the plane of the subject being studied, the thing in which we were interested was easily measured and observed.

QUESTION: I am curious to know what the light streaks are in front of the projectile.

MR. WADDELL: That, I believe, is a stick on the end of the shell which was used for measuring the acceleration as the shell was coming out of the barrel. Now, of course, these pictures were viewed frame by frame, for measuring the amount of travel between frames.

QUESTION: What type of lamp do you use in your camera for a timer?

MR. WADDELL: We are using an argon lamp; the neon, however, is not active enough for use.

CAPT. C. H. COLES: An interesting comment, we had one of the 16-mm Fastax cameras in the altitude chamber which we took up to the pressure of 40,000 ft altitude. We had some of the film in the tropical packing, that is the metalized foil and could hardly get it out of the container, because it blew up like a balloon.

MR. WADDELL: We can say one thing and that is we have used this camera out of doors at 10 above zero in winter time and no trouble was encountered with brittle film..

COMMENT BY A MEMBER: In the matter of packing and the film blowing up in tropical packing, we have yet to find out how we can pack film so that it is impervious to moisture and yet equalize pressure, and, if anyone has any suggestions along that line, we would be very happy to have them.

THE FILING AND CATALOGUING OF MOTION PICTURE FILM*

CARL M. EFFINGER**

Summary.—This paper describes the improved methods of cataloguing and filing motion picture film. While very compact, the film catalogue system permits very rapid location of a single frame of the desired shot.

Practical methods of cataloguing and filing film are the immediate concern of film librarians. But they also concern the industry, as a whole, because of the time and money saved in production costs by using a stock shot instead of having to shoot the scene.

Those of us who run the Film Library at Twentieth Century-Fox believe that our system is the simplest and least cumbersome used anywhere in the motion picture industry. The old-fashioned card index system had been in use for many years at the studio, but an entirely new system was needed to save time; one that was streamlined, simplified, and visual. After a good deal of experimenting, the system we now use was developed, and during 1932 it was put into practice. The system has paid ample dividends in time saved producers, directors, and editors, who constantly call upon the resources of the library. Stock shots, process background, sound effects, screen tests, newsreels, short subjects, *March of Time* films—in fact, every sort of material that gravitates toward a film library, responds to the method we use.

Under the system formerly in use at Twentieth Century-Fox, and still used by most of the studios, film of loosely related backgrounds and subject matter was spliced together, put on reels, and stored in the cans. When a producer or a director asked us what we had in the way of background of a particular nature, we would refer to the old card index, get out the cans indicated, and run off film until the customer found what he wanted, or gave up trying. With the shots not being broken down and segregated as to specific type, a great deal

---

* Presented May 18, 1945, at the Technical Conference in Hollywood.
** Twentieth Century-Fox Film Corporation, Beverly Hills, Calif.

of film loosely related as to subject matter had to be run. A barge on the Erie Canal might be wanted. Before we got to it we might have to look at a rowboat on the Thames, a destroyer in the Pacific, or a liner docking at New York, with day and night scenes all together. If the usable shot was at the end of a reel, the entire reel would be run off before we caught up with it. This cost the studio a lot of expensive time.

FIG. 1. The catalogues are small enough to be carried about and consulted by anyone.

Under the present system we get what we want in no time at all. A particular kind of shot is required. Only shots that come into the category asked for are run, and endless time is saved. Moreover, by breaking the material down into smaller, more exact categories, and making a separate roll of each, we have been able to dispense with the reels, which take up so much space in the can. A can holds 1000 ft of film on a reel. Off the reel, in rolls of varying length, the average is 1200 ft to the can, a saving of better than 10 per cent.

Another advantage of the system is that it is not a "one-man" show. Anyone who comes into the Film Library can consult the catalogues for himself, without calling upon the staff, and locate what he wants, provided the studio has it. The whole story is at his

fingertips, visual and in text, arranged alphabetically as to categories and subcategories, as exactly defined and as easy to locate as any word in a dictionary.   (Fig. 1.)

The speed and exactness with which available material can be located is particularly evident when an outside studio telephones us regarding some specific type of shot they happen to want.   While the person calling holds the phone, one can go straight to the catalogues and in one minute or less locate everything we have that appertains to the subject in which he is interested.   If we have what he wants, we take it from the can—150-ft roll, say—and that is all he gets.   This saves a good 10 min from the old way of sending an entire reel.

Let us take a close-up of the system at work; first of all, Short Subjects, on which only positive film is available to us for cataloguing purposes.

We receive copies of all subjects produced in. New York released by this company.   These are run by the 3 members of the Film Library staff, who make synopses of the usable scenes.   This material includes newsreels, *March of Time*, and short subjects, such as *Magic Carpet*, *World of Today*, *Sports Review*, *Adventures of a Newsreel Cameraman*, *etc.*   The synopses are now broken down into single categories for filing, so that if someone wants to see a Jap Zero being shot down, he does not have to look at everything appertaining to Jap warfare.   All he would see would be subjects containing a Jap Zero being shot down.   These categories are catalogued and filed in exactly the same manner as the usable material saved from our regular West Coast productions, which we shall discuss next.

Both negative and positive films of our West Coast productions are made available to us, and we proceed as follows: 2 members of the Film Library staff view the picture before the negative is cut, and order protective master-positives on all "one-take" scenes that we can use that will appear in every finished product.   These master-positives are for the Film Library files, all cut negatives being immediately sent to New York, where the release prints are made.   After the negative has been cut, the cut picture is viewed by at least 3 members of the Film Library staff.   Each of the three makes a list of the shots he sees which he thinks could be used again and, accordingly, should be catalogued.

These lists are then turned over to the catalogue girl.   She makes a composite of the several lists, condensing the material, eliminating

duplicate suggestions and ideas, but at the same time preserving the individual point of view of each of the librarians. On the basis of this composite list, the librarians now go through the positive film, in the cutting room, saving all usable scenes—those in which principals are not recognizable. Still using the composite list, they then examine the negative film, again saving what is usable.

FIG. 2. The catalogue pages contain 7 frame apertures in which the film frames are placed for viewing.

The next step is to match the positive and the negative film of the entire picture. A 4 × 6-in. filing card is prepared. On it is written a synopsis of the particular footage in question. To this are added filing data, such as production title, the names of the director and the cameraman, the date the shot was photographed, the "take" number, and the "key continuity" number. An identifying frame of positive film is next clipped to the card, or a negative is taken if no positive is available.

The cards and the film are now turned over to the filer, who deposits the film in the can, writes the number of the can on the film

leader, and on the card, together with a one- or 2-digit number to identify the roll among the other rolls in the can. So that every bit of space in the cans may be used to the best advantage, the rolls of film are stored where they will fit most economically, without regard to subject matter. Can *13101*, for instance, contains the following diverse shots:

```
13101-1  M.S. Tanker      Ocean      Nite      Fire      Neg
     -2  Ship Tanker      Deck       Pos
     -3  Street scene     Western town      Pos
     -4  Warfare     American Mechanized Review      Desert      Pos
     -5  Sound roll of a slap      Neg
     -6  Newspaper office      Ext.      Small town      Pos
     -7  Battleship in South Pacific      Firing      Neg
```

The larger the number, the smaller the roll, which saves time in locating the roll in cans.

Positive shots, negative shots, and sound effects all may be found in one can.

The cards are then classified into their categories and subcategories. After the classifications have been made, the cards are turned over to a stenographer, who lists alphabetically the essential facts on each card until she has a complete record of the picture to which they appertain. These supplementary lists are numbered, then filed. Their purpose is to show at a moment's notice everything that we got out of the picture, including sound.

The cards are then separated into their various categories, so that the information on them can readily be transferred to the catalogues.

The catalogue pages are loose-leaf so that as similar scenes accumulate more sheets may be added in order to keep like material together. They are then divided alphabetically into main categories. Each of the main categories is broken down into *DAWN*, *DAY*, *DUSK*, and *NITE* shots, which in turn subdivide into first, second and third subcategories, also alphabetically arranged. The key leaves of the main categories are identified by a blue tab, such as *SHIPS*. Some of the first subcategories of *SHIPS*, whether *DAWN*, *DAY*, *DUSK*, or *NITE*, are: *AUXILIARY*, *BARGE*, *COAST GUARD*, *EXCURSION*, *FERRY*, *FREIGHTER*, *HOUSEBOAT*, *LIFEBOAT*, *PASSENGER*, *etc.* These subcategories are identified by yellow tabs.

PASSENGER, let us say, now breaks down into secondary subcategories, such as, *AT ANCHOR*, *BELLS*, *BOW*, *BRIDGE*, *BUOY*, *CREW*, *DECK*, *DOCK*, *AT SEA*, and so on. These categories in

turn break down into third subcategories which identify *PASSEN-GER—SHIP—AT ANCHOR—DOCK—SEA*, *etc.*, as a *ONE-*

Fig. 3. A page from a catalogue showing the category at the top of the page description, and a frame of film for each scene.

FUNNEL, *TWO-FUNNEL*, *THREE-FUNNEL*, or *FOUR-FUNNEL* vessel. All these subcategories run through each of the 4 primary divisions, *DAWN, DAY, DUSK, NITE*, into which the

main category *SHIPS*, like every other main category, automatically falls.

Each loose-leaf page contains 7 frame apertures. (See Fig. 2.) Opposite each frame is a blank space for detail to be filled in on the typewriter. A stenographer types in its proper place the information she finds on the card. She then unclips the film frame on the card and slips it into the vacant aperture on the loose-leaf page. It fits

FIG. 4.   One of the 2 safes in which the 36 catalogues on 22 million feet of film are stored.

like a snapshot in an album. Only similar scenes appear on any given page. The stenographer then returns the loose-leaf to its place in the catalogue. When a similar scene from another picture turns up it will be enclosed in the vacant aperture below, or on the next page, if the subject matter carries over.

At the head of each loose-leaf page is an exact breakdown of the shots with which that particular page is concerned. (Fig. 3.) If the main category were *SHIPS*, the breakdown might read *SHIPS— PASSENGER—ONE-STACK—AT   ANCHOR—NEW   YORK*

HARBOR—DAY. At a glance this tells the type of shots with which
that particular page deals. If the summary does not embrace the
type wanted, the eye need travel no further down the page. If it
does, the various frames of film and adjoining typewritten descriptive
data are studied. The data consist of such information as "Shooting
from Pier 8—Brooklyn to New York—ships in f.g.—New York sky-
line in b.g.—no action." This tells whoever is consulting the cata-
logue exactly what he is looking at, and the clipping visually gives a
general idea of what the scene is like.

Duplicate catalogues of sound effects are furnished the Sound
Effects Department. Also, duplicate cards of all background ma-
terial, with frames of film attached, are turned over to the Back-
ground Department. The staffs of these departments may thus order
what they want direct, without coming over to the Film Library.

An invaluable feature of our film catalogue system is its compact-
ness. The 36 catalogue volumes are stored in 2 medium-sized safes,
as shown in Fig. 4. They catalogue 22,000,000 ft of film.

Two years ago Washington complimented the studio on the effi-
ciency of our method when the joint Chiefs of Staff asked that some-
one be sent back to the Office of War Information and the Office of
Strategic Services to establish a catalogue and filing system to be
known as The United States War Film Index Library. This was to
be a record of all war film shot by the Armed Services and by the mo-
tion picture studios. Three systems were developed. One of them
was essentially the manual system in use in our own Film Library.
The other two were the IBM Mechanical System and the Electro-
file Semi-Mechanical System; but both applied the unique features
of our own manually operated system.

The test of any method of cataloguing and filing film is the speed
with which a required shot can be located. Film that cannot be
found when it is wanted builds up picture costs. The simplicity of
our system and the smoothness and accuracy with which it works has
repaid the studio the investment in time and money again and again
during the years in which it has been in operation.

A NOTE ON CHEMICAL DRAG OBSERVED WITH VARIABLE-DENSITY SOUND TRACKS *

E. MESCHTER**

During the discussion period of the meeting of the Atlantic Coast Section of the Society held on December 13, 1944, in New York, F. G. Albin gave an interesting account of a study by which anomalous intermodulation results were traced to chemical drag. With this discussion as a background, it was possible to recognize the effect easily when encountered in a different manner; while purely qualitative the direct demonstration of an effect previously detected by indirect means appears to be of interest.

In the case under consideration, the 60- and 1000-cycle signal from an intermodulation track on an experimental material was impressed on the vertical plates of a cathode-ray oscillograph. A linear horizontal sweep, properly synchronized, permitted direct observation of the wave form of this signal. The oscillograph pattern exhibited a striking asymmetry with respect to vertical axes drawn through either the maximum or minimum points of the wave. The asymmetry apparently results from chemical drag, and has been accentuated by the particular combination of emulsion characteristics and developing conditions prevailing for this particular sample.

Wave forms representative of the effect have been photographed for record purposes. The signal was applied to the horizontal plates of an oscillograph equipped with a blue emitting zinc sulfide cathode-ray tube. A transverse image of this horizontal line was formed on du Pont Type *201* Sound Recording Film by means of a 75-mm $f/2.3$ lens, the final image being about one-third the size of the original. The system did not include a shutter; the film was driven continuously at 180 ft per min. This continuous motion provided a linear time axis, which is horizontal in the accompanying figures,

in which the original oscillograms have been retouched slightly for reproduction purposes.
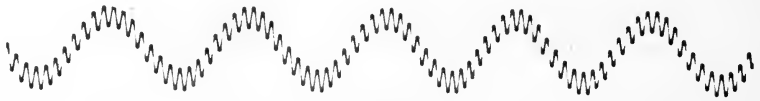
FIG. 1.   Original undistorted 60- and 1000-cycle signal impressed on the re-cording system.

Fig. 1 illustrates the wave form of the intermodulation signal which is impressed on the recording system.   This is a mixture of 60- and 1000-cycle signals, the former having 4 times the amplitude of the latter.   The amplitude of the 1000 cycles is constant at every point
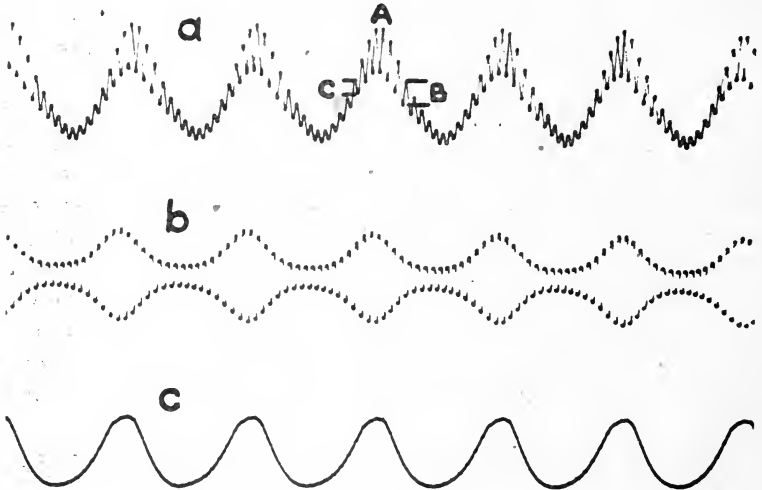
FIG. 2.   (a)   Distorted 60- and 1000-cycle output from an experimental VD negative, showing asymmetry of the 1000-cycle amplitude about the 60-cycle peak.   (b)   1000-cycle signal remaining after 60-cycle component has been filtered out of the signal o 2(a).   (c)   60-cycle intermodulation signal formed by rectification of and removal of the 1000-cycle component from the signal of 2(b).

of the 60-cycle swing, and the intermodulation of such a signal is zero.

Fig. 2, however, shows an entirely different state of affairs.   This is the wave form of the signal from a variable-density recording on an experimental coating.   The output from the negative itself, rather

than from a print, has been taken to avoid possible complications
from the printing operations in demonstrating the effect under con-
sideration.   Intermodulation values read from this film are meaning-
less so far as practical results are concerned, but the asymmetry
mentioned above is evident immediately.   The 1000-cycle amplitude
at B is much greater than that at C, whereas these would be equal in
the absence of directional effects.   Reaction products of develop-
ment from the higher densities at A have streamed back and retarded
development in the region of C, lowering the local gamma and de-
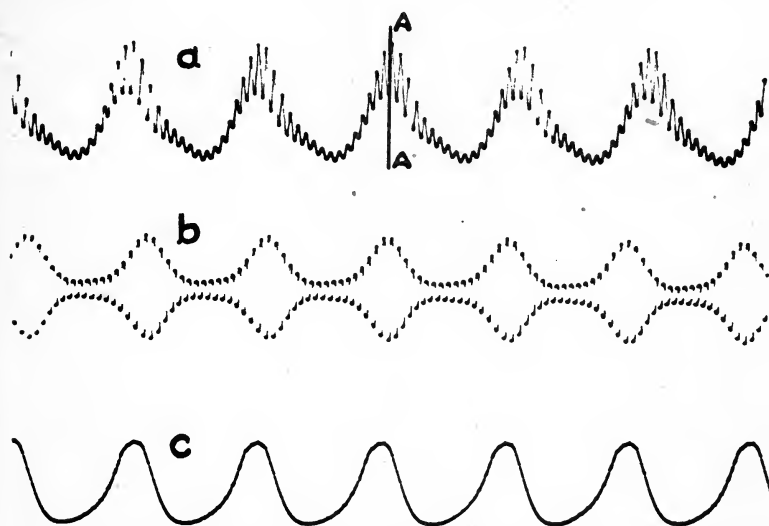
FIG. 3.   Distorted output and intermodulation signals similar to Fig. 2, show-
ing even more pronounced drag effect.

creasing the 1000-cycle response.   On the other hand, B follows a
low density region and is comparatively far removed from the pre-
ceding high density;   more vigorous development takes place here
and the 1000-cycle response is increased.

The oscillogram in the center is that of the modulated 1000-cycle
signal which remains after the 60-cycle component has been filtered
out;   close examination discloses some evidence of the effect here.
The 60-cycle intermodulation signal shown at the bottom, obtained
after rectification and removal of the 1000-cycle component, also
shows some horizontal asymmetry about the wave peaks.

A still more striking example of the effect is shown in Fig. 3, where the asymmetry about the line AA is plainly reflected in the wave shape of the final 60-cycle intermodulation signal at the bottom. These exaggerated results have, of course, been deliberately selected from experimental material and should not be regarded as typical of normal conditions.

The possibilities of further and possibly quantitative analyses of such oscillograms have not as yet been fully explored. However, it is hoped that this qualitative presentation will prove of interest and perhaps suggestive of other lines of approach.

REFERENCE

Albin, F. G.: "Intermodulation Distortion of Low Frequencies in Sound Film Recording," *J. Soc. Mot. Pict. Eng.*, **46,** 1 (Jan., 1946), p. 4.

WAVE PROPAGATION AND OUTDOOR FIELD TESTS OF A LOUDSPEAKER SYSTEM*

F. L. HOPPER AND R. C. MOODY**

Summary.—This paper discusses data and observations made with a loudspeaker system outdoors with regard to sound transmission as affected by such factors as wind, temperature, and humidity. Other data are given on measured and computed sound pressure distribution characteristics of multiple element radiators.

While loudspeaker performance measurements are usually conducted indoors in rooms[1] especially designed to be as nearly totally absorbing as possible, outdoor measurements lend themselves particularly to larger systems and to obtaining information as to sound field distribution and the intensity at some distance from the sound source. When these distances become great compared with the physical dimensions of the source, the sound transmission may be materially affected by atmospheric conditions, notably wind, temperature, and humidity, and by the nature of the terrain over which the sound propagation takes place.

In high-powered sound systems it is common practice to supply a group or array of loudspeakers instead of a single unit because of the limited power handling capacity of single commercial units. This requires that consideration be given to the pressure frequency distribution since it will vary, owing to the physical separation and plurality of the sound sources in the array.

This paper will present data and observations made during recent outdoor measurements of a large multiple source loudspeaker system with regard to the above mentioned factors.

The site chosen for test was a large flat, cleared section of land in the Mojave desert. The loudspeaker system could be placed such that at least a half-mile of clear ground could be had in any direction. This was useful when wind was encountered, since by orienting the

sound source, the effect of the wind upon transmission could be studied.   Beyond the clearing was typical desert sagebrush growth. This area was used primarily for listening tests using program material.

Measuring equipment consisted of an oscillator with motor-driven sweep and warble, a calibrated microphone,[2] amplifiers, and a volume indicator having a logarithmic response characteristic.   The output current of the latter operated a d-c recording type of milliamme-
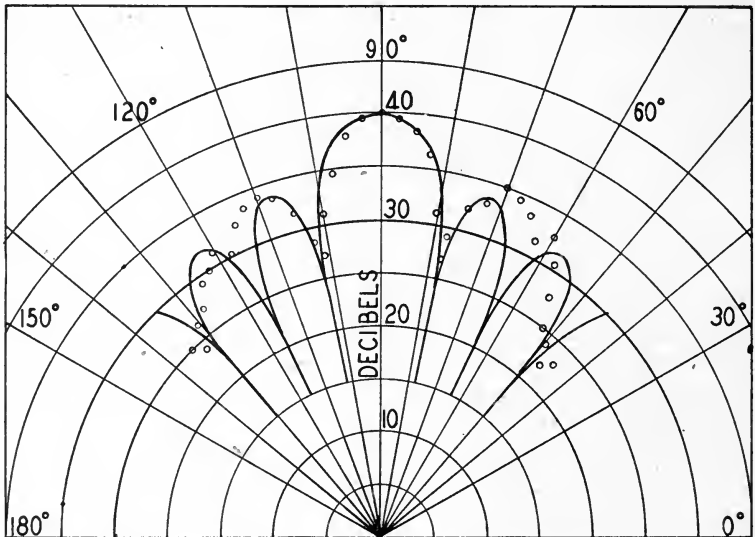
Fig. 1.   Horizontal field for 200 cps; ——— calculated at infinity; ∘∘∘ measured 200 ft.

ter.   Continuous measurements could then be made at a point of frequency response, or intensity measurements for a single frequency as a function of azimuth or distance.   A sound level meter was also used for the determination of absolute sound field intensities.

The variation of sound pressure with azimuth as a function of horn or radiator dimensions has been adequately covered in other publications.[3]   That there is an additional variation of pressure with respect to azimuth when multiple sound sources are used is not as well known. It will be shown that when the effects of multiple sound sources are calculated a reasonable agreement with experimental data can be expected.

Considerable work has been done in the calculation of directional characteristics of radiation from antennas, as well as from acoustical radiating systems.[4] In addition, these types of phenomena are quite comparable to diffraction problems occurring in optics.[5] As a basis for computation it is assumed that the point at which the distribution is to be determined is sufficiently remote from the source, so that lines joining this point with the elements of the loudspeaker array are essentially parallel. It is also assumed that all loudspeakers in the array are identical, and that the voice coil currents are equal and in phase. For such a system, the relative intensity resulting from the multiple sound radiators is given as

$$F_\alpha = \frac{\sin n Z}{n \sin Z} \qquad (1)$$

where the symbols are defined in the appendix. Calculations on a large array were made for a frequency of 200 cycles per sec. These data are shown on Fig. 1 in solid lines, the dotted lines showing data measured at 200 ft. It can be seen that the agreement is reasonably good in view of the difficulty involved in acoustical measurements of this kind.

FIG. 2. Vertical field for 200 cps (calculated).

It should be noted, also with reference to Fig. 1, that the calculated data are symmetrical about the line of propagation while the measured data show some dissymmetry.

When an array of n columns of speakers of m speakers per column is to be calculated as an approximation, we may disregard all except one horizontal row of speakers to obtain the pressure distribution with regard to the azimuth, while to obtain the pressure distribution with respect to the vertical or zenith angle the horizontal rows may be neglected and only one vertical column considered. Fig. 2 shows the calculated vertical distribution of an array 3 speakers high. No measurements were made to check this distribution.

Ordinarily the loudspeakers of an array are nearly identical in the

frequency range covered and are driven by a single amplifier. When more than one amplifier is used it is possible that all speakers will not obtain the same voice coil current and this will modify the distribution of an array. It is also presumed that all speakers are in phase. If separate amplifiers are used, care should be taken that the phase delay in all amplifiers is very nearly the same, as would probably be the case for identical amplifiers. Suppose that at some frequency one amplifier had a delay of one radian with respect to another amplifier. This time, phase difference is additive to the geometric delay and

LOUDSPEAKER ARRAY
ATTENUATION VS. DISTANCE
FROM 100 TO 450 FEET
SOLID LINES SHOW INVERSE DISTANCE SQUARED
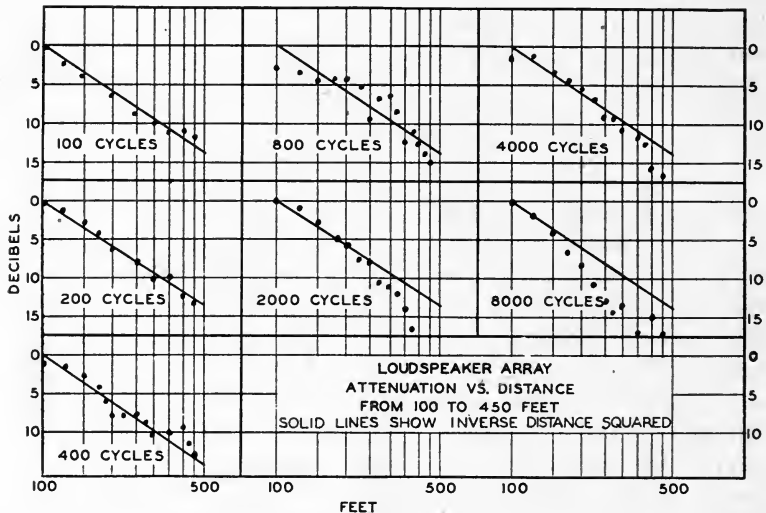
Fig. 3.

Eq (1) no longer holds. In most cases the effect is to cause a dissymmetry about the axis of propagation.

It is more likely that difficulty will be experienced in having an in-phase or out-of-phase condition as would be the case of reversed voice coil or amplifier connections. When the array is composed of many speakers it is not easy to determine the proper in-phase condition by listening tests. A method used in these tests may be of interest. Any reference speaker is chosen and arbitrarily assigned as having the correct phase. All other speakers are then compared one at a time with the reference speaker. This was done by setting up a microphone equally distant from the reference speaker and the speaker to be checked for phasing. A warble tone is then applied to the refer-

ence speaker and a volume level obtained from the microphone amplifier output.   The speaker to be checked is then connected to the same warbled source and if the speakers are in phase the volume level will increase 6 db, whereas if they are not in phase, considerable cancellation results.   If the warble tone chosen is the lowest frequency that the speakers are capable of reproducing, the difficulty of placing the microphone exactly the same distance from each speaker is not at all acute.   Alternately, the microphone can be placed at some considerable distance away so that the path lengths can be neglected, but the former method is desirable because it is more rigorous.

SOUND WAVE PROPAGATION OVER A PLANE

SHOWING MEASURED POINTS OVER A FREQUENCY RANGE OF 100 TO 8000 CYCLES AND A DISTANCE OF 100 TO 450 FT.
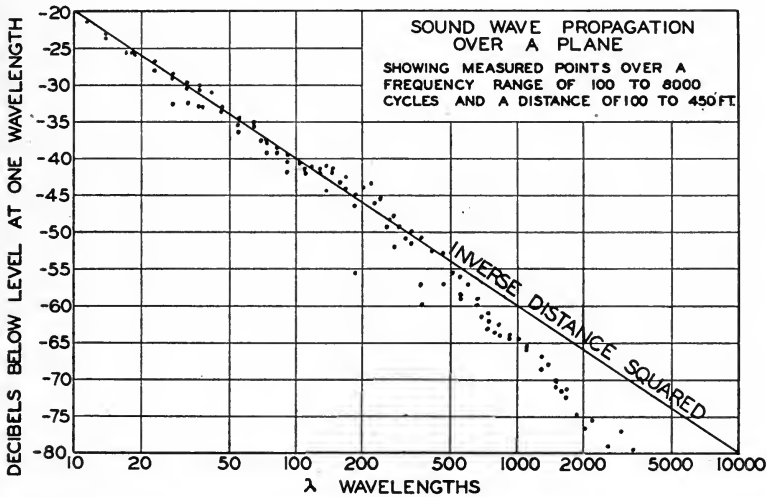
FIG. 4.

Classical theory states that the intensity of a sound wave in free space decreases inversely as the square of the distance from the source.   Many observers have noted that this rule of propagation is altered by such factors as terrain, e. g., flat level ground as opposed to undulating ground or ground covered with shrubs or trees, and to variations in atmospheric conditions such as temperature, humidity, and wind.   In general, these conditions become more severe as the distance from the sound source increases, and also as the frequency of the emitting sound source increases.

Fig. 3 shows attenuation versus distance measurements made in a sound field produced by a loudspeaker array whose center was $7^{1}/_{2}$ ft

above flat, hard-packed clay earth. The data are given for various frequencies and for varying distances from the source. Measurements at distances less than 100 ft from the source were not taken, since it was desirable that the measuring distances be large compared to the physical dimensions of the source. For convenience of measurement the microphone was located about 3 ft above the surface of the earth. A warbled frequency was used to minimize standing wave or interference phenomena. After calibrating the instruments, the microphone was continuously moved at a constant speed from 100 ft to 450 ft from the sound source. During this operation a level recorder was used to produce a continuous record of the sound field pressure. The pressure decline was very constant at low frequencies but became more irregular at higher frequencies. The points shown on Fig. 3 are measured, and the solid lines are the theoretical decrease in intensity following an inverse distance squared law.

The attenuation of 100 and 200 cycles shows good agreement with the inverse distance squared law. The 400- and 800-cycle data show general agreement but exhibit what appears to be a wave interference pattern which apparently the warble frequency did not eliminate. The 2000-, 4000-, and 8000-cycle data show a tendency to depart from the inverse distance squared law as the distance from the source is increased. This may result from a critical angle of incidence, or slight irregularities of the earth surface may have caused a dispersion of the reflected ray.

If the data of Fig. 3 are replotted with wavelengths as the abscissa instead of feet, all data may be placed on a single curve. This is shown in Fig. 4. It will be observed that up to about 400 wavelengths the data correspond to inverse distance squared, while for greater wavelengths the data show a tendency to follow an increased rate of attenuation. The curve bears a striking resemblance to the empirical curves of K. A. Norton[6] for attenuation of radio waves in the standard broadcast band. Unfortunately, no data were obtained on low frequencies at distances equivalent to 500 or more wavelengths. The data are useful, however, in predicting sound field intensities at various distances from the source for a loudspeaker system used outdoors, under similar conditions of terrain and atmospheric conditions.

The propagation of sound may be subject to other anomalous attenuations. Knudson[7] has shown that there is an absorption of sound in the air caused by interaction between oxygen and water vapor. Knudson's data showing the absorption of sound in air with respect

to relative humidity at 20 C have been replotted in Fig. 5 with absorption per wavelength instead of per centimeter as the ordinate.

Under optimum conditions the attenuation of the higher audible frequencies even for distances as short as 200 ft may become considerable. Listening tests made in the desert versus those made with the loudspeaker array over the ocean show a distinct improvement in high frequency radiation in favor of the latter condition. Other observed conditions effecting sound transmission which are undoubtedly not new but which furnish further confirmation of such effects, are briefly mentioned as follows.
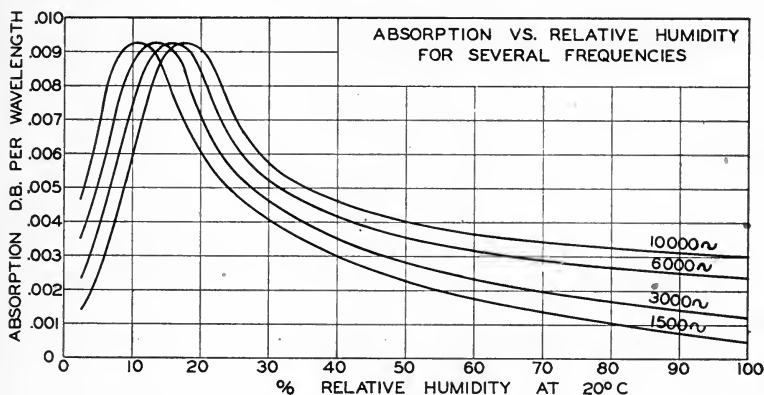
FIG. 5.

During a snowfall it was apparent that the attenuation was considerably greater although it appeared that this attenuation was not selective with respect to frequency. The apparent direction of sound seems also to change with a gusty wind, the effect being more pronounced at high frequencies. When listening to a high frequency test tone at some distance from the source the apparent movement of the source with wind direction and velocity was marked. At great distances the sound source appeared to be as much as 20 to 30 degrees removed and this seems to be true for all frequencies as both voice and music tests were conducted. A Doppler effect was noticed, particularly when the wind direction was toward or against the direction of sound propagation. This produced a pronounced change of pitch which had a most disagreeable effect on music. An apparent variation of pitch as a function of pressure as noted by other observers[8] was distinctly heard. Musical reproduction was decidedly off key until

the sound field pressure was reduced to values ordinarily encountered.

It thus appears possible with a fair degree of accuracy to predict the performance of a loudspeaker system as used outdoors both with respect to sound field intensity and distribution pattern. Other effects of a transient nature caused by wind, temperature, and humidity are seen to have a marked effect upon the performance of such a system.

APPENDIX

Mathematical expressions developed by Wolff and Malter,[4] are quite useful in predicting the directional response of a multiple source loudspeaker array.

For a combination of n equally spaced linearly arranged sources, having equal intensity, and moving in phase, the intensity at a remote point A is given as

$$F_\alpha = \frac{\sin n Z}{n \sin Z} \qquad (1)$$

where

$$Z = \frac{\pi d \sin \alpha}{\lambda} \qquad (2)$$

d is the separation between individual radiators, λ wavelength, and α the angle subtended between a line perpendicular to the linear array of loudspeakers and point A.

The intensity is a maximum in a direction perpendicular to the linear array when all sources are in phase, since $\alpha = 0°$ and $\sin \alpha = 0$ and the value of F_α in Eq (1) is unity.

For a straight line source having uniform intensity and all points in phase Eq (1) becomes

$$F_\alpha = \frac{\sin Z}{Z} \qquad (3)$$

since n approaches infinity and d approaches zero.

Other more complex expressions are developed for cases in which there is progressive phase shift along the array, and for cases where the points are in phase but the intensity is nonuniform. Uusally the first condition would not exist for an array in which identical loudspeakers are used, but might occur were the loudspeakers placed not in a line, but staggered with respect to each other. In the second case, nonuniform intensity could easily result were the loudspeakers operated from amplifiers having unequal gains, or from any cause resulting in different currents flowing in the individual voice coils of the loudspeakers.

REFERENCES

[1] BEDELL, E. H.: "Some Data on a Room Designed for Free Field Measurements," *J. Acoust. Soc. Amer.*, **VIII** (Oct., 1936), p. 118.

[2] HOPPER, F. L., AND ROMANOW, F. F.: "Determination of Microphone Performance," *J. Soc. Mot. Pict. Eng.*, **XXXVI**, 4 (Apr., 1941), p. 341.

[3] McLACHLAN, N. W.: "Loudspeakers—Theory, Performance, Testing and Design," Oxford Press, 1934.

[4] WOLFF, I., AND MALTER, L.: "Directional Radiation of Sound," *J. Acoust. Soc. Amer.*, **II** (Oct., 1930), p. 201.

[5] HOUSTOUN, R. A.:   "A Treatise on Light," Longmans-Green and Co. (New York), 1938.

[6] NORTON, K. A.: "The Propagation of Radio Waves Over the Surface of the Earth, and in the Upper Atmosphere," *Proc. I.R.E.*, **24** (Oct., 1936), p. 1367; **25** (Sept., 1937), p. 1203.

[7] KNUDSON, V. O.: "The Absorption of Sound in Air, in Oxygen, and in Nitrogen. Effects of Temperature and Humidity," *J. Acoust. Soc. Amer.*, **V** (Oct., 1933), p. 112.

[8] FLETCHER, H.: "Loudness, Pitch and the Timbre of Musical Tones and Their Relation to the Intensity and the Frequency and the Overtone Structure," *J. Acoust. Soc. Amer.*, **VI** (Oct., 1934), p. 59.

A FILM NOISE SPOTTER*

J. P. CORCORAN**

Summary.—*A machine is described by which defective splices, dirt, and "pops" are detected before running the film through a regular sound reproducer.*

In the translation of the useful signal from film sound tracks to audible sounds, quite often other undesirable signals are scanned by the light beam. These undesirable signals, commonly referred to as "pops," are caused from several types of imperfections in the track area. The types frequently encountered are small clear spots on the print, usually resulting from foreign particles on the negative. Other types may be caused by imperfect splices, scratches, and recorded noise, such as clicks, *etc.*

In the preparation of rerecording tracks these imperfections must be detected and painted out to prevent unnecessary delay during the rerecording process. The past practice has been to inspect each foot of the sound tracks under a magnifying glass. This method was very tedious, usually resulting in severe eyestrain. In addition, considerable inspection time was required with no particular assurance that all the "pops" had been painted out.

Upon investigation to determine whether the film cutter could be supplied with some tool by which this work could be performed with less fatigue and a saving of time, it was learned from Robert Cook of the Disney Studio that reasonable success had been achieved by the adaptation of a Moviola sound head. With this suggestion we built a small, compact sound reproducer unit which, being portable, could be placed between the rewinds on a film cutting table. This unit is shown in its operating position in Fig. 1. Four flanged rollers, two of which are located on each side of the scanning drum, are offset to retain the film in focus as it is pulled past the scanning aperture by the rewinds. The exciting lamp, which is located in the housing just above

the drum, is mounted on the objective lens barrel. This method permits the rotation of the lens while still retaining lamp focus.

In order for the "pops" and other undesirable signals to be distinguishable by the use of the earphones, it is necessary to suppress the normal signal. This can be accomplished in either of 2 ways, depending upon the type of track the operator wishes to inspect. If the operator is dealing with push-pull track, normal signal suppression is achieved by signal cancellation in the photocell circuit when adjusting the scanning beam azimuth to be parallel to the signal striations

FIG. 1.   Film noise spotter developed by Twentieth Century-Fox Studios.

on the film. For standard track, sufficient reduction of the normal signal is realized by rotating the objective lens barrel to approximately 25 degrees off normal scanning azimuth. The mask, which permits the scanning of 100-mil or 200-mil tracks, is located in the scanning region inside the drum. It is operated by rotation of the smooth knob on the end of the drum.

A photocell is located inside the drum and, as noted in Fig. 2, the signal is increased to earphone level by a 3-stage amplifier. The exciting lamp as well as the amplifier is a-c operated. A filter is located in the cathode circuit of the first stage to reduce the 60-cycle hum be-
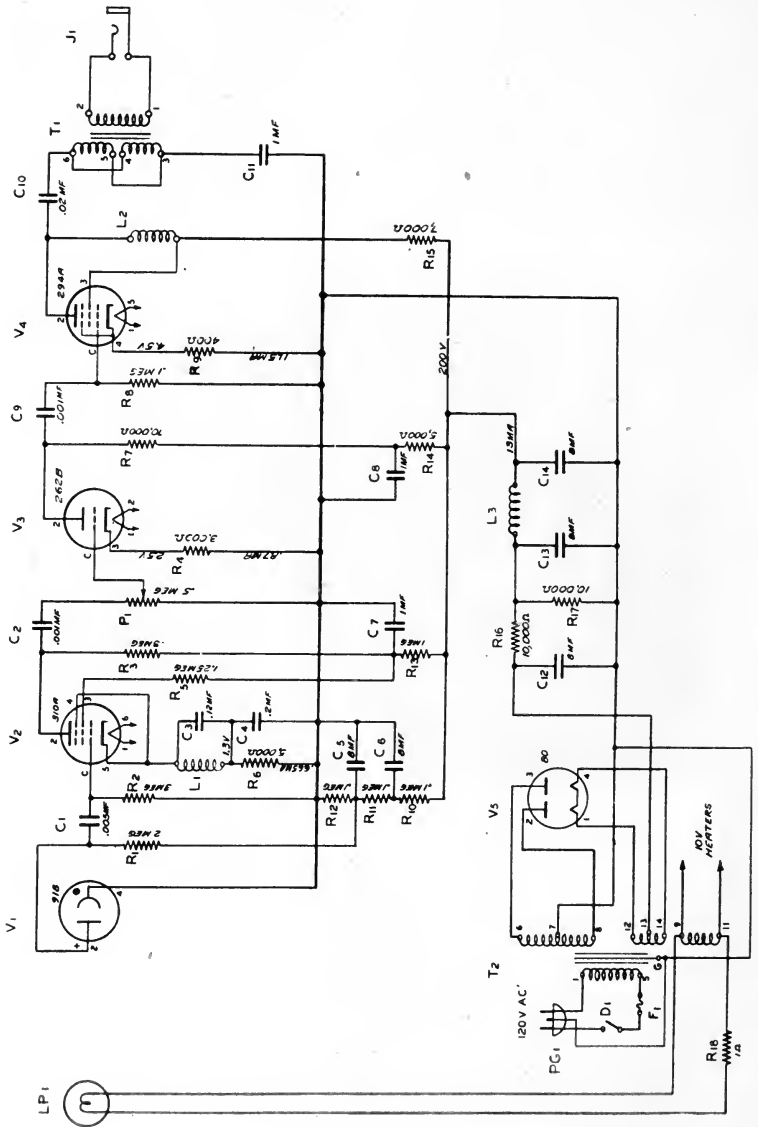
Fig. 2.   Schematic of film noise spotter amplifier.

low an objectionable level. A volume control is also provided for the operator's convenience.

The rate of film travel is approximately 100 ft per min. When a "pop" is detected, the film is stopped, and moved forward and backward by the use of the rewinds until the spot is located at the scanning light. The film is marked and then pulled forward over the inspection glass and the spot is painted out. Quick drying ink, which dries in about 3 sec, is used.

This film noise spotter has proved to be a popular tool with the film cutters whose work deals essentially with the preparation of the rerecording tracks. It is safely estimated that the work which required 8 hr to do by the usual inspection method, can, with the use of this device, be performed in one hour. In addition, the cutter has the satisfaction of knowing that all the imperfections which would give trouble in the dubbing monitor room have been painted out.

AN INTEGRATING METER FOR MEASUREMENT
OF FLUCTUATING VOLTAGES*

HAROLD E. HAYNES**

Summary.—*As a supplement to other types of meters for measuring voltages of fluctuating amplitude, one was developed which integrates the voltage being measured over a chosen interval (a few seconds), and at the end of the interval indicates the average value that has existed. The laboratory model of the meter is described and its operation explained. Some possible applications to sound engineering are suggested.*

REASONS FOR DEVELOPMENT

Many of the alternating voltages which must be evaluated in connection with sound studies are quantities that fluctuate at rates easily perceptible to the human senses. Ground noise in film recordings, surface noise and turntable rumble in disk recordings, ambient noise in various locations, and speed variations in sound recording and reproducing apparatus, are examples of this type of function. The purpose of making such measurements is usually to assist in analyzing the defects in equipment and processes that cause them, and for that purpose it is desirable to break down the over-all effect into components whose causes may be traced individually. However, for conciseness it is frequently desirable to express such a quantity by a single numerical value, even though such a value does not tell the whole story. This is particularly true in factory tests of equipment or processes where the chief objective of the measurement is to decide whether certain standards have been met, and more elaborate tests are not justified, or in comparing development models of a certain piece of apparatus, where it is necessary to decide which of several designs is preferable, and a "lump sum" evaluation may be very useful.

The ordinary indicating meter, while often satisfactory, requires

---

that the observer do some of the necessary averaging in his head, and if the amplitude of the voltage being measured is fluctuating quite widely at frequencies in the range of 0.5 to 10 cycles per sec, interpreting the action of the meter may be troublesome and the subject of disagreement among observers. An integrating meter, that is, one which measures volt-seconds for a time interval of appropriate length and registers only a single value proportional to average amplitude during the interval, was thought desirable as an auxiliary instrument in making these measurements.

Development of the voltmeter herein described was prompted by the need for a meter which would give accurate, consistent measurements of disk record surface noise in the short interval of time occupied by the unmodulated groove at the beginning or end of a disk record, without being subject to the vagaries of the observer in interpreting a fluctuating reading. When an indicating meter is used, a compromise must be made between heavy and light damping. Light damping permits the pointer to follow to some extent the amplitude variations of the voltage being measured (and the meter will overemphasize fluctuations near its own mechanical resonance frequency), and damping heavy enough to produce a satisfactorily constant indication requires a signal of longer duration than that which may be available in order to reach its ultimate reading.

The fluctuating a-c voltage to be measured must first be rectified (as is done electrically or otherwise in every a-c voltmeter) so that a certain amplitude will produce a given effect irrespective of its polarity. The rectifier may produce a d-c voltage proportional to the first power of the input voltage, or to the square or some other power of it; or it may produce a voltage proportional to the peak value of the a-c voltage. In order for the integrating meter to be directly comparable with the standard-type volume level indicator, it was designed to measure average value. However, the way in which an integrating meter responds to instantaneous voltage values is not restricted to average reading by its integrating action, as explained above. It is perfectly possible to design an integrating meter which reads average squared value, or average peak value, just as easily as true average value. Which of these types of action the meter should have involves psychological considerations, since the problem is one of evaluating a physical quantity in terms of its effect on the senses. It certainly depends upon the kind of quantity to be measured, and is, of course, debatable for any one kind.

PRINCIPLES OF CIRCUIT OPERATION

If a capacitor is charged for a given interval from a source of fluctuating voltage $e = f(t)$ through a resistance R, the voltage across the capacitor at time t will be $e_c = \frac{1}{C}\int_o^t i\,dt$. If i is kept proportional to e, e_c at time t will be accurately proportional to the integration of e over the interval; this can be accomplished by insuring that e_c is always small compared with e, since $i = \dfrac{e - e_c}{R}$. In the circuit de-
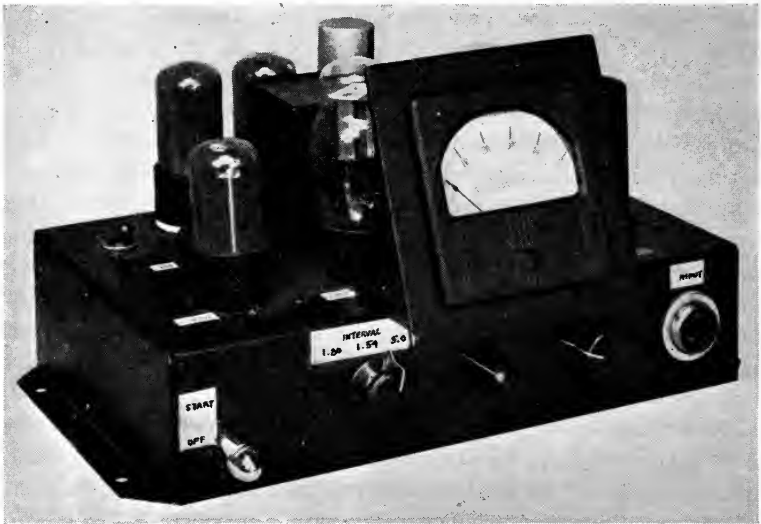
FIG. 1. Integrating meter for the measurement of fluctuating voltages.

scribed, e_c reaches only $1/_{20}$ the average value of e; if for some voltage of unusually low form factor it were found necessary to reduce this fraction to a lower value, such a change could easily be made.

The meter, shown in Fig. 1, consists of a voltage amplifier, a phase inverter, a full-wave rectifier, and a capacitor charging circuit of the type described, with the necessary timing circuit, and high-impedance d-c voltmeter. No particular attempt was made to make the meter an instrument of great absolute accuracy, since it was expected that its chief application would be in comparing 2 voltages (such as full-track modulation and ground noise) with attenuators providing the major part of the numerical measurement. However, stability is entirely adequate and calibration simple.

A valuable feature of the meter, though not peculiar to an integrating type, is its ability to withstand without damage to itself an input level far higher than full scale. This makes it unnecessary to take special precautions such as disconnecting the meter when high-level inputs are imminent, as, for example, when going from unmodulated to modulated sound track.

Frequency response is essentially flat from 50 cycles to 15,000 cycles, so that the meter may be used for any of several types of measurements by combining it with appropriate filters.

DESCRIPTION OF CIRCUIT

A brief reference to the circuit diagram, shown in Fig. 2, will serve to clarify its operation. One section of the $6SN7GT$ is a voltage amplifier, and the other acts as a phase inverter so that full-wave rectifier action can be obtained without the use of a transformer. A potentiometer in the input circuit permits calibration. The rectifier develops a fluctuating unidirectional voltage across R_1, and this voltage charges C_1 through a high resistance. (This is R_2, R_3, or R_4, depending upon the setting of the time interval selector switches S_1 and S_2, which are ganged so that properly related time constants will exist in the integrating and timing circuits at all times.) The voltage across C_1 is indicated by a vacuum-tube d-c voltmeter that has extremely high-input impedance, consisting of the two $6V6$ tubes in a balanced circuit of exceptional stability.

Timing is accomplished by another resistance-capacitance circuit, the 2050 thyratron, and a relay, in the following manner: when the switch S_3 is thrown to "start" (the upper position in the diagram), C_2 begins to charge from the stabilized d-c voltage appearing across the $VR105$, through R_5, R_6, or R_7 (depending on the interval desired). The voltage across C_2 appears at the grid of the 2050 thyratron, while its cathode is maintained at $+60$ v (before firing) by a voltage divider across the $VR105$. When the grid potential has risen to $+58.5$ v,* the 2050 thyratron ionizes, energizing the relay and breaking the signal-integrating circuit.

---

* Note that the time interval is determined almost entirely by R and C values, since the ultimate capacitor voltage is far greater than normal variations in the critical grid voltage for the thyratron (which is approximately -1.5 v). Both cathode and grid voltages are derived from the same d-c supply, causing any variations in this supply to produce only second-order effects on timing.

OPERATION

The proper input level for full-scale deflection is approximately
one volt rms (steady sine wave), and calibration is readily accom-
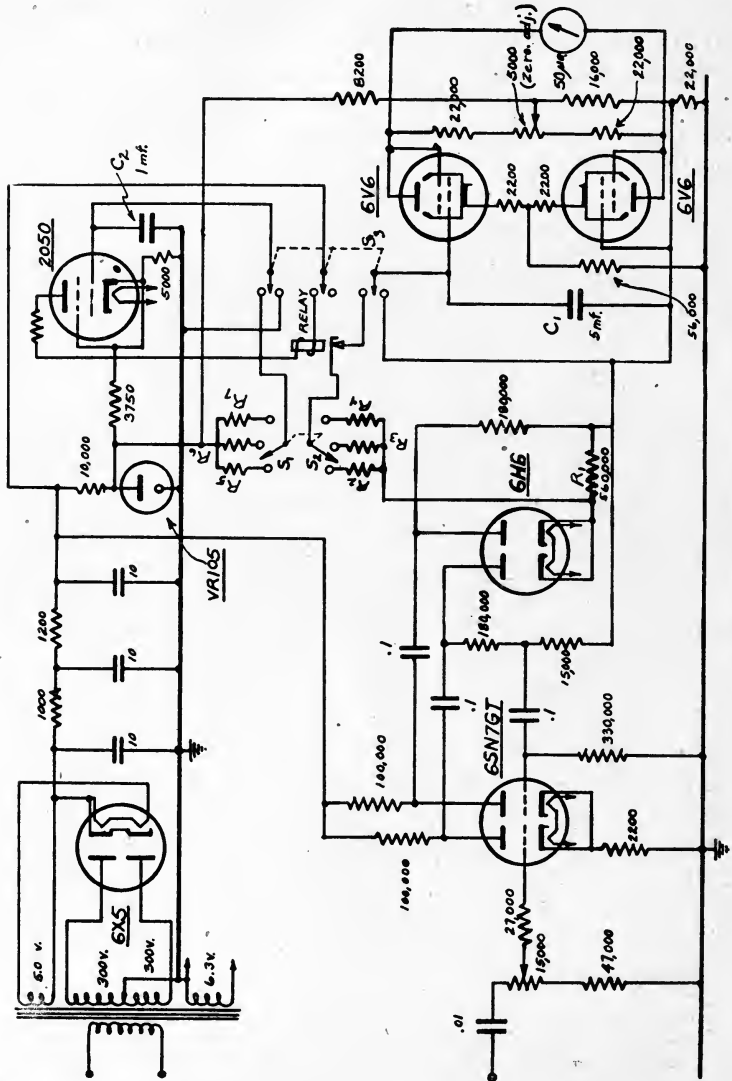
FIG. 2.   Circuit diagram of integrating meter.

plished if desired by means of a sine-wave input of known amplitude
and any convenient frequency within the range of the instrument.

Measurements are made by throwing the switch S_3 (normally at "off") to the "start" position. Timing action then takes place, as explained above, leaving a voltage across C_1 which is proportional to the integrated value of the charging voltage which appeared at the rectifier output during the interval. Owing to the extremely low current required by the measuring circuit, the meter reading remains virtually unchanged for several seconds (dropping about 5 per cent in 30 sec). This allows data to be taken in a leisurely fashion. After the meter has been read, the switch is returned to "off," which discharges both C_1 and C_2, thus preparing the meter for another cycle of operation.

Convenient time intervals may be from 0.5 sec to 5.0 sec, depending upon the specific application. It is only necessary to make the timing circuit constants (corresponding to C_2 and R_5) satisfy the relation $58.5 = 105(1 - \epsilon^{-t/RC})$, where t is the time interval desired, and to make the integrating circuit constants (corresponding to R_2 and C_1) satisfy the relation $RC = 20t$. In the instrument constructed in our laboratory, the intervals chosen were 1.80 sec, 1.54 sec, and 5.0 sec, the first two corresponding to one turntable revolution at $33^1/_3$ rpm, and 2 revolutions at 78 rpm, respectively. For ground-noise measurement, a representative sample may be obtained in one second or less. This integrating meter is directly applicable to flutter-measuring equipment of the Wheatstone-bridge variety, which indicates speed variations as amplitude modulation of an audio-frequency carrier. For this application, a longer interval is desirable, probably several times the period of the least frequent speed disturbance to which the reproducing apparatus is subject.

Utilization of the integrating meter has been found convenient and helpful in the evaluation of fluctuating alternating voltages when a few-second average can be of value. Since the principles of its operation are simple and straightforward, the basic design is flexible and can be adapted to somewhat different requirements.

A SURVEY OF PHOTOTEMPLATE METHODS*

FAUREST DAVIS**

Summary.—This survey covers phototemplate methods now in use in the Southern California airframe industry. These methods are concerned with the photographic reproduction of original engineering line drawings. Although the methods outlined are most extensively used in the manufacture of aircraft at the present time, they can be readily adapted to other fields where the rapid, accurate, and economical reproduction of engineering information is required. Engineers in the airframe industry are certain phototemplate methods will be indispensable in meeting post-war competition; it is thought other industries with similar line reproduction problems will find these methods indispensable to their post-war operations. Accordingly, working details on the following procedures, which have been proved by heavy production use, are given for the information and guidance of engineers: excitation, camera, and reflex methods; other satisfactory but less extensively used methods; and practical methods for applying gelatin-silver-halide emulsions to surfaces at the work site. The survey concludes with a table giving comparative cost and production data on the 3 major methods.

This survey covers phototemplate methods now in use in the airframe industry in Southern California, where the variety of operations has brought about development of a number of methods for making photographic reproductions of original engineering line drawings. The primary requirement of such reproductions is high size fidelity to the original, which must itself be dimensionally stable. Consequently, most originals and reproductions are made on metal, which so far is the most practical material having low size-change characteristics. The methods described below not only meet the requirement for accuracy, but are more economical and rapid than the hand layout methods formerly used. It is hoped that the basic working procedures given in this paper will be useful to engineers with line reproduction problems. All materials and methods described are in production use.

In the early days of phototemplate procedures (1940) it was planned to have sheet metal sensitized in the Midwest and shipped to the

---

Pacific Coast. The impracticability of this idea was soon evident, and fast sensitive materials and means of applying them to surfaces at the work site were sought.

PHOTOSENSITIVE PRODUCTS

Bulk Sensitizing Materials.—The Hammer Dry Plate Company has a bulk gelatin-silver-halide emulsion, which is used for spray application. This emulsion is of the colorblind process type and is suitable for ordinary photographic contact and projection use.

Ansco has 3 types of bulk emulsions available for industrial use. The first of these, Regular Type, is used for ordinary photographic contact and projection purposes, and has a speed about equal to that of Brovira No. 2 paper. The second, Type X, was designed especially to meet the requirements of excitation methods to be described. It is about 50 per cent faster than the Regular Type, is richer in silver, and is more contrasty. The third is Type RC, a negative reflex emulsion for those industries whose operations are large enough to warrant their setting up to sensitize prepared plastic or other translucent media instead of using reflex paper. This emulsion is the same as that used by Ansco in sensitizing its Reflex Paper *2505* described below. One kilogram of these emulsions produces slightly more than a quart when liquefied.

Prepared Sensitized Materials.—Some operations use sensitized stripping material in roll form for application to prepared metal sheets.

The Eastman Kodak Company has a product called Linagraph Transfer Paper, which consists of a calendered paper base of high tear strength coated with a cellulose stripping layer, over which is coated a silver halide emulsion. By means of a special motor-driven laminator this material is laminated to metal sheets, which have been prepared with a soft nitrocellulose lacquer. The laminator carries the lacquered sheet over a roller soaked with solvent to make the lacquer surface tacky, and passes it into rollers where the transfer paper is applied emulsion to the lacquer. Several hours are required for the lacquer solvent to escape through the paper base, which may then be stripped from the emulsion. The sheet thus sensitized is ready for exposure by ordinary photographic contact and projection methods, or by excitation methods.

The construction of the laminator limits the thickness of material that can be readily sensitized to $1/4$ in. In modern photographic

tooling methods a single order often calls for the sensitizing of several different types of materials with thicknesses of 0.036 in. (Alclad for prototype), 0.25 in. (plowsteel for dies), and 1.5 in. (Masonite or Richlite for formblocks).

The tooling department of one airframe plant uses the time honored bichromated colloid as a sensitizer, which is applied to a metal sheet in a whirler in the usual manner. Further details will be found in the discussion of a lithographic method. Theses ensitizers can be made up by anyone; formulas can be found in any lithographers' manual.

Ansco Reflex Paper *2505* is used extensively in the reflex method. It has high inherent contrast, clean-working quality, and sensitivity to red as well as other regions of the visible spectrum.

Defender Lithographic Paper is an orthochromatic paper satisfactory for reflex use.

APPLYING EMULSION AT THE WORK SITE

Spray Sensitizing.—This method was developed at Lockheed Aircraft Corporation and is now used in many airframe plants. It requires ordinary paint spraying equipment with the exception that the inner parts of the spray gun are of stainless steel or are silver plated; any rubber tubing through which the emulsion passes, as from pressure pot to spray gun, must be free of emulsion contaminants such as sulfur compounds. Operations must of course be carried out under proper darkroom safelight conditions, 25-w ruby lamps being satisfactory in most cases.

Bulk emulsion of the gelatin-silver-halide type is shipped from manufacturers in refrigerated insulated crates and is stored at about 45 F. It arrives in gel form, lumps or noodles, and must be gently warmed in a water jacket to 100 F to liquefy it. Glass, enamelware, or stainless steel vessels should be used as containers for the emulsion. The liquefying temperature is not critical, 95 to 110 F; it is not advisable to go much beyond 110 for prolonged periods, say an hour or so, because of the danger of building up a high fog level in the emulsion.

Metal sheets are prepared for sensitizing by washing them down thoroughly with wash thinner and wiping dry with clean cloths. If

the metal is intended for tooling operations, such as shearing, punching, bending, *etc.*, a single coat of highly plasticized pigmented lacquer is applied, allowed to dry to touch, and immediately followed by 2 coats of a highly pigmented white or tinted matte lacquer containing less plasticizer.   As far as phototemplate operations are concerned there is no objectionable halation from a sensitized white lacquered board.   These last lacquer coats must dry to handle in 5 min and within a few hours set up to a hard coat in order to hold the gelatin
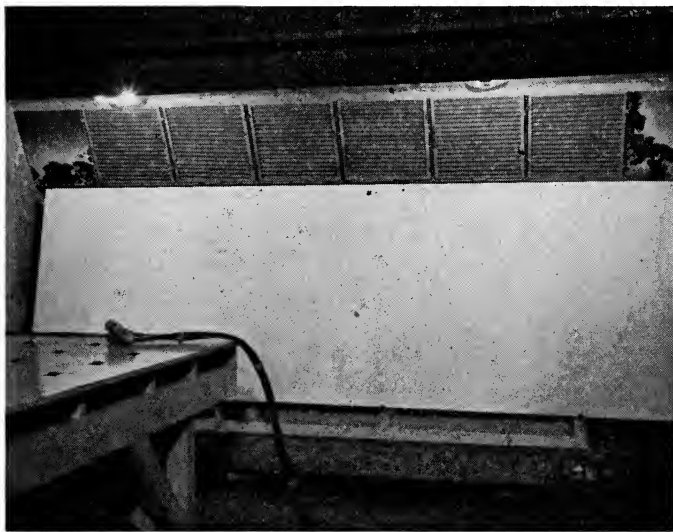
FIG. 1.   Spray-sensitizing installation at Lockheed Aircraft Corporation.

of the emulsion in place after it is hardened in processing and dries out on aging, when it exerts a tremendous pull on its lacquer support. The emulsion is sprayed directly onto this matte lacquer, and it is important that the lacquer be entirely free from sulfur compounds or other contaminants, otherwise serious fog troubles will be encountered. For proper control of metal preparation, it is desirable to have painting operations under phototemplate department management.

Facilities as required by most state laws for the spraying of lacquers are entirely adequate for carrying off any silver halides which would otherwise be dispersed into the workroom atmosphere during spray sensitizing. A satisfactory installation consists of a spray

booth with proper light-tight input and exhaust fans.   It has been
found desirable to have the input volume per minute exceed the
volume of the workroom, which should be entirely closed during
sensitizing, by 25 per cent.   In this region this input supply does not
have to be filtered.   The exhaust should carry off a volume of air per
minute equal to the volume of the workroom.   Thus a positive pres-
sure is built up to force dispersed silver halides immediately out
through the exhaust.   Three banks of metal filters should be put into
the path of the exhaust at the back of the spray booth to catch
residual spray and keep it from passing into the outside atmosphere.
The installation of a water bath in the spray booth is not necessary.

Fig. 2.   Brush-sensitizing at Douglas Aircraft Company.

Metal sheets or other materials are placed on an A-rack at an
angle of 15 deg to the vertical and hand-sprayed with a vertical over-
lapping stroke.   The pressure pot is used as a water jacket into
which is placed the inert vessel containing liquefied emulsion, which
is held at about 100 F for proper spraying viscosity.   The spray gun
is adjusted to give a flat "fan" about 8 in. wide when the gun is held
about 8 in. from the surface.   A hand flashlight with a red filter is
taped to the spray gun to permit inspection as the sensitizing pro-
ceeds.   Air pressure on the pot is 8 lb, just sufficient to force the
emulsion through the line to the spray head, where a second air line
supplies 40-lb pressure to blow the emulsion into a fine spray.   (See

Fig. 1.) A proper spraying technique results in no waste from run-off, but if there is any, it may be caught in a stainless steel trough and used over again.

For a 4 × 12-ft sheet of metal the spraying cycle is 3 min, including placing the material on the rack, spraying, and moving the wet sheet to a drying compartment, which contains heating coils, thermostatically controlled to hold temperature in the cabinet to 95 F, moisture-absorbing cellulose pads, and a blower. Notice that no

FIG. 3. Vertical tanks set in the floor are most efficient for processing large sheets of sensitized metal. A hoist is required for handling heavy pieces as shown in this installation at Consolidated Vultee Aircraft Corporation.

chilling is required. The sheet is ready for use or storage in 20 min. In this method of applying emulsions a gallon covers 250 sq ft.

Brush Sensitizing.—The Douglas Aircraft Company's plant at El Segundo, California, did not wish to set up a spray installation because of long delays necessitated in obtaining equipment. Bulk emulsion was best suited to the great variety of their requirements, and a method was soon worked out for its application to lacquered surfaces with a soft paintbrush. (See Fig. 2.) For this method the emulsion is liquefied and brought to 110 F, when a $1/4$-hp

Eppenbach Homo-Mixer or equivalent is placed in it and run at 5000 rpm; 7.5 cc butylcellosolve per 100 cc liquefied emulsion are added and the Homo-Mixer run for 3 min. A certain amount of foaming will occur during homogenizing and sufficient Foamex or other inert defoamer should be added in drops to eliminate it. The butylcellosolve acts as gelatin leveling agent and the Foamex in addition to defoaming will prevent air bubbles from being pulled out of the brush into the emulsion coating. Glycols other than butylcellosolve promise even better leveling, but these are at the moment difficult to obtain in required production quantities. An emulsion so treated can be resolidified and held for long periods without the finals separating out, and footage obtainable is truly surprising: 1000 to 1500 sq ft per gal! This brings the cost of sensitizing material to about one cent per sq ft.

In the case of the 1500-sq ft coverage there was a slight loss of speed and maximum density, but these are not important to the phototemplate method. One operation uses a silk screen for applying an emulsion similarly treated, and obtains similar coverage.

PROCESSING

Tanks.—Experience has shown that the most efficient installation for processing large sensitized and exposed materials is a bank of 4 vertical tanks set side by side in a well in the laboratory floor. The tops of the tanks are usually at or somewhat above the general floor level. (See Fig. 3.) Three-inch tongue-and-groove Douglas fir, cypress, redwood, or spruce are practical construction materials for this purpose. Heavy stainless steel is also used. Any plumbing is of stainless steel or hard rubber. Assuming a maximum sheet size of 5×12 ft, each tank has inside dimensions of approximately 5 in. $\times$ 6 ft $\times$ 13 ft, and has a volume of about 250 gal. In the excitation and camera methods, *D-11* is most generally used, but in the reflex method the following formula is often used for both negatives and prints:

Formula AP-80

Water 125 F..	$2^1/_2$	gal
Metol..	300	grains
Sodium Sulfite Anhydrous...................................	3	lb, 2 oz
Hydroquinone..	$7^1/_2$	oz
Sodium Carbonate Monohydrated...........................	1	lb, 14 oz
Potassium Bromide..	4	oz
Water to make...	5	gal

These developers are kept to volume by adding fresh stock developer and will last from 3 to 6 months before complete renewal is required.   Development is by inspection and is between 3 and 5 min at 68 F.   Some operators install mechanical agitators in their developer tanks, whereas others prefer merely to stir the solution up from the bottom with a long pole once or twice a day.

In some localities the range of temperatures is such that it is necessary to heat or cool the solutions.   In regions where the temperature range is short the tanks are set in a well-insulated well with sufficient free air space around them to permit circulation of heated or cooled air automatically supplied and thermostatically controlled, at a cost of $200 to $500.   However, where the temperature range is considerable, it will be necessary to set up a rather elaborate installation to circulate the solutions through heat exchangers with the cost ranging between $3000 and $5000.

To stop developer action and prolong fixer life, a solution of 2 per cent acetic acid is recommended as a stop bath.   This bath will gradually lose efficiency as developer is carried into it.   A rough check can be made periodically with litmus paper to determine whether the bath has lost its acidity.   When it has, it can be entirely replaced cheaply.

Either *F-5* or *A-204* makes a satisfactory acid-hardening fixing bath, 5 min immersion being sufficient.   A silver recovery installation is not practical for the scale of most phototemplate operations. It is the practice in this region to sell the exhausted fixing bath to local laboratories which recover the silver.   These laboratories will make a periodic check to determine the silver content and the degree of exhaustion of the bath.   Recovery is practical for them when the bath contains as low as 3 grams per liter, and as much as 25 grams per liter are recovered from some baths.

All metal sheets must be backed with clear lacquer to keep them from reacting in the acid stop and fixing baths.

Change of water in the wash tank should be rapid enough that washing is satisfactorily completed in 5 min.   The processed materials are squeegeed free of surface water and left in the room atmosphere to dry.   Drying time, 5 to 10 min for metal; 15 to 30 min for reflex negatives.

Metal sheets and other materials are moved and handled by hand in all operations except processing, where it is desirable to have a hoist on a monorail.   The hoist assembly should be able to support

500 lb and the monorail should run the short way of the tank group and extend well over either end of the tanks.

There are various methods of fastening materials to the crane. Some workers punch holes in the tops of the metal sheets and insert hooks attached to a wooden bar, which carries a loop in the center into which the hook of the crane is caught. Others use small friction clamps at the tops of the sheets. One of the neatest devices is a hardwood rod which has 2 vacuum cups mounted on it, and has a sturdy stainless steel foot attached at the bottom to take the weight of the material. At the top there is a handle for hand use and a slot for use with the crane. Two of these bars can be hung from a T-beam for large sheets. Glass reflex negatives up to 4 $\times$ 6 ft are placed in a hardwood frame which is suspended from a crane for processing.

Trays.—Smaller pieces of material are processed in trays of wood or stainless steel. In general the same formulas are used as for tank processing.

In older installations employing the reflex method, A-79 in trays large enough to take 4- $\times$ 6-ft sheets has been used to great extent for developing reflex negatives to high contrast, but this developer in open tray has a life of only 4 to 6 hr. The recent introduction of reflex paper of exceptionally high inherent contrast made especially for line work has obviated the necessity for such contrasty and expensive developers. Consequently the longer lived and entirely satisfactory formulas A-103 and AP-80 are beginning to be generally used. The inefficiency and waste of large open tray installations for this method have long been recognized, and vertical tank installations are being made as rapidly as heavy production conditions permit.

EXCITATION METHOD

The X-ray method takes advantage of the fact that certain materials absorb radiation at one level of energy and reradiate it at another. Aluminum sheets up to 5 $\times$ 12 ft are degreased, cleaned with wash thinner, primed with a clear lacquer, coated with 2 coats of white lacquer, and further coated with 10 coats of a cream-colored fluorescent lacquer, which on X-ray activation emits radiation in the short wave end of the visible spectrum to which silver halides are highly sensitive. This sheet is a drawing board on which the original engineering drawing is made.

The fluorescent substance will not remain dispersed in the lacquer vehicle unless a pressure pot with agitator is used in spraying. Care

must be taken that the highly abrasive fluorescent substance does not scour off too much of the pressure pot and agitator into a given batch of lacquer, otherwise the lacquer may become contaminated and deactivation result.   These sheets should be left to dry by air overnight, after which they are sanded with fine sandpaper.

All drawings were at one time made with *6H* graphite pencil. Unavoidable variations in line widths in the originals made X-ray exposure quite critical—so critical that there is now a strong tendency to abandon pencil in favor of a hypodermic needle pen and lac-

FIG. 4.   Consolidated Vultee's Downey plant designed and constructed this X-ray printer for both primary and after-glow exposure procedures.   It will accommodate 4×12-ft sheets.

quer ink technique developed by Consolidated Vultee at Downey, California, which gives a line uniform in width and density.

Original drawings in the aircraft industry are traditionally left-handed.   A symmetrical shell on either side of an airframe axis is presupposed and only the left-hand half is drawn.   Fluorescent master drawings can be reproduced either by a primary or an afterglow-primary method, depending on whether a right-hand or left-hand image is wanted.   In general about 40 per cent of reproduction orders are for right-hand images so that primary exposure is all that is required.   In Consolidated Vultee's phototemplate laboratory at Downey, California, an original is placed face up in an X-ray printer containing 2 fruit inspection X-ray units operating at 100 kv peak

and 7 ma. These are set at the bottom of a 6-ft concrete pit with 6-in. side walls to absorb X-rays emitted at this potential. (See Figs. 4 and 5.) One-inch plywood covers the pit and forms a table top, to which is hinged a lid carrying a vacuum blanket to insure good contact. A piece of nonfluorescent sensitized metal is laid emulsion down onto the original drawing, the lid lowered, and a 17-in. vacuum pulled in about 5 sec. After the lid, which is covered and skirted with lead to protect operators, is down a primary exposure of one minute to X-rays is given. This is sufficient to produce a satisfactory latent image. All operations are controlled by limit switches and interlocking mechanisms to minimize hazard to operators. Right-hand images thus produced have a black background with white lines. All lettering is of course a mirror image.
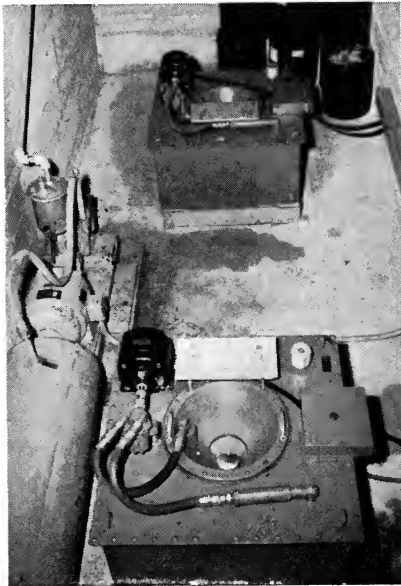
Fig. 5. The interior of Vultee's X-ray printer contains two 100-kv peak fruit inspection X-ray units.

The remaining 60 per cent of the orders are for left-hand images, which require metal intermediates corresponding to ordinary photographic negatives. Metal for intermediates is prepared in the same manner as the original drawing material. After the lacquer has dried and has been sanded it is sensitized with a silver halide emulsion. The intermediates are exposed by an afterglow technique in which the original engineering drawing alone is first placed face toward the activating units for an exposure of 5 to 10 min. During this time the electrons in the atoms of the fluorescent substance are rapidly pushed to outer orbits, but when the external energy source is cut off these electrons slowly drop back to their normal orbits, giving off energy and producing a phenomenon known as phosphorescence, which frequently requires 6 to 8 hr to subside.

After this activation, the original is placed face to face with the

sensitized intermediate in a vacuum frame and held for 5 to 10 min, during which time the phosphorescence builds up a negative mirror latent image. The processed intermediate, or metal negative, is then printed onto sensitized metal stock by the primary exposure method to give a left-hand positive image. Both primary and afterglow images are developed in ordinary photographic solutions, fixed, washed, and dried.

Flop-Matches.—Since it is the practice in the engineering loft to develop only the left-hand half of a layout, when the shop requires a completed symmetrical layout about a centerline the phototemplate department must furnish it. This involves registering a right-hand image with a left-hand on the same sheet within the narrow tolerances set by the department. To accomplish this a fluorescent metal negative is first made by primary exposure and from this a fluorescent metal positive is printed by the afterglow method. Small holes are drilled along the centerline of both of these at precisely the same points. The metal negative is clamped to a large sheet of sensitized metal, into which another set of holes is drilled using those of the metal negative as a guide. The clamps are removed, the 2 sheets bolted together, and an exposure given by the afterglow method for the left-hand half.

The metal negative is then removed, the metal positive bolted on, and an afterglow exposure given for the right-hand half. The final image is a positive for the left- and a negative for the right-hand halves, but the lines are legible and hence acceptable to the shop.

The excitation methods are size-for-size methods claiming "zero-zero size-change" since all printing is done by contact in vacuum frames (except for special jobs like "flop-matching") onto dimensionally stable materials.

Reference Reproductions.—Negatives may be made 1:1 from fluorescent masters onto translucent vellum stock, and these printed onto sensitized translucent materials to make positives for the inexpensive production of reference Ozalid white prints requiring only 2 steps—exposure and dry development. However, this scale limitation is a handicap in the case of original drawings 4 × 12 ft or larger, since sensitized translucent stock is at most 42 in. wide. Furthermore, reference drawings are unwieldly if too large. Consequently the use of a camera is indicated as an adjunct to the X-ray method for the reproduction of reduced scale reference drawings.

Costs.—A complete X-ray phototemplate laboratory installation

can cost anywhere between \$15,000 and \$100,000 depending on the method of working, the nature of the equipment, and the volume of work.

For a time a phosphorescent lacquer method showed promise in this group since it required activation by only ordinary illumination, fluorescent tube, photoflood, or daylight, but in 2 years it was found that the phosphors completely refused to be reactivated. Some original drawings are used again and again for 10 years or more; fortunately the hundreds of boards that could not be reactivated were able to be reproduced by the reflex or camera methods.

THE CAMERA METHOD

Original engineering drawings are made on sheet metal which has been coated with 2 to 4 coats of a matte lacquer with sufficient tooth to take $6H$ pencil or silver solder, and of sufficient plasticity that it will not chip. Silver solder is sharpened to a chisel point and because it is somewhat harder than graphite requires more pressure to make a line. This results in a slightly incised line which is not so easily smudged during the long-period development of a drawing on the loft floor. However, during such development lines are constantly changed, and because of this incision ordinary abrasive erasers soon dig through the lacquer coat to bare metal. It has been found that certain solvents such as trichloroethylene have a solvate action on some lacquer coatings, and if a cotton swab carrying a small amount of solvent is lightly touched to a silver solder line, it will disappear without leaving a trace. This results in a better quality drawing.

It was at one time thought that drawing surface lacquer should be of a greenish or bluish tint so as not to cause eyestrain among the draftsmen, but now nearly all engineering lofts are flooded with fluorescent illumination which causes no more eyestrain on a white board than on a tinted one; consequently, white loft boards are beginning to be used extensively because they give much more satisfactory photographic reproductions.

Original drawings are placed on the vacuum copyboard of large cameras and copied onto negative materials following conventional photographic copying techniques. (See Fig. 6.) However, the need for accuracy is great, and no camera should be considered for the job which does not permit a controlled adjustment of 2 working planes to ± 0.0005 in. There are as yet no cameras on the market

especially designed for phototemplate work and such as are now in use have been adapted from the photomechanical field. Some of these have been modified to take metal sheets up to 5×12 ft. They are quite rugged in appearance and some of them weigh up to 5 tons, but in spite of this they are delicate precision instruments, and a repeated load of over 100 lb on the copyboard will throw them seriously out of line. It is often desired to project images onto
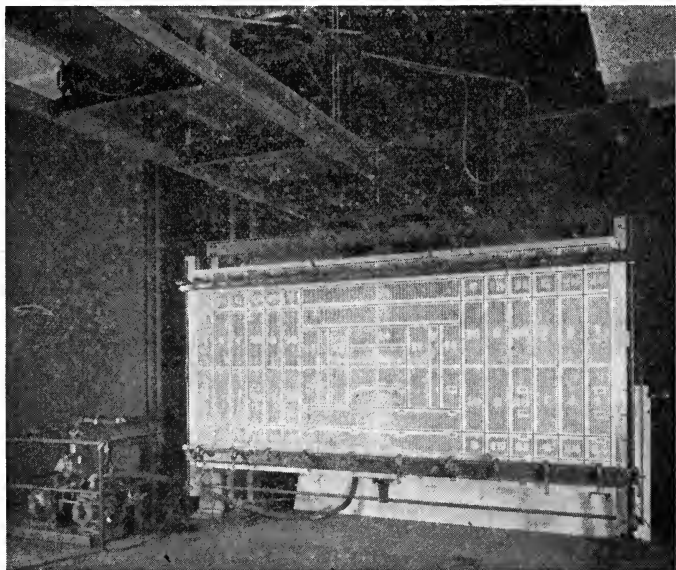
FIG. 6. The Lanston monotype camera, which was designed for photomechanical requirements, has been adapted to the phototemplate camera method. The vacuum copyboard is shown above.

sensitized materials weighing considerably more than this, such as drill jigs and formblocks. Thus the cameras currently available have this shortcoming for the phototemplate method; however, if only lightweight metal sheet is used they are quite adequate.

Glass plates are used for negative materials in the camera method and are of the high-contrast lithographic type. Hammer Ortho Offset and Eastman Kodaline have been found satisfactory for the purpose. Development is in a high-energy paraformaldehyde developer such as *A-79* or Paralith, with stop bath and fixing bath

as usual. These plates admirably satisfy the requirement for high accuracy. Careful measurement of a 16-in. photographic line grid on both brands over a protracted period did not reveal any line displacement; accuracy of the 18-in. cathetometer used was $\pm 0.5\ \mu$.

The only size-change effects that can be expected from glass plates are those caused by temperature changes, the coefficient of expansion being about the same for the commercial plate that is used as that for mild steel. However, temperature changes in and about the camera are often extreme, particularly if a cool light is not used as a projection source, or if copy is heated excessively with arc lamps. Experience indicates that it would be economical in the long run to have the entire camera installation temperature controlled, thus eliminating the continued necessity for shooting test strips, or otherwise checking the accuracy of the image. The cost of temperature control ranges from $15,000 to $25,000.

Scale of reduction onto glass negatives depends largely on job requirements. In the case of reproductions for ordinary airscrew models, photo department tolerances are ± 0.001 in. per ft, when it is practical to reduce the copy 4 to 5 times. At these ratios a 30-in. process lens will cover 5×10 ft satisfactorily at $f/45$ and $f/32$, respectively. There has always been a line-spread problem in the use of litho-type plates on pencil copy which results in large part from the fact that the pencil lines are not uniform in width nor density. The nature of the negative materials is such that if an exposure is given for the finer lines, there will be an excessive widening of the heavier lines. Cameramen have found that it is best to expose strongly in order to hold the heavier lines to a satisfactory width, and use Farmer's Reducer to clean out the finer lines during processing.

However, now that jet propulsion models are in production, tolerances are only ± 0.003 in. in 10 ft, less than a third as much as formerly. In addition to the product demand for greater over-all accuracy, the insistence on better line quality is strong. As a result, reductions for these models are only 1:2.

Templates are used in making tridimensional plaster patterns, from which molds are made for casting zinc or other alloy drop-hammer dies. These alloys shrink in various amounts depending on the alloy—usually 0.10 in. to 0.125 in. per ft—and allowances for these shrinkages can be easily made optically to produce templates oversize in the proper amount. The camera turns out such special jobs easily

and quickly. However the alloys do not shrink uniformly, so that in spite of the optical corrections there is usually a lot of handwork required on the dies. This has led to the present tendency to break away from so-called "shrink" templates and get back to actual size templates. Hand grinding is still required, and check templates are used to check contour accuracy.

The camera is used to a limited extent for the making of reduced scale templates for the construction of wind-tunnel models.

Reference Reproductions.—A most important use for the camera is in making reduced scale translucent vellum negatives from the originals. From these, translucent positives are made for the printing of the many thousands of Ozalid white prints required for reference purposes in aircraft manufacture. No phototemplate department can be complete without some kind of copying camera for this purpose.

Flop-Matches.—It is not satisfactory to turn a glass negative over image side away from the lens in order to project the right-hand half of a symmetrical contour even though customary compensations are made for refraction resulting from the thickness of the glass. Camera crews find that they spend hours trying to register the complex of fine lines at the centerline. This is because the amount of distortion, although zero on the optical axis, increases progressively as the extremities of the field are approached. They have found it much more satisfactory to make a positive print on glass from the negative. The glass negative with left-hand image including centerline is exposed and register points on the centerline developed up locally. The glass positive is then placed in the holder, registered on the developed centerline points, and exposed. The resulting match is half positive and half negative, but the image is accurate and the lines are legible.

Costs.—A complete phototemplate camera installation costs anywhere between $40,000 and $150,000 depending on the nature of the equipment, the volume of work, and the job requirements.

REFLEX METHOD

Original engineering drawings are made with *6H* pencil on sheet metal coated with white matte lacquer. There is no line-spread problem in this method and fine lines are reproduced faithfully. Therefore variations in line width and density do not cause trouble. The method employs common photographic contact printing pro-

cedure.   Even in the making of the negative, which is done by reflex printing, the materials are in contact.

The negative material is prepared by applying a varnish-type adhesive to $1/4$-in. plate glass with a silk screen.   The glass thus coated is placed horizontally in a rack for a sufficient time to allow the volatile solvents to escape—about 45 min.   It is then placed on a work table and a piece of reflex paper rolled out on the adhesive emulsion up.   In one plant this negative, 3×5 ft to 4×6 ft, is immediately placed in a vacuum frame for a few seconds to push the
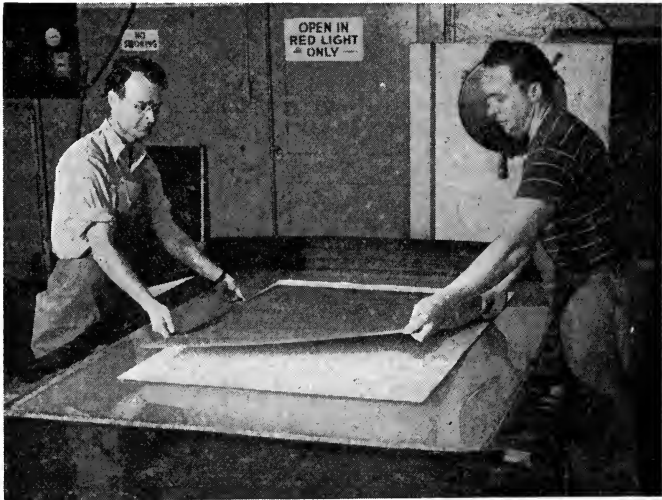
Fig. 7.   Making a reflex negative at Douglas Aircraft Company.

paper tightly against the glass and force the adhesive into the paper fiber.   In a long-period production test it has been found that by this method the negative can be exposed and processed within 30 min without detectable size variation.   However, it is good practice to allow sensitized glass negative stock to cure overnight at room temperature.   The reflex paper is factory sensitized over high-grade paper stock with silver halide emulsion. Ordinarily paper for this purpose does not have a baryta coating, since maximum translucence is desired. It has been observed that for optimum reflex results the transmitted-to-incident light ratio of the paper base is 1:6; materials deviating appreciably from this ratio do not give good reflex images.

The printing box for this method is basically quite simple. A light-tight box is constructed large and sturdy enough to take a piece of heavy plate glass somewhat larger than the maximum size of drawing to be reproduced. One side of the glass is sandblasted to diffuse the light source; this side is placed toward the source, which consists of a bank of incandescent lamps so spaced as to give even illumination. The intensity of the light is controlled by a variable resistance in the line, and is such that exposure times run 10 to 20 sec. (See Fig. 7.)

FIG. 8.   Consolidated Vultee uses pin-located reflex negatives for the reproduction of large master drawings.

Consolidated Vultee at San Diego has a printing table topped by a piece of $1/2$-in. plate glass $5^1/_2 \times 12^1/_2$ ft to take 5×12-ft metal drawings. For making reflex negatives of a full 5×12-ft drawing, four 3×5-ft glass negatives with a machined metal bushing set in each end are butted on long sides and firmly held in place on the printing table by tapered pins which pass into machined bushings set in register in the $1/2$-in. plate glass. (See Fig. 8.)

Douglas Aircraft at Long Beach, California, has set up a printing table at an angle of 10 deg to the vertical with a $1/2$-in. plate glass surface $5^1/_2 \times 13$ ft. For reproducing a 5×12-ft drawing, four 3×5-ft sensitized glass plates are set up on end on a rigid base support and butted at the longer sides. No registering pins are used.

In either case the drawing is placed to face the sensitized glass negative surface, a neoprene vacuum blanket rolled over the sandwich, a single exposure made, and the negatives developed. When these are dry they are placed in identically the same positions as when exposed, $1/4$-in. Scotch masking tape run down the butt joints, a piece of 5×12-ft sensitized metal placed to face the negatives, and a print made. Since such large prints are wanted in the shop for long contour developments, the three $1/4$-in. gaps left by the masking tape are not objectionable.

Orders for such large reproductions represent less than 5 per cent of total orders, most of them being for prints 4×6 ft or smaller. The method for these is the same as for the larger prints, without the necessity for registering or butting.

The procedures just described produce only left-hand images. For a right-hand image a positive transparency is made onto glass negative stock from a negative. From this positive a right-hand image is made on sensitized metal or other material.

The rationale of the reflex method is as follows. During negative exposure light is transmitted through both paper base and emulsion. When it strikes the white surface of the original drawing it is reflected back through the emulsion to the paper base. It continues to travel between these 2 reflectance layers until it builds up a strong latent image. Wherever the light strikes a graphite pencil line it is absorbed, so that the final result on the negative is a clear line image against a black background. A good reflex paper should produce negatives on which the line image can be clearly seen at a distance of a few feet by reflected light, it should have a sufficiently high threshold that it can be handled for a short time in subdued daylight or room light, and should have high inherent contrast to produce clean sharp lines without fogging.

Occasionally a red sensitivity in addition to yellow, green, and blue, is required in order to reproduce colors in proper value. This added sensitivity to red is desirable in those operations adopting the new hypodermic needle pen and lacquer inks, which are now being used in 6 colors including red. Colors are used for coding mold lines, pattern lines, centerlines, and the like, for immediate recognition on the loft floor; such information as is not required in the shop can be dropped in the reproduction process by proper filtering.

Ordinarily where the reflex method is used reproduction planning is so efficient that all reproductions required from a given negative

are made within 24 hr of receipt of the order, so that the negative is no longer needed. (See Fig. 9.) The plates are placed in large trays containing 10 per cent caustic solution and left to soak for several hours, when the adhesive is thoroughly softened and the paper with adhesive can be wiped off. The plates are washed and stood up to dry, when they are ready to be resensitized.
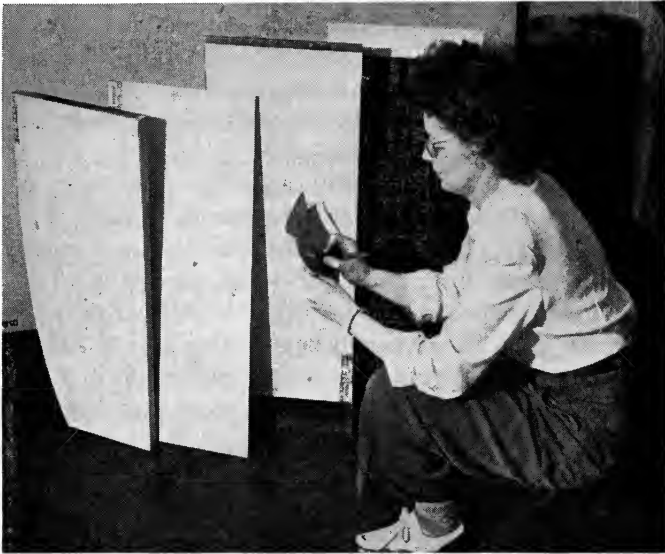

FIG. 9. Where photographic images can be placed directly onto tool material, intermediate templates are unnecessary. Materials shown carrying engineering information are: 1-in. Richlite for formblock, $1/4$-in. plowsteel for punch die, 0.036-in. galvanized steel check templates, positive and negative.

Flop-Matches.—A negative is made as usual from the left-hand information with centerline as furnished by engineering. Meantime a piece of 0.005-in. calendered unplasticized translucent Series V Vinylite large enough for the completed image is coated on both sides with a clear nitrocellulose lacquer. This sheet is then sensitized by brush on one side with emulsion containing butylcellosolve to make the emulsion adhere smoothly to the lacquer. An exposure is made on the sensitized Vinylite including centerline, a left-hand image developed, and the image dried.

The other side of the Vinylite is then sensitized by brush, the developed centerline, face up, is registered over the centerline on the negative, and another left-hand image exposed, developed, and dried. The result is a positive transparency with the entire symmetrical layout on it. This when printed produces white lines on a black background, the 0.005-in. thickness of the Vinylite not causing enough line fuzzing to give trouble.

Reference Reproductions.—Positive transparencies on sensitized materials can be made at 1:1 from the glass negative for the printing of Ozalid white prints. As with excitation methods this scale limitation is a handicap in the case of large original drawings. Here again some kind of copying camera is required for the reproduction of reduced scale reference drawings.

Costs.—A complete working reflex laboratory can be installed for from $3500 to $15,000, depending on the volume of work, the number and nature of the printing tables, and the job requirements. The $3500 unit is simple but efficient and can handle up to 3 × 5-ft negatives from any portion of a 5 × 12-ft original drawing. One large airframe plant has an installation costing only $6700 which for several years has consistently turned out an average of 26,000 sq ft of phototemplates per month of high quality and with great efficiency.

OTHER METHODS

Lithographic.—The tooling department of one of Northrop Aircraft Company's plants at Hawthorne, California, has worked out a lithographic method for reproducing line images. A piece of transparent 0.010-in. plastic is laid over the portion of an original engineering drawing that is to be reproduced, and fixed securely at the edges. Lines are scribed into the plastic with a sharp pointed tool. Scribing should not be too deep or the plastic will break. The burr is knocked off these lines, which are filled with black grease pencil.

A piece of metal, lacquered black on both sides, is coated in a whirler with bichromated gum arabic. The whirler is a rotating table, usually horizontal, upon which the metal to be sensitized is centered. The sensitizing solution is poured onto the center of the metal and the rotation rate is such that the plate is coated uniformly to the edges. Only sufficient sensitizer to coat the area of the plate is used. A circular band of metal is placed around the moving parts to prevent drops of sensitizer from flying into the room. Drying is hastened by electrical heating units placed in the hinged lid of the

unit.   Heat should not be excessive, since the sensitizer is hardened by heat as well as light.   An exposure of 7 min is given to a 35-amp twin-arc bank through the transparent plastic sheet carrying the positive line image and other information, with the image toward the light.

The plate is developed with a calcium chloride and lactic acid solution and the lacquer removed from the unexposed lines with furfural. After washing, the plate is placed as anode in a tank of saturated sodium chloride solution and electrolytically etched for 1.5 min at 800 amp, 7 v, d-c.   The plate is washed again, dried, and coated with clear lacquer to prevent oxidation of the bright metal line image.

No flexible transparent plastic sheet has yet been found that will hold size for long periods.   Consequently great care must be taken in choosing material for the positive line image.   Calendered unplasticized transparent Vinylite Series V sheet 0.010 in. is satisfactory if printed within a few days of scribing, otherwise it must be trammeled against the original to check size.

Electrolytic.—One of Lockheed Aircraft Corporation's tooling departments uses an electrolytic method for reproducing line images. The method requires scribing through a nonfusible lacquer to the base of a sheet of body steel or galvanized steel.   The layout is either made by hand from original engineering information, or a photographic replica is furnished.   The scribed image is moistened with transfer solution and placed face up in a press having thick pads of sponge rubber attached to the platens.   A clean piece of terneplate, aluminum, or galvanized steel is placed on the scribed sheet.   Copper bands across the rubber pads make contact with the 2 metal sheets. The press is closed and current applied for a few seconds.   Pressure is released and the mirror copy, black line image on silvery background metal, is washed and dried.   To prevent oxidation on the clean metal surface, a coat of clear lacquer is usually applied.   The method is fast, economical, and can turn out 100 to 200 copies before the lacquer of the original breaks down.

CONCLUSION

Table 1 gives a rough evaluation of the 3 phototemplate methods used most commonly in the West Coast region.

It should be pointed out that no phototemplate department in the airframe industry necessarily uses one method to the exclusion of all others.   In general, 5 years of heavy production experience have

TABLE 1

Comparison of the 3 Major Phototemplate Methods

	Excitation	Camera	Reflex
Production, sq ft per month	29,000	32,000	93,000
Photographic cost per sq ft	$0.74	$0.71	$0.37
Total personnel	36	62	56
Personnel required with 5–10 years' photo-graphic experience	None	30	None
Production, sq ft per man month	806	516	1,660
Total Capital Investment	$80,000	$300,000	$50,700

shown that where both a contact method for the accurate size-for-size reproduction of original engineering drawings and a copy camera for the production of intermediates for reduced scale reference drawings are used together, a complete and efficiently functioning phototemplate laboratory results.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y., at prevailing rates.

American Cinematographer
26, 10 (Oct., 1945)
Telefilming Horse Races (p. 334)   N. HARTFORD
The "Guzap" That Went to War (p. 335)
The Production of Scientific Films for Biological and
   Medical Purposes (p. 342)   J. Y. BOGUE
         26, 11 (Nov., 1945)
The History and Origin of 16 Millimeter (p. 376)   A. F. VICTOR
         26, 12 (Dec., 1945)
U. S. Government Report on Agfa Color Process (p.
   416)
G. E. Develops Miniature Flash Tube (p. 435)

British Kinematograph Society, Journal
         8, 3 (July–Sept., 1945)
Cutting Room Practice (p. 56)   C. FREND

British Kinematograph Society, Proc. Theatre Division
   (1944–45)
The Post-War Kinema and Its Equipment—Practi-
   cal Projection Problems (p. 2)   R. H. CRICKS
Double Reels and Film Mutilation (p. 11)   S. WILLIAMS
Kinema Screens and Their Maintenance (p. 14)   H. C. STRINGER
Over-all Projection Efficiency (p. 16)   R. PULMAN
Picture Presentation (p. 18)   S. T. PERRY
Kinema Engineering Efficiency (p. 19)   H. E. WHITNEY

Electronic Engineering
         17 (Dec., 1945)
The Pye "Videosonic" Television System (p. 814)   D. I. LAWSON

Electronic Industries
         5, 1 (Jan., 1946)
Lens Aberrations in Picture Projection (p. 86)   A. MONTANI
RCA Demonstrates Color Television (p. 178)

Photographic Society of America, Journal
        11, 10 (Dec., 1945)
Edward J. Steichen (p. 527)   G. E. MATTHEWS
Cows, Movies and Color Photograph (p. 528)   C. E. K. MEES

Radio News
        34, 5 (Nov., 1945)
Movies for Television (p. 10)   S. PATREMIO
        34, 6 (Dec., 1945)
Studio Acoustics—Pt. 1, Basic Principles and Recent
   Developments Involved in Designing Broadcast
   Studios to Give the Most Desirable Acoustic Prop-
   erties (p. 5)   R. H. BOLT
        35, 1 (Jan., 1946)
Studio Acoustics (p. 8)   R. H. BOLT

Technique Cinematographique, La
        15, 8 (Sept., 1945)
An Automatic System of Phasing the Shutters of
   Camera and Projector in Background Work (p.
   135)   L. MOHIER
Color Motion Pictures by the Chimicolor Process (p.
   136)   R. VALETTE
Scanning Losses Caused by the Slit in Motion Picture
   Sound Reproducers (p. 139)   H. E. ROUSSIN
        15, 9 (Oct., 1945)
New Negative Materials for Variable-Width Sound
   Recording (p. 151)   D. O'DEA
High Efficiency for Black-and-White and Colored
   Background Projection (p. 153)   J. VERGENNES
Conservation of Films (p. 154)

59th SEMI-ANNUAL TECHNICAL CONFERENCE

Hotel Pennsylvania, New York

May 6-10, 1946

Directory of Committee Chairmen

Atlantic Coast Section and Local Ar-
rangements.........................FRANK E. CAHILL, JR., *Chairman*
Registration and Information...........W. C. KUNZMANN
Luncheon and Dinner-Dance Commit-
tee.................................E. I. SPONABLE, *Chairman*
Hotel and Transportation...............O. F. NEU
Membership and Subscription Commit-
tee.................................JAMES FRANK, JR., *Chairman*
Ladies Reception Committee Hostess.....MRS. O. F. NEU
Papers Committee.....................BARTON KREUZER, *Chairman*
                                      C. R. DAILY, *Vice-Chairman*
Publicity Committee...................HAROLD DESFOR, *Chairman, assisted by*
                                      LEONARD BIDWELL
Projection Programs—35-mm............H. F. HEIDEGGER, *Chairman, assisted*
                                      by Members New York Projection-
                                      ists Local 306
                        16-mm...........J. E. STEOGER

HOTEL RESERVATIONS AND RATES

No hotel room reservation cards will be mailed to the membership for this Con-
ference. Therefore, members and others must book and reserve desired room ac-
commodations early and direct with Joseph Troise, Front Office Manager, Hotel
Pennsylvania, New York 1, N. Y., prior to April 20. Mention that the reserva-
tion is in connection with the SMPE Technical Conference. No rooms will be
assured or available unless confirmed by the hotel management.

160

Note: Out-of-town members who can schedule their New York arrival for Sunday, May 5, are more apt to get immediate room assignment on this date than if arrival is on Monday, May 6.

The following per diem room rates, European plan, are extended to SMPE members and guests when booking accommodations direct with the Hotel Pennsylvania:

Room with bath, one person..........$3.85, $4.40, $4.95, $5.50, $6.05, $6.60
Room with bath, 2 persons, double bed.......$5.50, $6.05, $6.60, $7.15, $7.70
Room with bath, 2 persons, twin beds........$6.60, $7.15, $7.70, $8.25, $8.80
Parlor suits for one or 2 persons............$10.00, $11.00, $13.00, and $18.00

REGISTRATION

The Conference registration headquarters will be located on the 18th floor of the hotel adjacent to the *Salle Moderne*, where all business and technical sessions will be held during the 5-day Conference. Members and guests are expected to register. The fee is used to defray Conference expenses.

TECHNICAL SESSIONS

SMPE members and others contemplating presentation of papers at this Technical Conference can greatly assist the Papers Committee in the early assembly of the program by mailing in title and author of papers together with an abstract by April 1, 1946. Complete manuscripts should be sent to the Chairman or Vice-Chairman of the Papers Committee not later than April 15.

Only through your earnest cooperation will it be possible to draft and announce the papers program prior to the opening of the Conference.

SMPE GET-TOGETHER LUNCHEON

The Society will again hold its regular pre-war social functions, and accordingly a Get-Together Luncheon is scheduled in the *Penn Top* (formerly the *Roof Garden*) on the 18th floor of the hotel, on Monday, May 6, at 12:30 P.M. Ladies are invited to attend this luncheon. Tickets must be procured at the registration desk prior to noon on May 6, so that adequate hotel accommodations may be provided accordingly.

The Board of Governors cordially invites the holders of Dinner-Dance tickets to spend a social hour with the Board in the hotel *Georgian Room* between 7:15 P.M. and 8:15 P.M., on May 8, preceding the Conference dinner. (Refreshments.)

The informal Dinner-Dance (dress optional) will be held in the *Georgian Room* promptly at 8:30 P.M., on May 8. Dancing until 1:30 A.M.

Note: It is imperative that Dinner-Dance tickets be procured and table reservations made at the registration headquarters prior to noon on May 8. Your earnest co-operation with the Arrangements Committee is requested.

LADIES' PROGRAM

A reception parlor will be provided in the hotel for the ladies' daily get-together and open house. The ladies' entertainment program will be announced later.

MOTION PICTURES AND RECREATION

Conference identification cards issued to registered members and guests will be honored at New York *deluxe* motion picture theaters which will be listed in later issues of the JOURNAL.

Those interested in other entertainment while in New York should consult the hotel information bureau, or the SMPE registration headquarters.

Technical Sessions Scheduled

Monday, May 6, 1946

Open Morning.

9:30 a.m. *Hotel, 18th Floor:* Registration. Advance sale of Luncheon and Dinner-Dance tickets.

12:30 p.m. *Hotel Penn Top:* (formerly *Roof Garden*), *18th Floor:* **Get-Together Luncheon.** (Eminent Speakers.) *Note:* Luncheon tickets must be procured before noon on May 6, at the registration desk.

2:00 p.m. *Salle Moderne:* Opening session of the Conference. Business and Technical Session.

8:00 p.m. *Salle Moderne:* Evening Session.

Tuesday, May 7, 1946

9:00 a.m. *Hotel, 18th Floor:* Registration. Advance sale of Dinner-Dance tickets.

9:30 a.m. *Salle Moderne:* Morning Session.

2:00 p.m. *Salle Moderne:* Afternoon Session.
Open Evening.

Wednesday, May 8, 1946

Open Morning.

10:00 a.m. *Hotel, 18th Floor:* Registration. Advance sale of Dinner-Dance tickets.

2:00 p.m. *Salle Moderne:* Afternoon Session.

7:15 p.m. *Georgian Room* (Reception Foyer): A social hour with your Board of Governors preceding the Dinner-Dance. (Refreshments.)

8:30 p.m. *Georgian Room:* Fifty-Ninth Semi-Annual Technical Conference Dinner-Dance. Social get-together, entertainment, and dancing until 1:30 A.M.

Note: Tickets must be procured and tables reserved prior to noon on May 8, for this function.

Thursday, May 9, 1946

Open Morning.

2:00 p.m. *Salle Moderne:* Afternoon Session.

8:00 p.m. *Salle Moderne:* Evening Session.

Friday, May 10, 1946

9:30 a.m.   *Salle Moderne:* **Morning Session.**
2:00 p.m.   *Salle Moderne:* **Afternoon Session.**   Adjournment of the Fifty-Ninth Semi-Annual Technical Conference.

Note: All sessions during the 5-day Conference will open with an interesting 35-mm motion picture short.

IMPORTANT

Those desiring hotel rooms *must* book their accommodations *direct* with the Hotel Pennsylvania management prior to *April 20*, which are subject to cancellation prior to May 1.

Owing to the acute travel conditions, it is imperative that out-of-town members and guests who contemplate attending the May Technical Conference consult their local railroad passenger agent regarding rail and Pullman accommodations, within the existing Pullman reservation period.

W. C. KUNZMANN
Convention Vice-President

SOCIETY ANNOUNCEMENTS

ATLANTIC COAST SECTION MEETING

The first meeting in 1946 of the Atlantic Coast Section of the Society was held on January 16 when Rollin W. King and Emmanuel Berlant discussed the Robotron camera. Mr. King dealt with the scope of the equipment as it relates to medical, dental, and scientific photographic records. Mr. Berlant described the engineering aspects of the camera.

"Specialty photographic equipment usually found on the market is either too cumbersome or difficult to operate," Mr. King said, "and generally requires an operator with photographic background and considerable experience. Therefore, many photographic records are not made that would be of great value in the various professions. Most equipment used in the professional fields—medical, dental, scientific, *etc.*—has been adapted from commercial or amateur models, which often prove inflexible. The Robotron camera was designed to fill the requirements of these specific fields."

Mr. Berlant described the engineering development of the camera, designed for use by the government during the war. "It combines in one lightweight unit a self-contained high-speed vapor discharge flash tube, with complete automatic operation. It is necessary only to focus and frame the picture, all settings for shutter speed, diaphragm stop, *etc.*, being eliminated," Mr. Berlant said.

Swinging Into Step, a 16-mm motion picture furnished through the courtesy of the Army Pictorial Service, opened the meeting held at the Hotel Pennsylvania, New York.

PACIFIC COAST SECTION

The Pacific Coast Section of the Society opened its 1946 series of programs with a meeting on January 22 at which W. Bradford Shank, of the Federation of Atomic Scientists, spoke on "Atomic Energy and Civilization." The speaker's highly interesting presentation was followed by an open forum in which questions from the audience on all phases of the subject were discussed.

The meeting, held in the ERPI Review Room, opened with a showing of the Army Air Forces motion picture, *The Last Bomb*.

We are grieved to announce the death of William B. Bamford, Associate member of the Society, on April 10, 1945, in Belmar, New Jersey.

MEMBERS LOST SERVING THEIR COUNTRY

The Society desires to compile a list of members who gave their lives while serving with the Armed Forces of their country. Such a list will include members abroad who served with Allied military forces as well as those in the services of the United States.

The general office of the Society is not always advised of deceased members, and it will be appreciated if readers of the Journal will forward the name of any member known to them to have been a war casualty. Please include with names submitted the approximate date, place, and any other information available.

Your co-operation will assist the general office in obtaining a complete and accurate list for the records of the Society.

EMPLOYMENT SERVICE
POSITIONS OPEN

Designer and engineer experienced in optics, lighting, and microphotography, capable of designing microfilm reading equipment and products related to microfilm industry. Reply to Microstat Corporation, 18 West 48th St., New York 19, N.Y.

Position available for Optical Designer, capable of handling the calculation and correction of aberrations in photographic and projection lens systems. Junior designers or engineers will be considered. Write fully giving education, experience, and other qualifications to Director of Personnel, Bell and Howell Company, 7100 McCormick Road, Chicago 45, Ill.

POSITIONS WANTED

Sound recording engineer, 16- or 35-mm equipment, studio or location work, single or double system. Free to travel. For details write J. J. K., 354 Ninth Ave., New York 1, N.Y.

Honorably discharged veteran with 15 years' experience in all phases of motion picture production, including film editing, directing, producing. For details write F. A., 30-71 34th St., Long Island City 3, N.Y. Telephone AStoria 8-0714.

Projectionist-newsreel editor with 15 years' experience just released from service. Willing to locate anywhere. Write P. O. Box 152, Hampden Station, Baltimore 11, Maryland.

Newsreel cameraman, overseas U. S. Army veteran with honorable discharge, desires position with educational or commercial organization with work-training arrangement. Will supply prints on Army work in ETO. For full references, experience, and record, write Tom J. Maloney, 406 Oak St., Ishpeming, Mich.

SOCIETY of MOTION PICTURE ENGINEERS

HOTEL PENNSYLVANIA • NEW YORK 1, N·Y· • TEL. PENN. 6 0620

APPLICATION FOR MEMBERSHIP

(This page should be completely filled out by applicant in conformity with Qualifications and Requirements given on the opposite page for grade desired. References given should be members or nonmembers who will supply information on applicant's experience and serve as sponsors.)

Name_____Age_____

Address_____

City_____

Employer_____

Occupation_____

Grade Desired: Associate ☐ ;   Active ☐

Education*_____

_____

_____

Record of Employment* (list companies, years, and positions held)_____

_____

_____

_____

Other Activities*_____

_____

_____

REFERENCES

(Name)	(Address)	(City)
1		
2		
3		

The undersigned certifies that the statements contained in this application are correct, and agrees, if elected to membership, that he will be governed by the Society's Constitution and By-Laws so long as his connection with the Society continues.

Date_____19_____   (Sgd)_____

* If necessary, use additional sheet to give complete record.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

CONTENTS

AN APPLICATION OF DIRECT-POSITIVE SOUND TRACK IN 16-MM RELEASE PROCESSING BY DUPLICATION METHOD*

G. C. MISENER AND G. LEWIN**

Summary.—*When dupe negatives are employed to make large releases on 16-mm positive, 3 successive printing operations are normally involved in arriving at the release print. That is, the master positive, dupe negative, and release print are made in order. Since each printing operation is attended by some degree of quality degeneration, it is desirable to reduce the operations to a minimum.*

In the application described, the first printing is eliminated by rerecording to direct positive on 16-mm film. The amplifier channel feeding the direct-positive recorder is suitably equalized and compressed for 16-mm projection conditions, and bridges the channel used to make the normal rerecorded negative for 35-mm release. A 32-mm release negative is then made on a nonslip printer from the 16-mm direct positive.

Introduction.—The 16-mm release prints of most Signal Corps films have been made by a laboratory which employs the dual 32-mm dupe negative process in making volume release. The usual procedure, when working from a 35-mm rerecorded negative, is to make a 35-mm fine-grain master positive, reduce the fine-grain master to 2 tracks on the 32-mm dupe negative, and release print on 32-mm positive stock which is subsequently slit. Each of the 3 printing and developing operations thus involved contributes some degree of image deterioration. Close control of each operation is necessary in order to avoid cumulative errors in sensitometric conditions or printing quality, which might lead to serious distortion and poor intelligibility in the final print. Moreover, a troublesome amount of noise may result from the handling involved in each stage of the process, particularly that caused by foreign material and abrasion.

It might reasonably be suggested that the most satisfactory method

---

* Presented Oct. 16, 1946, at the Technical Conference in New York.

* * Signal Corps Photographic Center, Long Island City, N. Y.

of eliminating certain of these printing steps would be to extend the application of rerecording. That is, it would be possible to rerecord directly to the 32-mm release negative simultaneously with the making of the 35-mm rerecorded negative, through a parallel channel arrangement. Another possibility would be to rerecord "electric dupes" from a nonslip print of the 35-mm rerecorded negative, as is common practice in making 35-mm release.

These solutions to the problem were not feasible, however, since a special recorder for the 32-mm stock was unavailable. This being the case, use of a direct-positive[1] recorder, to permit rerecording directly to the fine-grain master positive, suggested itself. This would not only eliminate one stage of printing and developing, but would also afford the opportunity to introduce equalization and compression in the 16-mm rerecording channel suitable for 16-mm projection conditions. The latter was a most important consideration as has been established by experience in recent years.[2, 3]

In the cases of films which will have both 35-mm and 16-mm release, the previous practice at the Signal Corps Photographic Center has been to make only one rerecorded negative, using frequency and compression characteristics, which represented compromises between the optima for 35-mm and 16-mm release. Lack of sufficient equipment, as well as time and film economy considerations, precluded making two 35-mm rerecorded negatives, with special characteristics for the 2 classes of release.

Equipment.—A 16-mm recorder was selected for conversion to the direct-positive arrangement, a unit capable of high-quality performance being on hand. Use of 16-mm stock would also affect an economy in raw stock. The recorder, a Maurer Model *D*, was converted by the manufacturer to make direct-positive variable-area track of the bilateral type. An unmodulated bias line of approximately 5 mils is normally used. The conversion included, of course, modification of the galvanometer to expose track of standard print width and placement.

The recording and noise-reduction amplifiers used with the recorder are standard Maurer units, Models *120-B* and *130-A*, respectively. Along with the amplifier and recording lamp supply, they are mounted semipermanently on a rack near the recorder. A Maurer 16-mm film phonograph is located on the same bench with the recorder, as shown in Fig. 1. Since the recorder and film phonograph are equipped with 1800 rpm synchronous motors permanently at-

tached, interlock operation was provided for by coupling interlock motors to the shafts of the synchronous motors with bonded rubber couplings.   The interlock motors are camera type with the gear reduction modified for 2400 to 1800 rpm operation.

The electrical arrangement of the complete 16-mm channel and its relation to the 35-mm channel are indicated in the block schematic of Fig. 2.   Mounted on the racks of one of the 35-mm rerecording channels are the components which complete the 16-mm channel. This section of the 16-mm channel consists of a bridging coil, a vari-

FIG. 1.   Layout of 16-mm equipment.

able T-pad, an RCA *MI-10206-C* electric mixer or compressor, an *MI-10108* variable high-pass filter and a variable compression ceiling control pad.   The setting of the latter affects the amount of compression realized, once the recording amplifier gain has been set at a suitable fixed value.   The channel components appear on patch bay jacks and are normalled together.   Thus, to set up for parallel recordings on 35-mm negative and 16-mm direct positive, it is merely necessary to patch the bridging coil across the bridging buss of a 35-mm channel.   The *MI-10206-C* compressor has an attack time of approximately 0.001 sec, and is adjusted for a compression rate of approximately 2:1.

Experience has shown that it is generally good practice to compress the over-all signal, with the volume range reduced to as little as 15 db for 16-mm projection conditions.[2,3]   The intelligibility of speech, especially the low level passages, is enhanced, and low level music and effects are made audible above ambient projection room noise.   Perhaps the one undesirable result is that high level music and high level effects, such as gunfire and bomb explosions, are held down, whereas the effects, at least, might normally be permitted to overshoot the modulator considerably.   The *MI-10108* high-pass filter is adjustable to sharp cutoff positions at 80, 100, 120, 135, and 150 cycles, and has an off or flat position.
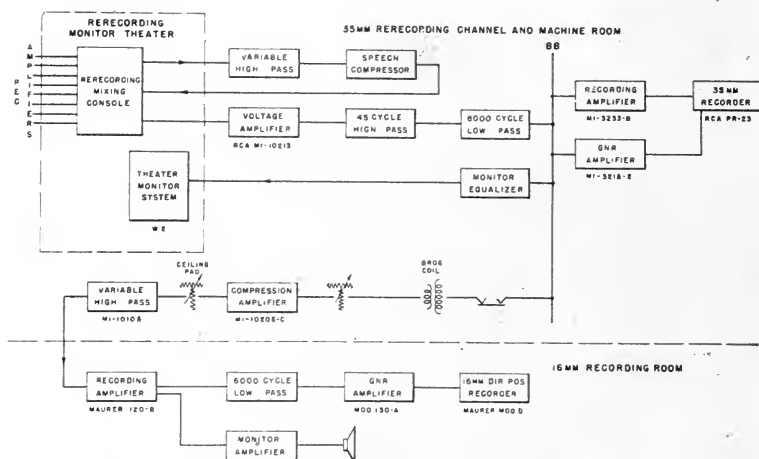
FIG. 2.   Block schematic of parallel recording arrangement.

Recording Characteristics.—Comparison listening tests, made with standard issue 16-mm projection equipment set up in a fairly large room, have indicated that the low-frequency cutoff may well be in the range of 100 to 120 cycles.   This cutoff reduces masking of intelligibility by the reverberation of reproduced low frequencies, without seriously affecting the content of low frequencies in music and effects.   It was found that the high-frequency cutoff could be as low as 5000 cycles without appreciable detriment to the quality of reproduction.   A low cutoff frequency was favored, since it would exclude the higher frequencies which would require more critical control of sensitometric conditions and printing quality to minimize cross-modulation or envelope distortion.

The listening tests also indicated a satisfactory amount of compression to be 14 db into 7 db.   That is, the ceiling control is so adjusted that the 14-db range of input immediately below the 100 per cent modulation level is compressed into 7 db.   The compressor input pad is adjusted so that average peaks modulate between 80 per cent and 100 per cent on the 16-mm track.   Hence, the top 25 db of volume range on the 35-mm dubbing prints are compressed into approximately 18 db on the 16-mm direct positive.   This means that even the lower levels of signal will produce at least 10 per cent modulation on the 16-mm track, insuring a satisfactory signal-to-noise ratio.
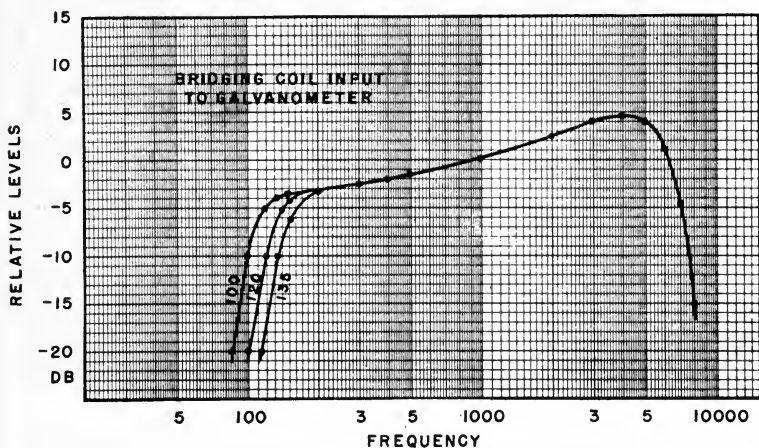
FIG. 3.   Frequency characteristic of 16-mm channel.

The voice modulation will be maintained at a particularly good level since, as we noted in the schematic, a compressor is also employed in the speech position of the rerecording console, ahead of the point bridged by the 16-mm channel.   The mixer bases his determination of the compression used in the speech position on his judgment of the 35-mm channel monitor quality.   In the instances of original narration tracks recorded with 20 into 10 compression, little, if any, compression is applied in recording.   As much as 20 into 10 is used if the original track has no compression.

The frequency characteristic of the 16-mm recording channel, from bridging coil input to galvanometer input, for 3 positions of the high-pass filter, is shown in Fig. 3.   The response of the galvanometer is

essentially flat over the recording range covered. The rise shown in the high-frequency region results from the film loss equalization in the recording amplifier. The combination of this equalization with the low-pass filter leaves a broad peak in the range which contributes most to intelligibility, namely, 2500 to 5000 cycles. However, the rise in this range is sufficient to provide the desired film loss and intelligibility equalization only when combined with the film loss equalization in the photocell amplifiers of the 35-mm rerecording channel. The over-all characteristic from 35-mm photocell amplifier input to
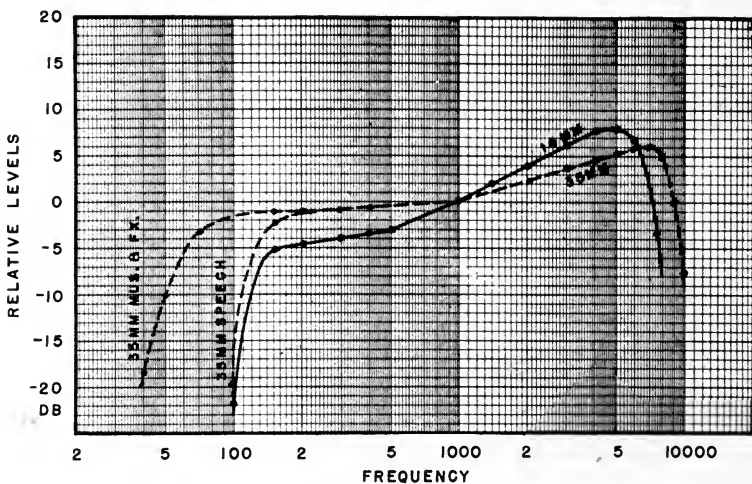
FIG. 4.   Over-all 35-mm and 16-mm recording characteristics;   photocell amplifier input to modulators.

both 35-mm and 16-mm rerecording busses is shown in Fig. 4. As indicated, a relatively extended frequency range is used for the 35-mm release, with the low-frequency cutoff at 45 cycles for music and effects, and approximately 100 cycles for speech. The low-pass filter is usually set at 8000 cycles.

Although provision has not yet been made to allow the mixer to switch his monitor to the 16-mm channel for quality checks, the generally fixed relationship between the 35-mm and 16-mm recording characteristics rather obviates the necessity for such an arrangement. Moreover, the contrast in monitor quality between the 2 channels might tend to affect the mixer's critical evaluation of the 35-mm characteristic. A good quality monitor speaker is provided in the

16-mm machine room, and since this room is acoustically treated and the recorder is quiet in operation, the recordist is able to detect abnormal quality in the 16-mm channel.

Film Characteristics.—In order to compare the film losses involved in the 2 methods of duplication, a frequency run was recorded on both the 35-mm and 16-mm machines. The 35-mm negative and 16-mm direct positive thus obtained were used as the originals in the processes of duplicating and printing. The resulting equivalents of release prints, as well as the originals, were measured on soundheads which are capable of giving reliable modulation level indications at
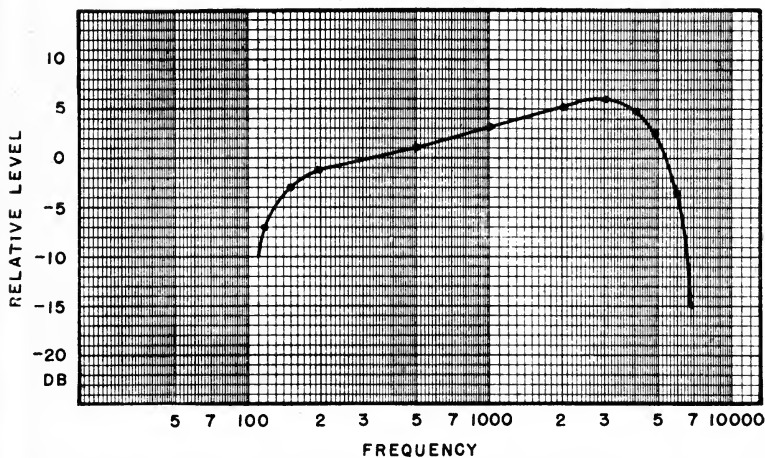
FIG. 5. Over-all system and film characteristic as measured on 16-mm release print.

the higher frequencies. In each case, calibrated frequency test films were also measured in order to determine and deduct the losses of the soundheads and their associated systems, and thereby obtain the actual characteristics of the films in question.

It was found that the printing losses sustained in the direct positive to release print process were somewhat less than those incurred in the old procedure involving 3 printing operations. For example, approximately 2-db improvement at 6000 cps was noted for the direct-positive method, while at 4000 cps the difference was one db.

The image losses in the 2 originals were also determined. This was done by comparing the effective modulation values obtained on the soundheads with the impressed amplitudes on the tracks as meas-

ured with a microscope.   The 16-mm direct positive has somewhat greater image loss, as might be expected, since, for example, 6000 cycles on 16-mm track is the equivalent in image width of 15,000 cycles on 35-mm film.   The 6000-cycle loss of the 35-mm negative was found to be less by approximately 2.5 db.   Thus, it is seen that the total film losses for the 2 methods, from modulator to effective release print modulation, are about equal, the lower image loss in the 35-mm negative approximating the lower printing losses in the direct-positive process.
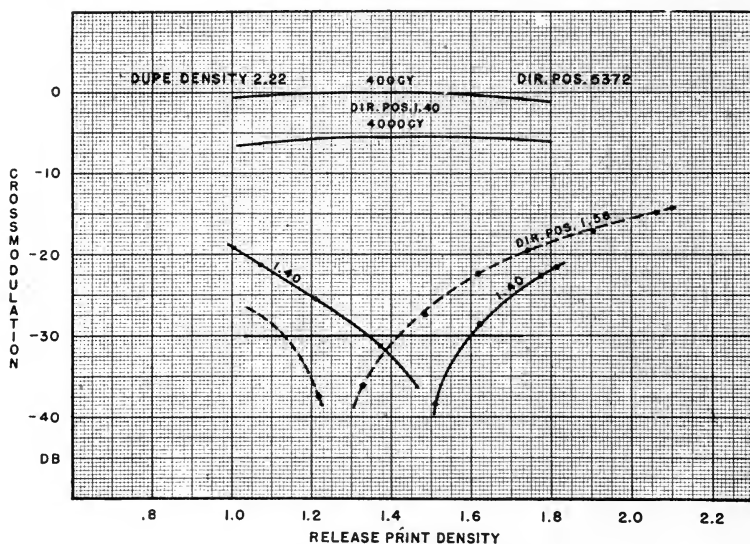
FIG. 6.   Cross-modulation of release prints.

It is emphasized at this point that consideration of the average relative film losses, particularly since they are essentially equal, is of secondary importance.   Elimination of the possible variations, image

TABLE 1

Sensitometric Conditions

	Stock	Total Density	Base Plus Fog	Density Latitude	Gamma
16-Mm Direct Positive	5372	1.40	0.28	...	2.30
32-Mm Dupe Negative	5302	2.22	0.40*	...	2.60
16-Mm Release Print	5302	1.48	0.04*	1.35–1.60	2.60

* Includes print-through.

losses, and handling effects in a stage of printing and processing, is the more important consideration.

An actual over-all frequency characteristic realized under normal operating conditions, *i. e.*, the photocell amplifier input to effective 16-mm release print modulation characteristic, is shown in Fig. 5.

Sensitometric Conditions.—The stock used for the 16-mm direct-positive recording is Eastman Type *5372*, a high contrast fine-grain emulsion on blue base. The characteristics of this film have been described in the JOURNAL previously.[4] A blue filter, Jena No. *BG12*, is
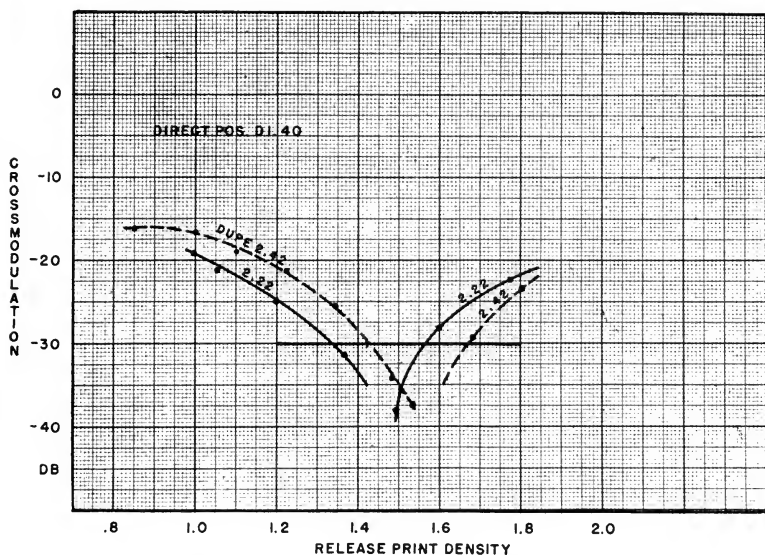
FIG. 7   Cross-modulation of release prints.

employed in the recorder to enhance image resolution. The laboratory makes the 32-mm dupe sound negatives on fine-grain positive stock with a nonslip printer and *UV* exposure. The release prints are made on sprocket-type printers, using fine-grain positive stock and white-light exposure. A set of sensitometric conditions which gives satisfactory results is tabulated in Table 1. Other combinations of dupe negative and release print densities will also give good results, as will be seen in Fig. 6. The optimum sensitometric conditions were determined by making cross-modulation tests and plotting the results against various density parameters. A 4000-

cycle carrier, amplitude modulated approximately 75 per cent at a 400-cycle rate, was used as the test signal in these investigations.

Although there would ordinarily be no occasion to reproduce the direct-positive itself on a soundhead, its cross-modulation cancellation was found to be approximately 20 db at the total density value of 1.40, or a silver density of 1.12. Still greater cancellation is attained at lower but less practical density values. While the density contrast of the dupe negative, which is printed from the low-density
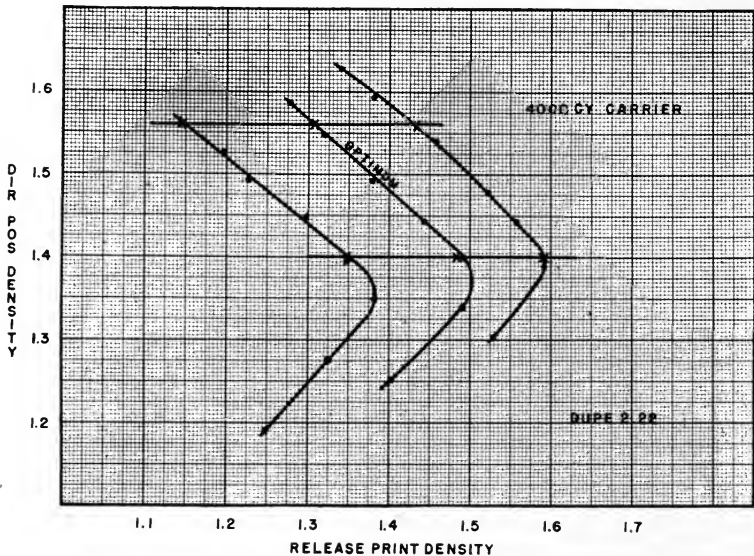
FIG. 8. Density tolerance for 30 db cross-modulation cancellation.

direct positive with its blue base, is not as high as might seem desirable, the density contrast and effective modulation of the release print are good. In fact, higher values of release print density are indicated for this method than is the case when duping from the regular 35-mm rerecorded negative. At the same time the clear area density is only about 0.04. The data of Table 2 demonstrate that the effective release print modulation level is good over a range of workable sensitometric conditions.

The family of curves in Fig. 7 represents the cross-modulation results obtained when printing dupe negatives of D2.22 and D2.42 to a range of release print densities. Essentially, the same data are

plotted in another form in Fig. 8 to show the density tolerances in the direct-positive and release prints, for dupe density of 2.22. It will be noted that reasonable ranges of densities give satisfactorily low cross-modulation.

TABLE 2

Effective Modulation Level at 400 Cycles for Dupe Negative Density of 2.22

	Density	Reproduced Level
Direct Positive	1.40	−2.0
Direct Positive	1.56	−2.0
Release Print	1.48	0.0
Release Print	1.30	0.0
Z52.8 Test Film	. . .	0.0

All 3 sound tracks have same amplitude.

REFERENCES

[1] DIMMICK, G. L., AND BLANEY, A. C.: "A Direct-Positive System of Sound Recording," *J. Soc. Mot. Pict. Eng.*, **XXXIII,** 5 (Nov., 1939), p. 479.

[2] BRIGANDI, P. E.: "Rerecording 35-Mm Entertainment Films for 16-Mm Armed Forces Release," *J. Soc. Mot. Pict. Eng.*, **44,** 1 (Jan., 1945), p. 18. (Including appended discussion by E. M. Honan.)

[3] MILLER, W. C.: "Preliminary Report of Academy Research Council Committee on Rerecording Methods for 16-Mm Release of 35-Mm Features," *J. Soc. Mot. Pict. Eng.*, **45,** 2 (Aug., 1945), p. 135.

[4] O'DEA, D.: "Comparison of Variable-Area Sound Recording Films," *J. Soc. Mot. Pict. Eng.*, **45,** 1 (July, 1945), p. 1.

THE WARTIME RECORD AND POST-WAR FUTURE OF PROJECTION AND SOUND EQUIPMENT*

ALLEN G. SMITH**

Summary.—*This paper is a case history of the manufacture and distribution of 35-mm motion picture projection and sound equipment under wartime restrictions as imposed by War Production Board regulations. It tells about the difficulties and problems which were encountered and overcome so that the Armed Forces might obtain all of the equipment needed, with a limited quantity for our civilian theaters. The paper also discusses the reasons why our manufacturers cannot now produce as much new equipment as will be needed for replacements, and makes recommendations for future planning.*

Every person in the motion picture industry will remember the uncertain status of all manufacturers and distributors of projection and sound equipment, repair parts, and accessories soon after the Pearl Harbor disaster. We had a war on our hands.

The War Production Board in Washington, D. C., was the one war agency charged with the responsibility of conserving vital materials, labor, and plant facilities so that the Armed Forces could have full and uninterrupted access to the productive capacities of every industry. Motion picture projection and sound equipment, like many other commodities so necessary to our commercial and industrial development, quickly became a wartime casualty. Certain conservation and limitation orders issued by the War Production Board prohibited the manufacture of projection and sound equipment except that which was needed to fill orders for the Armed Forces.

At the beginning of World War II our military minds worked quickly and thoroughly to overcome the difficult problems of training the staggering number of men needed for combat duty. They did not have enough skilled instructors available for the training of such large forces of men who were inducted into the different armed services. Naturally, their attention was drawn to the use of motion

---

* * National Theater Supply, New York; formerly Chief, Theater Equipment Section, War Production Board, Washington, D. C.

picture projection and sound equipment, from which was created many ingenious synthetic training devices.

Some of our manufacturers were called upon to work with the Ordnance Department of the U. S. Army, and the Department of Special Devices, Bureau of Aeronautics of the U. S. Navy, in the development of many different types of synthetic training devices through the use of the standard types of equipment which each manufactured. These amazing devices, after having been put into use in the training programs, saved millions of dollars in ammunition and guns and countless lives in the vigorous training campaigns.

The Armed Forces needed standard types of equipment for other training purposes. Army training centers and Navy shore stations were provided with equipment for specialized training courses in all phases of military activity. The equipment was also used for the showing of films produced especially for the Medical Corps illustrating proper surgical, first aid, and other techniques. Aside from the technical uses of the equipment, motion pictures were the only form of entertainment available in many military installation and training centers. They had a morale job to take care of and "movies" played a most important part.

The reputation of our manufacturers for the production of precision parts spread to the Army and Navy material procurement staffs. The Army and Navy could not produce in their own plants the precision equipment and instruments required. Consequently, they had to turn to plants with known reputations for the production of precision equipment. The production of motion picture equipment for the most part requires precision manufacturing within tolerances of $1/10,000$ of one inch and many manufacturers were given contracts for certain high precision combat instruments.

This meant expansion of plant facilities, the installation of new and intricate machine tools, and the training of operators to handle the tools. And yet, we could not stop production of our standard types of sound and projection equipment because the Armed Forces also needed that class of equipment.

Industry manufacturers had a difficult problem to crack in getting as much equipment as required because of the high priority war work they were doing on direct war material. It then became the job of the War Production Board to correlate the activities of all the manufacturers of projection and sound equipment into one co-ordinated function. If the Armed Forces needed projection and sound equip-

ment, they needed it complete in every detail, even though many of the different units were being manufactured in different plants in many different cities. Their program could not be carried out if everything was ready for installation except the lamp houses, or the sound system, or even a pair of lenses. Everything had to be delivered on time. The War Production Board scheduled the production of every unit of equipment needed by the Armed Forces in such a manner that all units arrived at their destination on time, notwithstanding that the manufacturing cycle extended from 3 months on lamp houses to 12 months for sound equipment.

Because of the demands of the military on the productive capacities of the equipment manufacturers for their normal product and military items, the motion picture industry faced a tremendous task in keeping its theaters in operation. The production of almost every item of equipment needed had been stopped, including projection and sound equipment, *etc.* Repair parts for sound and projection equipment could not be purchased because production of them had likewise been stopped.

What could be done to relieve the distress of the motion picture industry? The answer could not be readily reached because all of our industrial resources were geared to war production. We hardly dared to suggest a solution which, in any manner, might interfere with the delivery of military goods. Yet, here was an industry which by its limitless energy was selling more war bonds, collecting more money for the Red Cross, and doing a bigger job of prosecuting the war effort generally than any other single industry. Copper, rubber, paper, tin, and aluminum were collected. Millions of dollars were spent through the War Activities Committee to make each co-operating venture a success from which the only return was the satisfaction that the industry was doing its level best to help win a war. These accomplishments could not be continued unless the theaters could continue to operate. They needed repair parts, accessories, and a limited amount of new equipment to make the more urgent replacements of equipment which could no longer be economically repaired or efficiently maintained.

The industry tightened its belt and learned for the first time the true meaning of maintenance, improvising, and substituting. Theaters patched and reversed their carpets, spent countless hours welding and nursing their auditorium seats. Some of their customers steamed and sweated in the summer because air-conditioning plants could not

be repaired or Freon was not available. Some patrons practically froze in their seats for two winters because fuel was not available, or the heating plant could not be repaired. But the industry operated just the same because it still had pictures on the screen and they did talk!

The supply dealer soon became the theater owners' best friend and confidant because he still had a few repair parts and a little new equipment on hand in the early months of the war. If he did not have the necessary parts, he would rush emergency equipment to the theater. The supply dealer was his own rationing board so far as his rapidly dwindling stockpile of new equipment was concerned, and he parceled out that new equipment only when its installation became the factor between closing down or continuing to operate a theater. He took pride in his part of the job, in return for which he received the overwhelming thanks of the theater owner.

By April, 1942, the importance of the motion picture was firmly established with the top officials in Washington. The War Activities Committee of the Motion Picture Industry had been organized, the leadership of which was vested in the biggest and most resourceful men in our business. They brought the efforts of the industry to the attention of men like WPB's Donald Nelson, Secretary of the Treasury, Henry Morgenthau, Jr., and Secretary of Commerce, Jesse Jones. President Roosevelt knew what was happening in our business. The industry received immediate recognition of its efforts and the Amusement Section of the War Production Board was subsequently established, later changed to the Theater Equipment Section.

In August, 1942, R. J. O'Donnell of the War Activities Committee asked me to accept an appointment to the War Production Board as a Consultant on problems relating to the production and distribution of motion picture equipment in general, which appointment was accepted with humility and a deep sense of responsibility.

Our immediate problem was the production of repair parts for projection and sound equipment. In October, 1942, the Iron and Steel Order and the Copper Order were each amended to provide for the production of repair parts. Priority regulations, however, made it necessary at that time for theater owners to furnish their supply dealer with a priority rating for delivery of a part. We needed accessories, such as rewinders, reels, change-over devices, film cabinets, *etc.* We needed a limitation order which would permit the production of repair parts and accessories, and which could be carried in

stock by supply dealers and sold without priority ratings.   We needed a WPB instrument by which we could schedule production and regulate distribution of a limited quantity of new equipment then urgently needed to replace worn-out or burned-out equipment.

Because of these circumstances, the WPB deemed it desirable and necessary that jurisdiction over the sound and projection equipment industry should be placed in one Industry Division, and that control over the production and distribution of projection and sound equipment be co-ordinated into one limitation order.   Therefore, Limitation Order *L-325* was prepared and issued so that the necessary demands of the Armed Forces and of the civilian theaters might be met, and yet to provide that there shall be no interference in the production of actual war goods.

Under the terms of that order enough new equipment was scheduled for manufacture to make urgent replacements in civilian theaters. Dealers' stocks of repair parts and accessories were gradually replenished and sold without restrictions.

The credit for the orderly and continued operation of the motion picture theaters belongs to no one individual.   The success of our business during the war years can be attributed to a combination of ideals and ideas contributed by the War Activities Committee, the manufacturers and distributors of projection and sound equipment, the Society of Motion Picture Engineers, the projectionists, the officials of the War Production Board, and countless others.

Now that the war is over doubtlessly most of us face the immediate future production of sound and projection equipment with undue optimism.   There are 17,000 theaters in the United States, which figure represents only a small percentage of the theaters in the world. Our manufacturers must not only now plan to produce enough new equipment to meet a pent-up demand in the United States of 4 years, but they will also be called upon to fill orders for equipment to rehabilitate theaters in bombed-out areas and for thousands of new and modern theaters which will be built in nearly every foreign country in the world.

Naturally, our manufacturers will build equipment to fill domestic orders first, at least enough to make the immediate and urgently needed replacements, and for new installations.   Some new equipment will be exported because it is good for our business to have American made projection and sound equipment in use in foreign theaters.   Our manufacturers must protect their foreign markets.

It may also be expected that some of the better used equipment which is replaced by new equipment in the United States will be rebuilt and restored for export, thereby making more new equipment available for domestic installations.

If we look at cold and practical figures, we get a startling picture of the job our manufacturers face. We require in the United States annually approximately 4500 standard projectors, 2250 standard sound systems, 6200 arc lamps, 4500 rectifiers, and 1000 motor-generator sets. We also need nearly 1500 of the portable types of 35-mm sound projectors. Multiply these figures by the pent-up demand of 4 years, and we have a need in the United States for 18,000 projectors, 9000 sound systems, 24,800 arc lamps, 18,000 rectifiers, and 4000 motor-generator sets.   We will need 6000 of the portable types of sound projectors. Only approximately 50 per cent of one year's production has been manufactured under wartime restrictions for non-military uses since 1942, and considerably fewer motor-generator sets were produced since 1942.

How can our manufacturers meet this demand for new equipment within a reasonable length of time? It is not an easy job for several reasons. Before the war, when materials and components flowed freely, the production cycle ranged from 3 to 10 months, depending on the class of equipment produced. That can be cut in the near future because new and better machine tools will be available. Our manufacturers have the "know-how" of mass production of precision instruments, a technique acquired during the war years.

The time when our manufacturers will be delivering equipment in large quantities will depend greatly upon the availability of parts and components which they must buy elsewhere. They now must wait for other manufacturers to convert their facilities to meet our own specifications for such necessary parts as ball bearings, fractional horsepower motors, indicating meters, a host of electronic parts, switches, *etc.* Foundries must be geared to make the precision castings we now need. Lumber in large quantities will be needed for shipping boxes. It will take time to train the additional skilled labor needed for such expanded production.

Theater owners should consult their supply dealers and evaluate their equipment requirements now. The dealer was most helpful during the war years, and you may need his friendly co-operation and expert advice now more than ever. He might suggest the installation of a third projection unit, an emergency rectifier, or motor-generator

set, or dual amplification for your sound system. The demand for so much new sound and projection equipment now would not be so great if such installations had been made before the war. It is insurance well worth the additional costs, and theater owners should look forward to the future when new equipment will be available in greater quantities so that such emergency equipment can be purchased.

Until new equipment is generally available to all who need it, we should not relax our efforts to keep in perfect repair the equipment we must continue to use for the time being. The theater patron demands perfect projection and sound, and by continuing to keep our present equipment properly maintained, we reduce the basic causes of dangerous and costly film fires, and thus keep faith with the public.

THE MEASUREMENT AND CONTROL OF DIRT IN MOTION PICTURE PROCESSING LABORATORIES*

N. L. SIMMONS** AND A. C. ROBERTSON†

Summary.—The commonest sources of contamination of motion picture film in processing laboratories are discussed, and suggestions are made for preventing foreign matter finding its way onto the surface of the film. The "tacky-dish" technique and other methods of detection of dirt sources are described, and examples are given of surveys made in actual Hollywood laboratories.

The film handled in processing laboratories can be contaminated by dirt associated with the outside air used in the laboratory, by personnel, by mechanical equipment, or by processing solutions. It has been found that when there are complaints about dirt, etc., a systematic investigation usually reveals the source of the trouble quickly. This is particularly true if quantitative measurements are taken. These data allow one to construct a flow sheet which indicates the place where dirt is entering the system. The new tools used for this purpose are the smoke recorder, the "tacky-dish," and the method of "lifting" samples. The Greenough microscope is a most useful and almost indispensable adjunct.

The choice of air filtration systems and the proper kinds of uniforms are also discussed briefly.

Introduction.—The superior screen quality of present-day film is the result of much care in the processing laboratories. Dirt is an ever-present enemy of screen quality and is one of the main obstacles to further progress now that sensitometric quality has reached such a high level.

The methods of locating and minimizing sources of dirt have been developed to a high degree by the film manufacturers. When one observes what harm can be wrought by "loose dirt" it can be understood that dirt, firmly anchored in wet emulsion, would present a hopeless problem. The dirt control techniques which have been developed by the manufacturers to aid them in the handling of film

---

have been used by some photographic processing laboratory managers to advantage, and more recently, by various war industries. The latter include manufacturers of electrical equipment, radio tubes, and optical devices. The sources of contamination can be:

(1) Outside air which generally carries with it unwanted material in the form of cinders, dust, and smoke.

(2) Personnel, who introduce dirt into the process by reason of their activity and clothing.

(3) Equipment, which may have rust or oil on it, or metal grindings resulting from the wear of moving parts.

(4) Processing solutions, because of sediment, sludge, and scums.

The problem is to learn which sources are dominant.

During the past 2 years, 3 Hollywood laboratory superintendents have requested that a thorough survey of their plants be made with the idea of locating and eliminating the outstanding sources of dirt. In each case, investigation disclosed the existence of unsuspected causes for the presence of dirt on the negative or positive film. Likewise, it was found that the original ideas held by the laboratory superintendents as to the likeliest sources of dirt in their respective plants were not always verified by the survey. Each laboratory took steps to eliminate the specific dirt sources and to improve general conditions. Retests made by the "tacky-dish" and other techniques (to be described later) indicated that the gain in cleanliness of the air was considerable and that the improvement in the product was well worth the effort expended.

Air Filtration.—The drying cabinet of a motion picture developing machine is fundamentally a likely source of dirt on motion picture film, since at this location the emulsion is wet and tacky and is exposed to a large mass of air. For this reason, it is primarily essential that the air used for the drying operation be filtered. It is also of great benefit to cleanse by filtration all air entering the film processing laboratory. In order to facilitate the entrance of clean air only, a slight positive pressure should be maintained inside the laboratory so that open doors, *etc.*, act as clean air exits rather than inlets for uncleaned air.

Air-borne dirt may be classified according to size. The coarsest class includes dust, cinders, and lint-like particles. Smoke is much finer and has many particles smaller than 0.5 mu in size. The coarser dirt particles can be removed from air easily by air washers using sprays of water, or by viscous filters. This latter type includes a host

of appliances which depend for their effect upon the adhesive action of liquids of high viscosity held upon supports of the most diverse sorts.   The objective in designing an air filter of this kind is to produce a support of relatively low air resistance and large area.   The designers have produced many forms of filters in their attempt to meet these requirements.   Among the viscous filter supports commonly used are ones made of crimped wire, folded paper, wire mesh, and glass fibers.

Filter media of the viscous type may be of the "throw-away" variety for small installations, or the permanent cleanable types where there are enough units to justify a cleaning operation and subsequent reoiling.   Where air is used in large volumes for noncritical operations, the "moving-curtain" automatic self-cleaning filter is cheap and effective.   This filter consists of a device which supports and drives an endless curtain which is slowly drawn through a bath of oil held in the base of the filter.   This operation cleans the filter continually and minimizes the need for close attention.   The manufacturers' recommendations should be followed in the installation of viscous air filters since too low an air velocity gives poor efficiency. An air velocity which is too high leads to spraying of oil, and can be very serious.

Filters using bags made of canton flannel have frequently been used in filtering air.   They do a better job of air filtration than viscous filters but they have enough drawbacks so that their installation cannot be generally recommended.   The fabric bags can generate lint when they are improperly installed so that they rub together. In addition, they often dislodge showers of dirt after they have been shutdown temporarily.   Collapsing the bags loosens the dirt, which is free to move when the fans are started.   Filter bags also have the defect that their capacity is badly affected as they remove dirt from the air.   Their resistance often increases very rapidly at the end of their useful life.

Filters made up of bundles or mats of soft crepe paper have been used.   In one form the mats of paper are held in book-like frames of iron mesh which are then assembled in sets of 3 or 5 pairs to form a pocket-type filter.   The pocket units are then assembled into headers in the usual fashion.   Under some circumstances, it seems best to use these filters at lower than recommended face velocity.

Electrostatic filters are more efficient than the foregoing types. They remove most of the smoke in the air, commonly working at an

efficiency above 95 per cent.   Smoke is removed only to the slightest extent by viscous filters, their efficiency in this respect generally being 5–10 per cent.   However, it is not always necessary to remove most of the smoke from air unless one desires to lengthen intervals between duct cleanings.   No air filter is completely efficient, therefore, some smoke remains in the air which has passed through it.
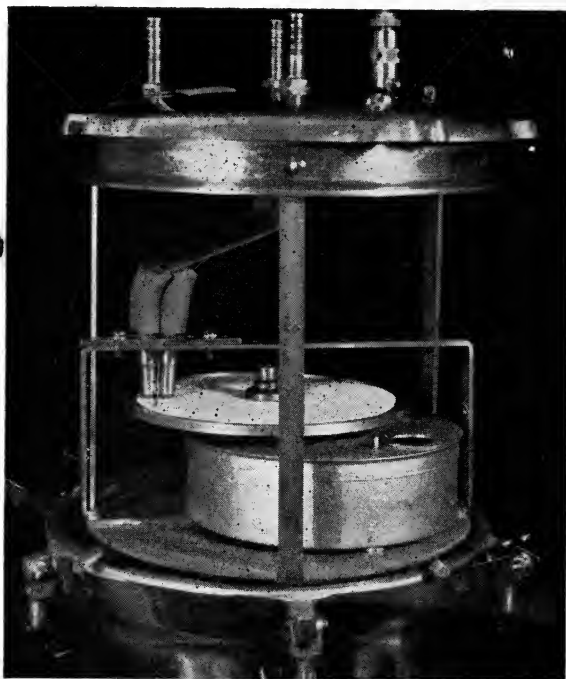
Fig. 1.   Smoke recorder open for examination.

While smoke is made up of particles so small that they settle very slowly indeed by the effect of gravity, nevertheless they do deposit from air.   Such smoke particles, or dirt, are slowly deposited on the walls of the duct by impingement and other causes.   Later, the dirt is dislodged by vibration, or similar disturbances and flies out of the duct in a shower.   Accordingly, it is good practice to place a viscous filter at the end of a long run of pipe in order to stop such showers of dirt.   Smoke caught in electrostatic filters can also be dislodged upon occasion.   Electrostatic filters of the self-cleaning type have the

attractive feature that their efficiency is not badly affected by failure of the high-tension electrical system.

The efficiency of air filters with respect to smoke is measured by a smoke recorder[1] (Fig. 1). The smoke recorder functions on this principle: Dirt is drawn into an evacuated container through a small slit (Fig. 2) and impinges upon a piece of paper moved past the jet by a 24-hr clock. The air stream, which is moving with the speed of sound, deposits the dirt it is carrying upon the paper, where it can later be measured (Figs. 3 and 4). The instrument is quantitative since the jet delivers a constant volume of air as long as the
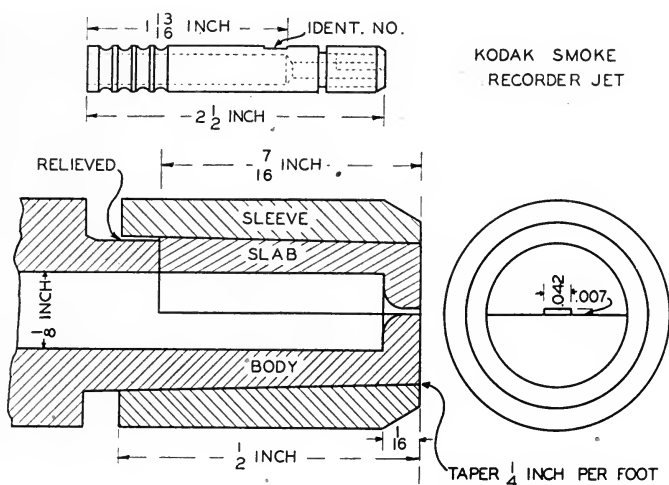
FIG. 2. Jet for smoke recorder.

pressure difference between the 2 sides is greater than 0.53 atmosphere. The 2 dark lines constituting the record are measured. Since one line represents the raw air and the other line the cleaned air, the efficiency of the filter can be calculated from these data.

The instrument is easily portable and makes continuous records. It is of great assistance in studying air filter installations to see if the performance is as good as the design intended. If a departure is observed from the values one would have predicted from laboratory studies, then one must look about. It is often found that there are leaks around the edges of the filter housings, or that the fan is installed on the clean air side of the filter and that leaks in the ducts, *etc.*, allow dirty air to be drawn into the system.

The gravimetric measurement of coarser particles is done according to the practices of the American Society of Heating and Ventilating Engineers by drawing measured samples of air through an alundum crucible filter, which is later weighed in order to learn how much dirt has been collected.   By measuring the dirt concentration in the filtered and unfiltered air, the efficiency of the filters can be computed.

All air ducts should be inspected regularly even when there are filters in the system.   Accumulation of very fine particles on the duct surfaces may give a constant supply of black agglomerates of
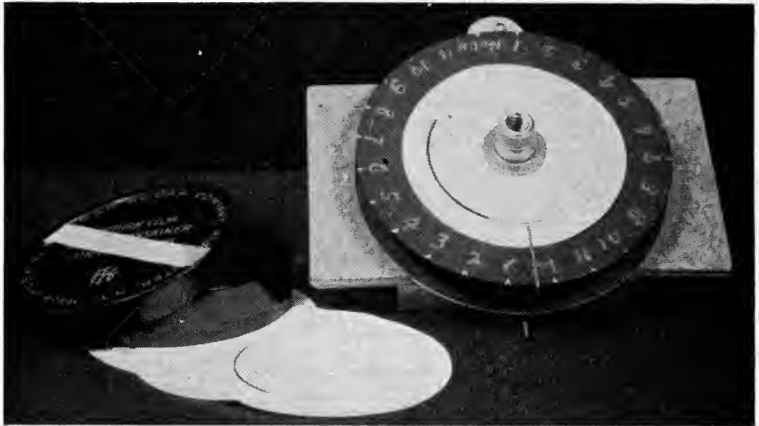
FIG. 3.   Charts on holder for visual examination of dirt traces.

soot and other atmospheric dirt.   This can be avoided by regular cleaning of all ductwork.

The use of conditioned air of from 60 per cent to 70 per cent relative humidity will minimize the pickup of dirt by the film as the static tendency of the film is at a minimum at these conditions.

Contamination from Personnel.—While it is comparatively easy to produce clean, lint-free air, it is difficult in practice to avoid difficulties caused by lint since the clothing and movement of workers continuously produces a steady cloud of fine particles of various sorts unless appropriate steps are taken to prevent the occurrence.   The nature of the process dictates the steps that must be taken.   In film manufacture, the workers have special uniforms adapted to the process involved.   Men working near freshly coated film wear new uni-

forms which are changed daily.   Dandruff is a serious source of con-
tamination, so the uniforms include head coverings which confine the
workers' hair.   Loose particles are prevented thereby from falling on
the work, and the workers are prevented from getting hair, oil, *etc.*,
on their hands and thence on the work.   It has been found that raw
edges or threadbare fabrics are the sources of much lint.   After
certain indications of wear, the uniforms are used in less critical
areas.   These uniforms finally are used by the departmental me-
chanics, whose need for lint-free clothing is not great.

Workers in other departments, such as those where film is proc-

FIG. 4.   Instrument for photoelectric examination of dirt traces.

essed, are normally uniformed only to the extent of wearing smocks
and caps.   However, these workers are forbidden to wear woolly,
fluffy sweaters.   The latter are notorious for the way they spread
fibers broadcast.

Not all the lint comes directly from the clothing of workers; they
may dislodge it from other locations by their movement.   Accord-
ingly, working surfaces should be wiped frequently with a wet cloth.
Floors should be mopped, never cleaned by being swept with an
ordinary broom.   In order to prevent generation of dust from chipping
or surface disintegration, floors should be waxed with a soft, dirt-
retentive wax.   Under some conditions, a soft varnish using much
tung oil can be employed.   Concrete needs frequent attention in this
respect.

If the best operating conditions are desired, one must use a "clean-cab," which resembles a chemical fume cabinet, except that the air runs backward, and is carefully filtered. These arrangements have been made familiar by the advertisements of penicillin plants and optical factories.   The use of clean-cabs is a utilization of a general scheme of routing dirt as one would route product. If this concept is borne in mind, the organization of precautions becomes a more reasonable matter.

Carefully filtered air is useless unless it is used while still clean; therefore, it is sent over the work, past the worker (who is an important source of dirt), and then back to the filter.   Since lint is the thing to be removed, the air need not be sent back to the central station, but can be filtered and recirculated by a local unit using a viscous filter. Personnel bring in dirt on their shoes.   In many locations the entrance is narrow, thus forcing the worker to walk over a number of cocoa mats, *etc.*   The mats remove much of the street dirt, but if more care is needed, an automatic shoe cleaner can be employed.

Designation of clean areas in the laboratory should stop all unnecessary traffic of personnel and hand trucks through rooms where film is exposed and handled.

Dirt from Equipment.—Equipment made of materials which will serve well enough for most manufacturing purposes generally proves disappointing in the photographic industries. Slight amounts of corrosion, for example, mean little in most devices.   The usual criterion is "how long will it last?" However, in photography the question is, "how long will it stay clean?"   For example, some hard-used equipment will look nice if painted white, yet after a while the wear and tear of daily use will chip off the paint.   Trouble ensues either from flakes of paint, or rust from the unprotected metal surface thus exposed.   Such machine surfaces can be advantageously protected by heavy nickel- or chrome-plating.   Ordinary plating is not adequate.

Surfaces which rub together generate dirt, and provision must be made to localize the contamination.   This contamination may be caused by over-generous lubrication or, in the case of neglected bearings, metal powder.   Difficulty from this source is more widespread than one might think since many surfaces rub together.   It is usual to think of bearings only in terms of shafts alone.   For example, door latches and hinges fall in the category of moving parts.

Other causes of dirt are to be found in the work rooms themselves. Concrete floors have been mentioned and comments made about methods for preventing dusting as a result of surface disintegration. Battleship linoleum is a good floor covering if there is no heavy trucking and if special care is taken to hold the edges down by cementing and the use of mop-boards, *etc.* Walls should be smooth so that dirt will not lodge freely, and solid so that dirt cannot be shaken off easily. In critical locations it sometimes pays to cover plaster or concrete walls with canvas to prevent dirt from sifting from cracks.

Since many of the minus-density spots found on prints are located near splices, special attention should be paid to splicing benches. Rewinding operations can collect dirt because of static electrification. This effect is generally small and is made smaller by the use of relative humidities above 50 per cent. Electrical conductivity of film increases rapidly with humidity, and allows static charges to leak off. However, splicing operations generally permit the film to touch the worktable. This contact should be kept to a minimum by taking care not to overrun, *etc.*, in rewinding. It is good practice to work on tables of white glass, which are intrinsically clean and which, by reason of their color, cause dirt to be easily visible.

Combating dirt from the actual splicing operation itself is a problem. One can easily avoid dust and prevent clippings, dried cement, *etc.*, from accumulating, but one cannot easily handle the scrapings which come from a properly sharpened scraper blade. Properly placed suction will do much to remove the film scrapings from the work area. This device is used successfully by a number of laboratories. Dirt from splicing is primarily a matter of care on the part of the operator, and demands understanding and cooperation from every splicing machine operator for its prevention.

Many processing laboratories use cloth-covered drums in the drying cabinets for buffing the base side of film. Often the cloth wrapping on these drums becomes a lint source because raw edges of cut cloth may be allowed to flap against the film as the drums revolve. A little care in proper sewing of the cloth sleeves for covering the drums will usually take care of this dirt source. Proper choice of a lintless fabric is helpful in this connection also.

White gloves are used by splicing machine operators, cleaning room workers, and others in laboratories in order to prevent fingerprints. If these gloves are given a thorough laundering prior to use, much of

the lint will be removed.*   It is often observed that workers using such gloves allow them to become exceedingly dirty, to such a point, in fact, that they introduce dirt.   It is a good plan to provide a closed receptacle for soiled gloves, and a container for a supply of clean gloves, in order to maintain orderliness and to make it easy for workers to discard gloves too dirty to use on film.

One common method of cleaning film is to rewind it, usually in a room set aside for this purpose alone, through a soft cloth pad saturated with cleaning solvent.   The solvent employed is either carbon tetrachloride or a petroleum fraction of high volatility.   It has been found that oftentimes there is a large concentration of lint in such cleaning rooms.   Plush pads are notoriously bad for their release of lint fibers unless they are used with care and skill.   The accumulated load of dirt is generally dropped from the pad at each stop unless care is taken to prevent such action.   Pads should be made by folding the plush and sewing it so that the cut edges are enclosed within the pad. Suction vents may be supplied adjacent to the sources of generation of lint.   This is highly desirable also as a means of removing toxic or inflammable solvent vapors.

Another source of loose dirt is that caused by film rubbing sidewise against guides during rewinding.

Processing Solutions.—Experience in the field of apparatus construction is great enough that extensive compilations of recommendations are available.[2]   The properties of various materials are given, as well as methods for fabricating them.

Formation of calcium sulfite in developing solutions can bring about many attendant difficulties, such as scale formation on rollers, scum on film, and sludge in the solutions.   This can best be prevented by filtering the solutions.   For this purpose various types of cloth filters are prepared.   Diatomaceous earth as a filter aid is used in a number of laboratories for obtaining greatest clarity of developing solutions.

Other means of preventing the formation of insoluble calcium salts in developers are (1) the use of softened water, and (2) the use of calcium-sequestering agents, such as sodium tetraphosphate[3] in the developer formulas.

Some motion picture laboratories mix developers and do not filter

* Gloves treated with synthetic resin particles dispersed in water have shown themselves to be nearly lint-free.

them, but allow a period of standing for the calcium sludge to floccu-late and settle out. Sedimentation continues for a long period of time owing to the slow formation and settling rate of very fine crystalline particles of calcium sulfite and other similar compounds.

The need for cleaning and polishing motion picture negative follow-ing development would be much reduced if the water-insoluble sub-stances were removed from the processing solutions. Likewise, the maintenance cost of the developing machines would be much re-duced, because of avoidance of scale build-up on the rollers, shafts, and other parts.

A microbiological slime often forms in wash-water tanks. The growth of the slime can be prevented by the use of sodium penta-chlorphenate or similar compounds. If slime becomes established, thorough cleaning is necessary, which may include circulating a warm solution of trisodium phosphate through the parts of the circulating system which cannot be reached with brushes. The concentration of trisodium phosphate needed depends upon circumstances and may be from $^1/_2$ per cent to 3 per cent.

Measuring Dirt.—In order to study and control the unwanted material we call dirt we must be able to describe its occurrence quantitatively. Measurements not only allow us to gauge improve-ments, but generally furnish the information that makes improve-ments possible. Knowing the direction of air travel and relative dirt concentrations, one can follow the trail to its beginning. Dirt in the air is measured by such methods as:

> (1) Sedimentation,
> (2) Filtration,
> (3) Centrifugation,
> (4) Impingement,
> (5) Thermal precipitation,
> (6) Electric precipitation.

Three simple methods of dirt evaluation have been used very suc-cessfully in locating the chief sources of dirt in motion picture labora-tories. These methods are, (a) the tacky-dish technique, (b) the examination of samples lifted by adhesive tape, and (c) the micro-scopic examination of the film itself. Various related techniques are discussed by Bloomfield and Dallavalle,[4] and by Drinker and Hatch[5] in their publications, which also include extensive bibliographies.

It is important, in undertaking a complete study of dirt sources in a motion picture laboratory, to lay out first in detail the handling pro-

cedure, step by step, for both the negative and print, so that the investigational methods may be applied in an orderly fashion and at the most critical points in the laboratory.

The particular techniques to be described are useful primarily in locating concentrated localized dirt sources, which may cause more trouble than general personnel and building conditions. However, no amount of detective work done in locating sources of dirt can replace
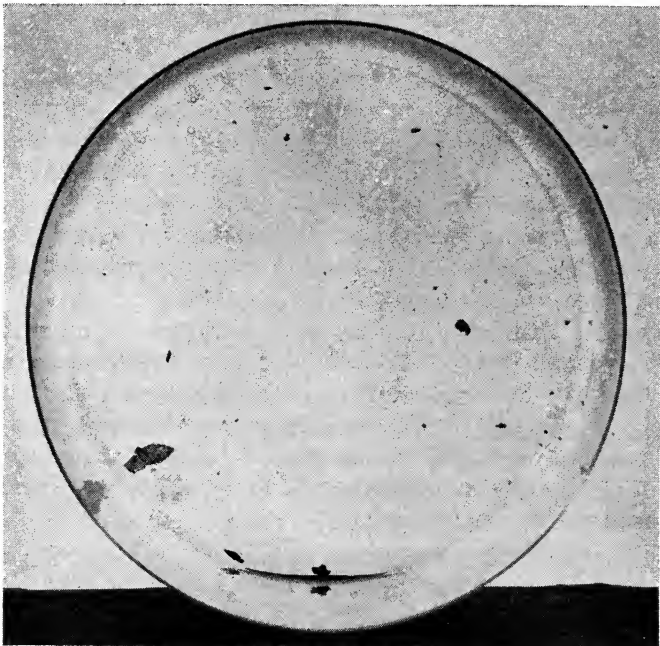
FIG. 5.   Tacky dish used in dirty location.

a continued insistence on high standards of maintenance and care on the part of personnel.

Tacky-Dish Technique.—This method is useful in measuring contaminants settling from the air, as well as contamination from equipment and personnel. It is particularly adaptable to the measurement of dirt carried in the film drying air.

The method consists of exposing a definite area of a tacky surface (Fig. 5) to the atmosphere that is being tested for a known length of time. A solution is prepared by soaking one part of gelatin in 7 parts

of cold water for 30 min, followed by warming to approximately 135 F until all the gelatin is dissolved. Glycerin, 2 parts, is added and a trace of thymol for preservative action. This solution is poured into the bottom of a glass Petri dish. When the entire surface has been covered by tipping, the dish the excess is allowed to drain off and the top of the dish is immediately put into place. Both top and bottom of the dish must be thoroughly clean and free from lint. This surface will remain tacky for a period of several days, which is ample for most tests.

The covered dishes are uncovered at the point where the sample is to be taken. For most determinations the dishes are placed in a horizontal position so that the particles in the dish represent particles falling directly into the dish or settling out of the air. When placed directly in the air stream in developing machine drying cabinets, the test dish may be placed upside down, if necessary, on the wire grating which often covers the bottom of the drying cabinets, so that the air impinges directly on the tacky surface. It is possible to use the dishes in a vertical position; this may be necessary when there is a right angle bend in an air duct and the cleanliness of the air in the duct is wanted. Dishes placed in front of and behind an air filter will give an indication of the filter efficiency for large particles by this method.

When the sampling has been completed the dishes are covered carefully and their contents examined microscopically. The Greenough type of binocular microscope is especially recommended for this purpose. Quantitative results are obtained with the tacky-dish technique by counting the number of particles of each type that are present in a given area. It has been found that reflected illumination is most suitable. The field which is being counted can be defined by a photographic grid fastened to the dish with tape, or by a hole of known size cut in black paper. A grid in the eyepiece of the microscope (Whipple disk) is also very convenient. The results are usually expressed as particles per square foot per hour, calculated from the area of the dish and the time of exposure. Low magnification $(25\times)$ is used for general counting, while higher powers should be used for the examination of individual particles.

In motion picture work, it has been found convenient to make a separate count of all particles having a maximum dimension of 0.002 in. or greater, as it may be arbitrarily assumed that this size particle on a motion picture negative would produce a "window" or "star" on

a print which would be objectionable on the screen, whereas anything smaller would be noticed only in the form of "shower," where many such spots would appear at once on the screen.

Many types of contamination are easily recognized when observed under adequate magnification, while other materials require further study before they can be positively identified. Simple chemical tests requiring only small amounts of reagents are the surest method of identification. Color reactions or spot tests may be used under the microscope. Fragments of emulsion can be detected rapidly by development and bleaching while film support is usually identifiable through its solubility in acetone or other solvents. When making chemical tests on various particles in the dishes it is advantageous to transfer the particle to be tested to a microscope slide. Only in special cases where a specific contaminant is sought is it advisable to add reagents to the entire dish.

A tacky dish using reagent in the gel can be employed when metal dust is being studied. The reagents keep poorly, so the active material is made fresh each time. Extreme accuracy is not needed in weighing the chemicals, but care should be exercised to avoid the presence of dust. The reagents can be prepared as follows:

To one liter of 10 per cent gelatin solution, add 30 cc of water containing

> 0.5 gm potassium ferrocyanide
> 0.5 gm potassium ferricyanide
> 10.0 cc conc. hydrochloric acid
> 4.0 gm calcium chloride
> 50.0 cc ethyl alcohol

Finally, add 300 cc of glycerin to the mixture. Particles containing iron produce blue spots, while copper-bearing compounds give brown spots.

Sedimentation data have been made more useful occasionally by keeping track of time. This is done by placing the dish upon a turntable driven by a clock. An angular space representing about one hour is exposed by means of a hole cut in a stationery mask. Examination of the chart will show how the sedimentation of dirt varies with time. There will be an uncertainty in the exact time, but this is usually unimportant since the information generally enables one to identify the cause by reason of prior knowledge of procedure.

Results of a typical set of tacky-dish dirt count tests are given in Table 1 and shown graphically in Fig. 6.

TABLE 1

Sample No.	Location of Test Plate	Dirt Count (No. of Particles Per Sq .n. Per Hr)
1a	Negative developing machine, main air inlet duct. After air filters	16
1b	Ditto, after cleaning and painting the main air inlet duct	6
2a	Negative developing machine drying cabinet, position 1 (directly in air stream after air has passed over drying film)	225
2b	Ditto, after cleaning and painting louvers in drying cabinet	8
2c	Negative developing machine drying cabinet, position 2 (further removed from air inlet duct than position 1), after cleaning and painting louvers	7
3	Printing room, on top of cabinet (8 ft from floor level)	40
4	Cleaning room, on top of cabinet (8 ft from floor level)	5
5	Table in assembly room on which negative rolls are broken down into scenes. Test plate placed close to one end of rewind	20
6	Splicing bench No. 1 in assembly room. Test plate placed within 8 in. of splicer	33
7	Splicing bench No. 2, otherwise ditto	30
8	Splicing bench No. 3, otherwise ditto	38

It is apparent from examination of these data that an extremely bad condition existed in the developing machine drying cabinet at the start of these tests (sample No. 2a).   Tests on the material picked up from the air stream by the tacky dish showed the presence of copper and a powdery material resembling pumice or talc.   Investigation showed that the lower louvers under the drying cabinet contained a considerable amount of dusty material, with some greenish particles which analysis showed to be a copper compound.   Further investigation brought to light the fact that the brass rollers in the

developing machine were periodically cleaned with a metal polish containing pumice and aqueous ammonia. This was wiped off the polished brass rollers, but a certain amount left in crevices, *etc.*, had dried and fallen through the grating floor of the cabinet into the louvers below.

As further proof that this dirt source was vitally important, small specks of foreign matter were removed from the processed negative film emulsion surface and analyzed. These showed the presence of copper and the same characteristic appearance under the microscope as the particles found in the tacky dish.
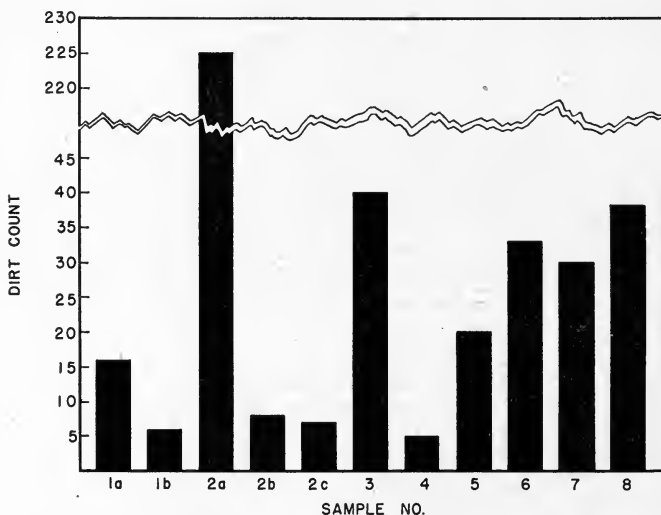

FIG. 6.   Chart of dirt count, according to Table 1.

After cleaning and painting the louvers and discontinuing the use of the pumice-base brass polish in favor of ordinary aqueous ammonia, a retest gave the result labelled "Sample No. *2b*" in Table 1.

In Table 2 and Fig. 7 are shown the results of tacky-dish tests made at another motion picture processing laboratory. These tests indicate the most dangerous conditions to be an excessive amount of lint found in the cleaning room, and an excessive amount of fibrous material, chiefly from the worker's gloves, in the daily assembly room. Steps were taken to correct these conditions by installation of suction equipment in the cleaning room, and by the use of laundering methods to render the cotton gloves more nearly lint-free.

Tape Samples.—Dirt which has settled on surfaces can be observed in place if conditions permit, but is generally "lifted" if the location is in a darkroom.   This procedure consists of pressing a piece of adhesive tape firmly against the surface of the area to be sampled, removing, and mounting for microscopic examination. Either black or white tape may be employed, depending on the color of the dirt picked up.   Mounting is best done by using a cardboard
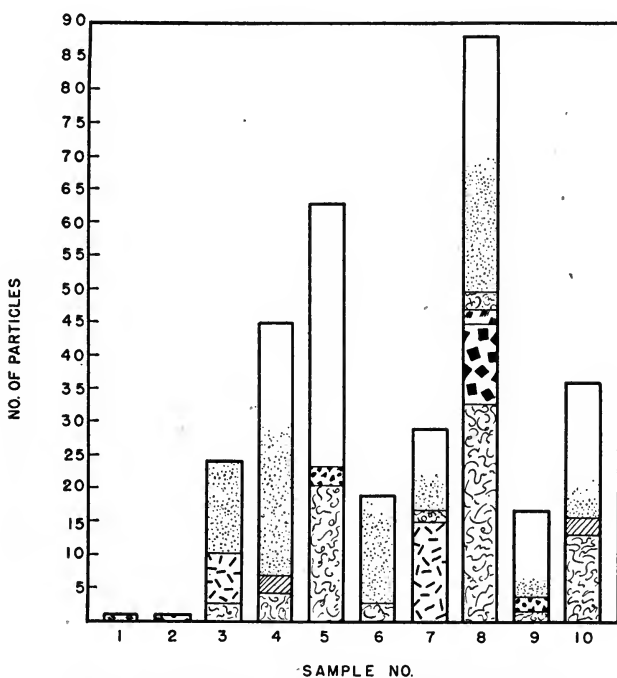
FIG. 7.   Chart of dirt count, according to Table 2.

mask of distinctive color with a small cutout hole sandwiched between the sticky surface of the tape and a glass microscope slide.   The mask prevents too tight contact between tape and glass slide, which would tend to make identification of the particles difficult.   The method of lifting dirt offers a very rapid way of looking for rust or scaling paint and makes possible a rapid check upon housekeeping practice.   A few examples are shown in Fig. 8.

Microscopic Examination of Film.—There are a number of observations that can readily be made with the aid of a microscope

TABLE 2

Sample No.	Location of Test Plates	No. Particles Per Sq In. Per Hr	Description of Test Plate
1	Negative developing machine drying cabinet. Floor of 4th bay	1	Very clean. No fibers. Several pieces brownish material like rust or clay. No fine dust
2	Negative developing machine drying cabinet. Floor of 4th bay	1	Same as No. 1
3	Negative breakdown room, surface of work bench	24	Few white fibers. Many short slivers of film base or emulsion. Much fine dust
4	Negative breakdown room. Back of splicer	45	Blue wool fibers. Few large scrapings of film base. Much fine dust
5	Negative cleaning room. Work bench, center, rear	63	Many pink and white fibers. Few small opaque particles
6	Printing room. Top of rheostat box for No. 11 printer	19	Few white fibers. Much fine dust
7	Printing room. Floor, between printers No. 4 and No. 5	29	Very few fibers, some colored. Some fine dust. Many film base and emulsion slivers
8	Daily assembly room. Work bench surface, center east side	88	Many white fibers. Large green plastic-like particles. Some red fibers. Much fine dust. Some rust particles
9	Negative cutting room. Work bench surface, S. E. corner	17	Very few fibers. Few opaque particles, brown or green in color. Little fine dust
10	Negative cutting room. Back of splicer	36	Many white fibers. Some film base scrapings. Some fine dust

Note: The particle counts refer only to particles larger than 0.002 in. in any one dimension. The term "fine dust" refers to those particles too small to be counted.

that will serve to elucidate screen examination of the finished print and limit the possible sources of film contamination. Some of these may be listed:
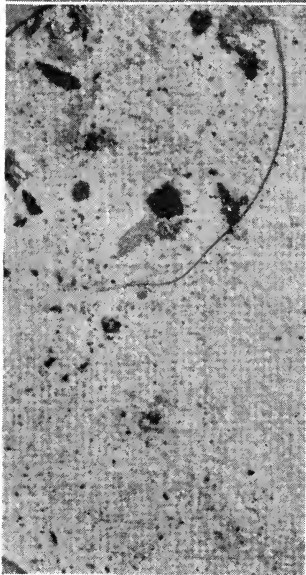
Rusty
Spring

Brass'
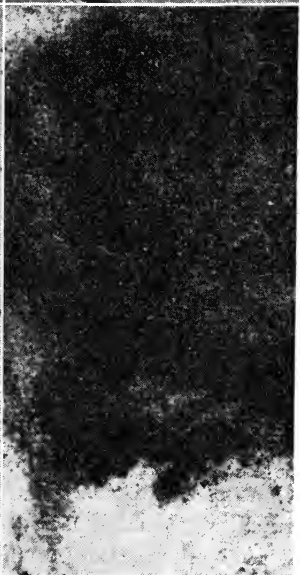Grind-
ings
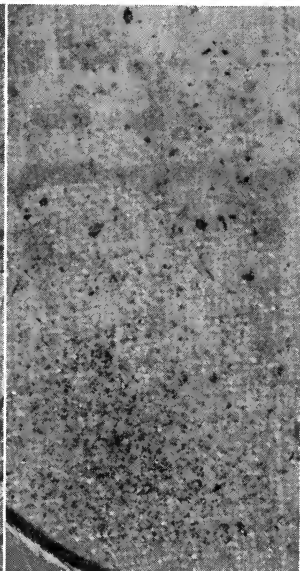
Wood,
Cinders,
etc.

Door
Latch

FIG. 8.   Tape samples showing "lifted" dirt.

(1) Position of the particle on the film.
    (a) Emulsion or support side.
    (b) Concentrated in the neighborhood of splices.
    (c) Consistently near the starts or ends of rolls.
(2) Confirmation of actual particle rather than a "shadow pattern."
    (a) Often the "windows" or "stars" observed on prints are shadow patterns of actual dirt particles adhering to the negative or of loose dirt lying between the negative and positive films during the printing operation.
(3) Photographic effect.
    (a) Sensitized or desensitized area (sometimes both) surrounding the particle after development. Many substances, notably metals, will react with the photographic emulsion and produce characteristic spots. The area of the spot may be many times the size of the actual particle.[6]
(4) Distance between particles.
    (a) Repeat pattern, owing to contamination on a sprocket or idler roller.
(5) Chemical nature of the particle.
    (a) Solubility tests.
    (b) Color reactions of metals.

When the processed film contains an objectionable amount of dirt, this is proof that an abnormal condition existed at some point in its handling by the user, or in some stage of manufacture. The amount of contamination on or in the emulsion of modern motion picture films before exposure is extremely low. If any large amount is suspected on the film as received, a strip should be taken directly from the can without excessive handling and examined in white light.

The high standards of quality of present-day motion pictures makes it well-nigh imperative that some measure of dirt control be instituted as an integral part of the production system, providing a safeguard against contamination of the finished product.

The authors wish to express their appreciation to Emery Huse, under whose guidance the motion picture laboratory investigations herein described were undertaken, and to the management of the several laboratories where such tests were carried out.

We also want to express our thanks to colleagues at Kodak Park, particularly J. M. Mulder, F. G. Van Saun, and J. R. Peer, who aided in the development of many of these techniques.

REFERENCES

[1] ROBERTSON, A. C., MULDER, J. G., AND VAN SAUN, F. G.: "Measuring Smokes and Rating Efficiencies of Industrial Air Filters," *Ind. Eng. Chem.* (Anal. Ed.), **13** (1941), p. 331.

[2] CRABTREE, J. I., MATTHEWS, G. E., AND MUEHLER, L. E.: "Materials for the Construction of Photographic Processing Apparatus," Kodak Research Laboratories, Eastman Kodak Co. (Rochester, N. Y.), 1945.

[3] HENN, R. W., AND CRABTREE, J. I.: "Calcium Scums and Sludges in Photography," *J. Soc. Mot. Pict. Eng.*, **43**, 6 (Dec., 1944), p. 426.

[4] BLOOMFIELD, J. J., AND DALLAVALLE, J. M.: "The Determination and Control of Industrial Dust," *Pub. Health Bull. No.* **217**, Government Printing Office (Washington, D. C.), 1935.

[5] DRINKER, P., AND HATCH, T.: "Industrial Dust," McGraw-Hill Book Co. (New York), 1936.

[6] CRABTREE, J. I.: "Stains on Negatives and Prints," Eastman Kodak Company (Rochester, N. Y.), 1945.

DISCUSSION

QUESTION: How do you launder your special uniforms? Can commercial laundries do the work?

DR. ROBERTSON: A great deal of our laundry work is done by a commercial laundry. We have had good results, which may be due in part to close technical co-operation.

QUESTION: What about oil on the film? There has been no mention made of the presence of oil in the compressed air used for the squeegees.

DR. ROBERTSON: You are quite right about the trouble caused by the presence of oil on film. The best air compressors for this purpose are the·ones which are water-sealed.

QUESTION: What is the name of the compound used to prevent the growth of slime in wash-water tanks?

DR. ROBERTSON: Sodium pentachlorphenate is the chemical name of the material. It is sold under various trade names, such as Dowicide, Nalco, and Santobrite, and the manufacturers' salesmen will be glad to help you further. Since the material is not very soluble in water, it is sometimes added to the water in the form of a stock solution. Sodium pentachlorphenate has been used by a number of West Coast laboratories, but I do not know if it is employed in New York City. It can also be used in air washers, but it is best to use it in the pure form. If sodium carbonate is present, some foaming may ensue.

QUESTION: What about radium buttons? The material tends to powder and give trouble.

DR. ROBERTSON: They should be hermetically sealed, as in glass or plastic, and handled only by authorized personnel. We have also had trouble with girls wearing "black-out" jewelry. There are other troublesome materials such as face powder, *etc.* I could go into great lengths about similar necessary precautions, but not everyone is interested in that matter.

A NEW RECORDER FOR 16-MM BUZZ TRACK*

M. G. TOWNSLEY**

Summary.—*A new recorder is described which produces direct recorded 16-mm buzz track film of exceptional accuracy. The track has a dense center portion to reduce ground noise and the edge modulations form a continuous exposure with the center portion.*

In a paper published in 1938, Kellogg[1] pointed out the advantages of recording buzz track film directly rather than making it by printing from a negative, and described a recorder for producing directly recorded film. This recorder used a single "chopper" wheel to produce edge modulations having frequencies of 300 and 1000 cycles on opposite edges of the track. The chief disadvantage of the film so-produced was that the unmodulated portion of the track was clear film and had a tendency to produce considerable ground noise.

After some experience with a recorder similar in principle to Kellogg's, it was found that the ground noise could be very appreciably reduced by separately printing an exposure in the unmodulated area. This was done by removing the modulating chopper wheel, placing a mask to define the edges of the strip to be printed, and re-exposing the film on which the modulation had already been exposed. This left a narrow line of light between the outer edge of the center strip and the inner edge of the modulation, which tended to fog slightly and reduce the effective track width.

A track was finally evolved in which the center exposure was accurately controlled for location and the width, and the edge modulations were printed extending into the center strip for a few thousandths of an inch on each side, eliminating the white line. This produced some modulation near the edge of the center strip but the density could be kept sufficiently high so that the output from this slight modulation was well within the tolerance limits.

When the American Standards Association Committee on Photography and Cinematography Z52 adopted the War Standard for 16-mm buzz track film,[2] the Standard specified a track having the narrow white line between the outer edge of the center strip and the inner edge of the modulation.

The necessity for producing considerable quantities of buzz track for our own use and for the Signal Corps pointed to the desirability of producing a new recorder, which would replace the nearly worn out unit then in use and, at the same time, improve the accuracy and convenience of producing the track. It is the purpose of this paper to describe the recorder for the record and point out some of the desirable features of buzz track produced with it.

It seemed desirable to continue the feature of making the edge of the center strip the accurate element, with the modulation extending from it. This consideration, and the necessity for eliminating any modulation from the edge of the center strip, dictated the making of the entire track in a single exposure, with the modulation produced by interrupting the light along both edges of the track. This is accomplished by

Fig. 1.   Buzz track.

the use of a long slit which is imaged on the film and interrupted at the ends by 2 separate chopper wheels.

Fig. 1 shows a short section of buzz track produced in this manner. The basic dimensions conform to ASA War Standard Z52.10-1944, but, as described, the track differs from the Standard in omitting the narrow light line just inside the end of the modulation, and in having the width of the black, continuous center strip equal to the standard width of the scanned area. The Signal Corps has accepted large quantities of this film as being in accordance with the American War Standard.

The recorder itself is simply but ruggedly constructed, and is made as convenient as possible to adjust and operate. All elements are
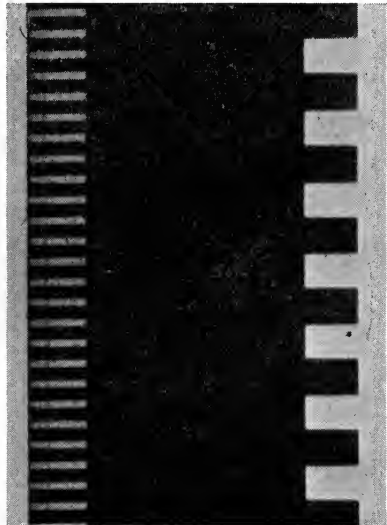
mounted on a main frame which consists primarily of 2 steel plates at right angles to each other. Fig. 2 shows a general view of the complete recorder, and Fig. 3 shows the optical arrangement. The lamp house is at the left end, and contains a 10-v, $7^1/_2$-amp exciter lamp arranged to be readily adjustable for proper illumination of the slit. A condenser L_1 close to the lamp images the filament a few inches to the right of the slit and a field lens L_2 just ahead of the slit images the filament in the objective lens L_3 to provide uniform coverage of the wide track required.
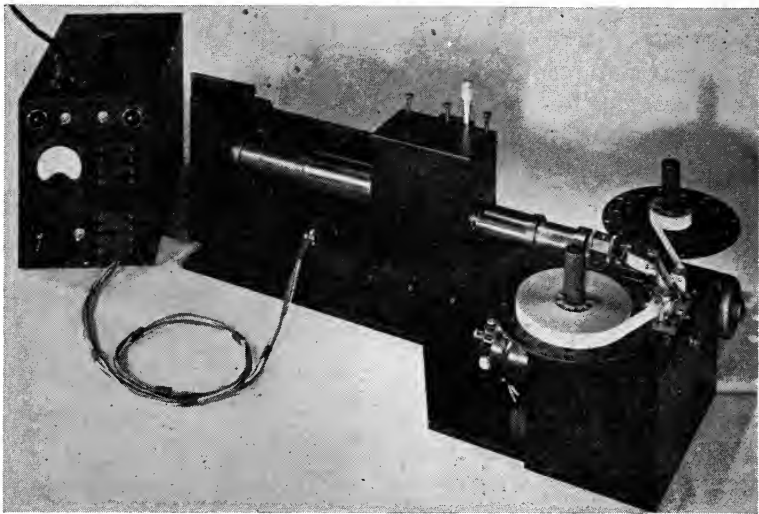

Fig. 2.   Buzz track recorder.

The slit is vertical and is set to a width of approximately 15 mils. Since the objective is set to a magnification of 0.1, this gives a beam width at the film of 1.5 mils. Just to the right of the slit are the 2 chopper wheels with their independent motors.   Separate motors were used because there were available a quantity of small governor controlled motors with appropriate speed range. The chopper wheels have 3 and 10 notches, respectively, in their edges and accurately running outside diameters. It is the outside rim of these choppers which is imaged on the film to give the accurate track location and width.   The notches in the edge of the chopper wheels allow light from the ends of the slit to reach the film and produce

the modulation.   Motor speed and number of notches were chosen in relation to the translational speed of the film to give frequencies of 1000 and 300 cycles per sec on the finished film.

Each motor is mounted on a separate angle plate as shown in Fig. 4, which is a detail of the chopper and slit assembly with the light-tight cover removed.   The angle plates are mounted in slides on the main frame so that they may be moved up or down as required for adjustment of the location of the track edges.   Separate micrometer heads are provided for each motor so that adjustment of the location of the edges of the track to within 0.1 mil is quickly and easily accomplished.

The film is transported horizontally from a feed flange through sprockets and an idler roller system, borrowed from a sound pro-
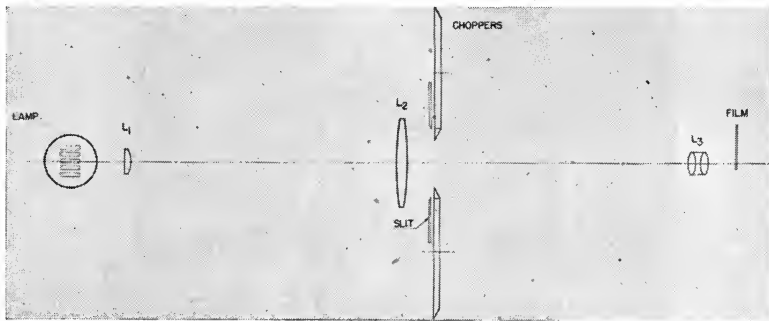

Fig. 3.   Recorder optical system.

jector, to a drum on which the recording is done, and then to a take-up flange.   Holdback and take-up tension is provided by friction washers which support the flanges.   This method of handling film with the roll laid flat is very convenient in devices of this type, keeping the roll in good condition, permitting the use of laboratory packed film without elaborate guide flanges, and keeping the film above all lubricated bearings and thus free from oil.

Edge guiding at the exposure point is provided by a stationary block which is surfaced with polished hard chromium plate.   The sound track edge of the film is held against this guide by a slight crown on the film drum analogous to the crown on a flat pulley which is used to keep the belt running on the center of the pulley, and by a light spring which bears on the opposite edge of the film.   The drum is supported in ball bearings and is driven by the film.   It was found

that the use of a fixed guide gave better precision with a ball-bearing
drum than a flange on the drum because of minute roughness in the
bearings available.

The sprockets and sprocket-drive mechanism are driven through
a fiber idler gear from a synchronous motor. A separate take-up
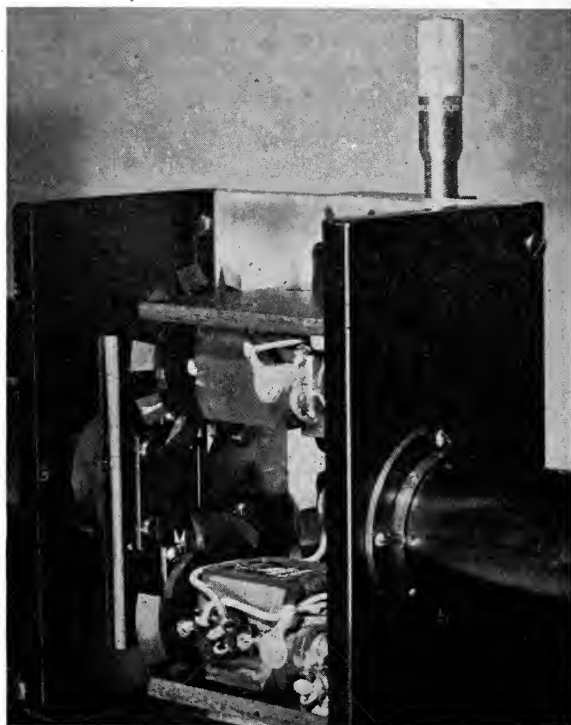
FIG. 4.   Chopper and slit assembly detail.

motor is provided to drive the flange on which the take-up flange
rests. While this arrangement results in the use of a total of 4 motors
on the recorder, it was simpler to use multiple motors than to make
the necessary mechanical devices to drive everything from one motor.

Electrical controls are provided in a separate case connected to the
recorder by a 6-wire cable. Current for the lamp is provided by a
constant voltage transformer, step-down transformer, and full-wave
rectifier, and is controlled by a rheostat and ammeter. Motor cur-

rent for the various motors is provided, and controlled by separate switches.

This recorder produces buzz track of minimum ground noise and excellent accuracy in a single pass through the recorder. It has been found possible to consistently maintain an accuracy of track location well within the limits specified in American War Standard Z52.10-1944.

REFERENCES

[1] KELLOGG, E. W.: "A Recorder for Making Buzz Track," *J. Soc. Mot. Pict. Eng.*, **XXX**, 2 (Feb., 1938), p. 150.

[2] AMERICAN STANDARDS ASSOCIATION, NEW YORK: War Standard Z52.10-1944.

NEW PERMANENT MAGNET PUBLIC ADDRESS
LOUDSPEAKER*

JAMES B. LANSING**

Summary.—This paper describes the permanent magnet type of Duplex loud-speaker and its use in theater public address systems. Its efficiency and frequency response is shown. Special types of baffles for the sides of the stage and above the screen are described. Because of its high efficiency and wide angle of distribution and extreme frequency range along with its small physical size, it provides a 2-way horn system with many advantages over those in present use.

This paper describes the new Duplex loudspeaker with permanent magnet fields, and its application to theater public address systems. At the Hollywood Technical Conference in October, 1943, an earlier model was described[1] which used separately excited field structures. The general performance and operating efficiency of the new speaker has been improved through the use of new manufacturing techniques and new materials. Fig. 1 shows the *604* Duplex loudspeaker.

Although permanent magnet speakers have been manufactured for years, they have been for the most part of very low efficiency because of the poor operating characteristics of the magnetic materials which have required large, costly, structures for the efficient use of the energy available from them. As a consequence, where attempts have been made to obtain high loudspeaker efficiency, it has been the practice to use the older magnet materials in an inefficient manner, usually in the form of ring castings, with the resulting very high stray fields with which most engineers are familiar.

The use of the Alnico No. *5* magnets has contributed considerably to the high performance and efficiency of the new Duplex loudspeaker. Through the use of these new highly efficient magnets, which are 3 times as powerful as any magnets previously used, it has been possible to obtain the high flux densities and the large total flux required for high-efficiency loudspeaker operation, which has been obtainable in

---

the past only with electromagnets. The new magnets are used in this design in the same manner as field coils; that is, they are surrounded by the field pot or the return circuit. The stray flux or external field surrounding these field structures is lower than that generally encountered in the electromagnetic speakers, even though the flux in the gap is greater than has ever been used before in commercial practice. The stray fields are low enough so that these speakers may be used in close proximity with oscilloscopes without affecting their operation.

Fig. 1.   Altec Lansing *604* Duplex loudspeaker.

The use of permanent magnets permits the voice coils to operate at considerably lower temperatures than would be the case if the surrounding magnetic structures were heated by the power dissipated by the field coils of the electromagnetic structures.

The high-frequency diaphragm of the Duplex loudspeaker utilizes tangential corrugations in the compliant portion surrounding the center dome (see Fig. 2). The increased freedom of movement of this new diaphragm over the older types which use annular compliance permits it to handle greater excursions without transmitting undue flexure stresses to the center dome, thereby increasing the peak amplitudes which it will handle and increasing its life. These new dia-

phragms are easily replaceable.   Accurately positioned dowel pins in the top plate and corresponding holes in the rings of the diaphragm assembly assure proper alignment of the voice coil in the gap.

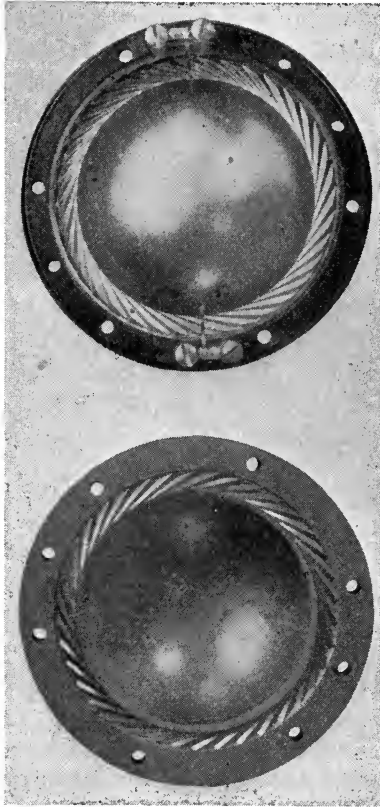Another contributing factor to the better performance of the new speaker is the use of edgewise wound ribbon wire in the voice coil.   High baking temperature varnish is applied to the ribbon as it is being wound.   The winding is clamped securely so that the turns are firmly pressed together and baked at temperatures considerably in excess of those encountered in the operation of the speaker.   The resultant coil, therefore, is quite stable and is not affected by the peak currents which it must handle in normal operation.

FIG. 2.   High-frequency diaphragm and voice coil assembly for *604* Duplex loudspeaker.

The ribbon wire permits the use of 27 per cent more conductor in the same space as compared with round wire, and thus provides the maximum utilization of space available in the gap.   Since these ribbon-wound coils are always single layer and the voltage developed between turns is very small, insulation requirements are minimized and the heat radiation of the coil is improved.

The high-frequency response of the Duplex loudspeaker has been improved through the use of the ribbon coil construction by increasing the sensitivity of the high-frequency speaker without increasing the mass of the moving system.

The low-frequency response has been improved by the use of increased magnetic flux, the ribbon coil construction, and the use of a

larger diameter voice coil to provide better coupling between the cone and the forces acting upon the coil (see Fig. 3). The increased coil diameter also decreases the depth of the cone and increases its effective stiffness thereby causing it to act more nearly as a piston. The over-all gain in performance with the Duplex loudspeaker has been such that satisfactory results are obtained at a crossover frequency of 2000 cps. The crossover network is shown in Fig. 4.

Permanent alignment of the pole pieces and gap are assured by the use of centering rings, fitting snugly over the inner pole pieces and into recesses in the top plates. A heavy die-cast cone housing is used in order to insure proper alignment of the low-frequency voice coil. The multicellular horn is a single bakelite casting with a mounting base attached by means of drive screws.

The application of public address and speech reinforcement systems to the theater has posed many problems. Such systems in the past have consisted of the microphone and amplifier channels and a multiplicity of cone speakers distributed about the theater.

FIG. 3. Low-frequency diaphragm for *604* loudspeaker.

In the applications where cone speakers have been used, the over-all efficiency of the system has usually been very low and the quality very poor. The polar distribution patterns of cone speakers has prevented uniform sound distribution throughout the auditorium and the marked resonance peaks of the cones at various frequencies have made it impossible to obtain any appreciable reinforcement without serious feedback or "howls." Such systems have proved as unsatis-
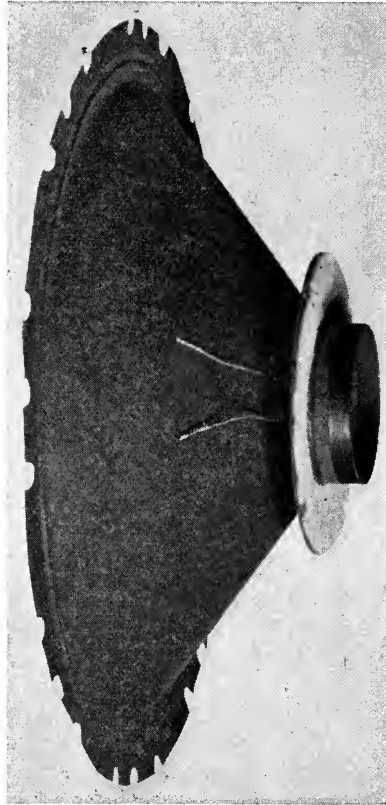
factory for theater public address work as they have for use with

FIG. 4.   *N-2000-A* dividing network.

motion pictures, since no amount of electrical compensation could make up for their inherent deficiencies. Microphone characteristics or amplifier capacity had little or no effect upon the final result.

The use of conventional exponential horns either in cluster or in multicellular array has provided improved distribution patterns and greater sound reinforcement. Although the quality is greatly improved over that obtained with systems using cone speakers alone, the limitations of the speakers that have been available heretofore for this type of service have been a serious drawback. Usually, too, the low-frequency cutoff of these horns is too high to permit satisfactory reproduction

FIG. 5.   *613* loudspeaker.

below 300 cps.   Where cone speakers on a flat baffle have been used with these systems to improve the low-frequency response, the over-all efficiency level of these systems has necessarily been reduced to that of the cone s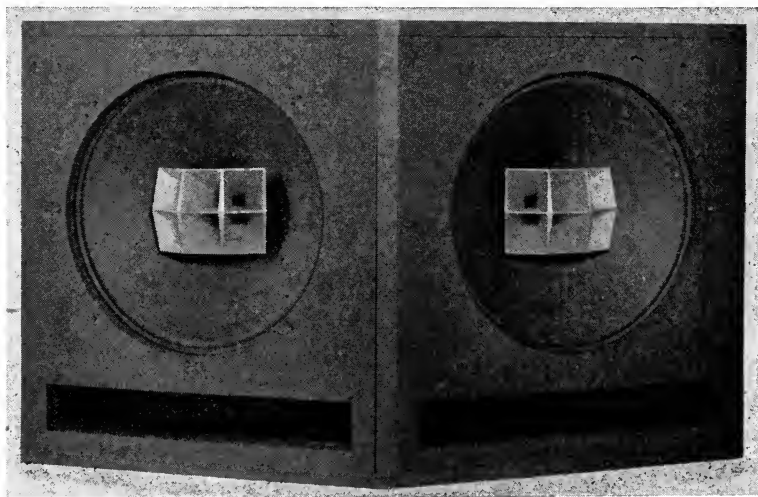peakers used.   The large size of such speaker systems makes it diffi-cult, or impossible, in most cases to find the space in the stage area where they will be out of the way, or will not present an unsightly appear-ance in the auditorium.

The Duplex loudspeaker dis-cussed earlier in this paper will prove invaluable for the fore-going applications.   Also, it can be used advantageously as a monitoring speaker in those cases where the high quality of the pickup is to be maintained for re-cording or broadcasting purposes.

FIG. 6.   *606* loudspeaker.

This loudspeaker can be mounted in an enclosure as small as 4 cu ft
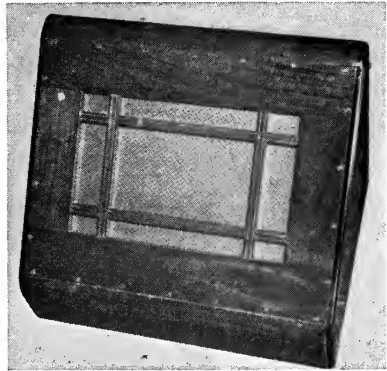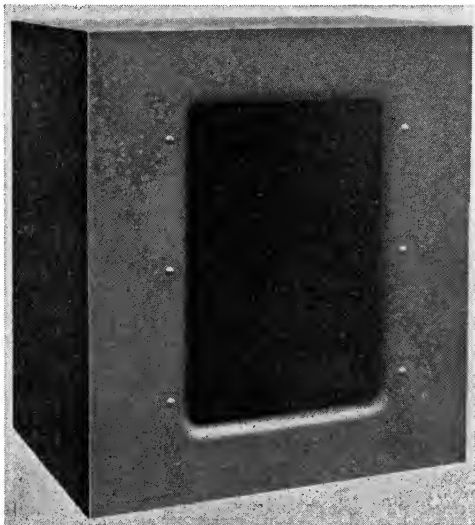

FIG. 7.   *612* loudspeaker.

for small auditoriums.   Where greater coverage is required for larger
auditoriums, 2 or more speakers can be enclosed, as shown in Fig. 5.
With this type of enclosure, maximum illusion of stage presence
is obtained.   Because of its small size it can readily be placed on stage
near the proscenium arch without being too conspicuous.

Odd-shaped cabinets (see Fig. 6) can be made as required to meet
particular adaptations so long as they are deep enough to house the
speaker, which is 12 in. from front to back.
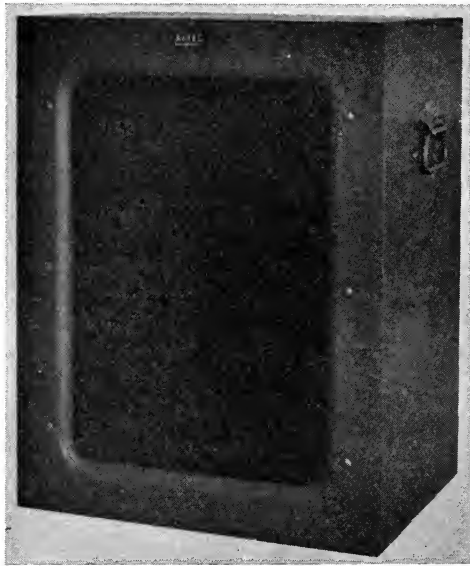
FIG. 8.   *614* loudspeaker.

The *612* loudspeaker for use in theaters and industrial applications
is shown in Fig. 7.   The cabinet is finished in dull gray and its volume
is $6^1/_2$ cu ft.

The *614* loudspeaker (see Fig. 8) for use in portable public address
systems utilizes a cabinet of only $4^1/_2$ cu ft, finished in dull gray.

The uniform frequency response and wide distribution angle of the
Duplex loudspeaker make it possible to obtain reinforcement levels
above those which can be obtained with other systems for the same
auditorium positions.

Amplifier power capacity requirements when using these speakers

are approximately equal to those required for the most efficient back-stage speakers.   A maximum of 30 w of amplifier capacity should be installed for each Duplex speaker in the system.

REFERENCE

[1] LANSING, J. B.: "The Duplex Loudspeaker," *J. Soc. Mot. Pict. Eng.*, **43**, 3 (Sept., 1944), p. 168.

SPECIALIZED PHOTOGRAPHY APPLIED TO ENGINEERING IN THE ARMY AIR FORCES*

P. M. THOMAS** AND C. H. COLES†

Summary.—High-speed motion pictures, high-speed still pictures, special recording devices, and color photography have all played important parts in the design and engineering program of the Army Air Forces. This paper outlines some of the more important applications.

Historical.—Although sporadic attempts had been made from time to time at Wright Field to employ the latest methods of photography toward the solution of aircraft problems, no concentrated effort was made to press its advantages until the Photographic Engineering Branch of the Technical Data Laboratory, Engineering Division, was organized in the middle of 1943. Now it has grown to a total personnel of 65, and has spread into 2 buildings. Its work has been deemed so important that its program has remained virtually unchanged since V-J day.

Organization.—The organization gives a good idea of how a problem is attacked. When a laboratory on Wright Field requests work to be done, the Projects Branch surveys the problem. The varied experience of its project engineers is of tremendous value in deciding a method of attack. One of these engineers makes an outline of the essential information to be obtained. For problems involving special electronic flash equipment, Dr. H. E. Edgerton and Gjon Mili, staff consultants for this organization, may be called in for advice.

As an example, the Jet Powered Unit requested that velocity and acceleration studies be made of the take-offs of the newly completed American version of the German *V-1* flying bomb. A project engineer flew to the test base where the launching ramps were under construction. He decided that a camera tower had to be constructed

---

at a certain location and 10-foot distance markers erected along the launching track.   These were built under his direction.

The project was now turned over to the Field Branch and a crew was sent with high-speed motion picture cameras, batteries, timers, and developing equipment.   The first few take-offs of the experimental bombs were filmed and the records flown back to Wright Field, where the Analysis Branch took over.   Here the films were studied and velocity and acceleration curves were drawn from the information obtained from the films.

The curves and tables were now returned to the same project engineer who initiated the action.   From these data he assembled the

Fig. 1.   Take-off of jet propelled bomb as photographed by automatic camera at Proving Ground.

final report and submitted it to the engineers of the Jet Powered Unit.   This completed the job.

An interesting side light on this particular project was that the films showed not only that the first flying bombs failed to attain adequate speed to enable them to fly, but also the exact cause of the failure.   It was poor rocket placement and consequent loss of power during take-off.

The high-speed photographic equipment does only a part of the work of the organization. Special photographic triangulation methods are employed to determine the height of aircraft and bombs at any point, the path of an airplane or falling projectile, the successive positions in space of a helicopter or a parachute.

When existing cameras are inadequate for a required purpose, the

Installation and Fabrication Unit designs its own or turns its speci-
fications over to a commercial company. A specially constructed
camera of this type is being used to photograph the indications on
instrument panels during flight tests or wind-tunnel tests. One of
the first to come off the production line was used to make the famous
pictures of the explosion of the first atomic bomb in New Mexico.

Color photography has grown in importance as a recording me-
dium for engineering data. Corrosion, combustion, color signals,
moisture detectors, medical subjects, all require color photography
for adequate recording. Complex production graphs and engineer-
ing charts also require color for clarity. To make the color records
of value, they must be capable of being printed for reports, so an ex-
tensive color printing service has been instituted which can turn
out as many as 500 prints per week. The original transparencies
are processed in our own laboratory. The color prints are made by
direct contact, or by enlargement from the original transparencies
and are also entirely processed with our extensive facilities.

The organization is constantly experimenting with new methods
and applications for enlarging its scope and attacking new problems.
New applications of infrared, x-rays, photomicrography, radar,
stereoscopic processes, cathode-ray oscilloscopes are constantly being
tried to discover new approaches for the solution of problems pre-
sented to this organization. The limits of photography as an aid to
engineering have by no means been reached.

High-Speed Photography.—High-speed photography as prac-
ticed at Wright Field may be conveniently divided into 2 general
classifications: high-speed motion pictures, high-speed still pictures.
Each of these may be subdivided into qualitative records and quan-
titative studies.

High-Speed Motion Pictures—Continuous Light.—To make the
high-speed motion pictures, several pieces of equipment are in use.
The Western Electric Fastax camera, in both the 8-mm and 16-mm
sizes, is used for the bulk of the projects. Although the Eastman
Type III 16-mm camera is gaining favor, each camera has certain
advantages for various types of problems.

These cameras operate on the principle of continuous film motion,
the individual frames being defined by a glass prism which, by rotat-
ing, moves the image formed by the camera lens along with the ad-
vancing film.

The definition obtained with this type of optical compensation is

not as good as with the standard intermittent motion, but it is adequate for any but the smallest detail.   The best use of these cameras is made by filming close-ups of the most important action and in this way not depending upon rendition of small detail.

At full speed, the 100 ft of film take about $1^1/_2$ to 2 sec to pass through, so exact timing of the starting of the cameras is essential. It is all too easy to have the important action occur after the film has passed through the camera.

In one application where it was desired to record the final velocity of a cart falling in a vertical track, a switch was installed on the track to turn the camera on just before the cart appeared in the picture, thus assuring that the camera would be running at that time.   The switch was then moved up the track until the camera started $1/_2$ sec before the cart arrived in the scene.   In this way the camera was allowed to come up to its full speed of 4000 pictures a sec before the cart appeared.

To measure the velocity of the cart it was necessary to determine the distance traveled in a certain time   The track was marked in one-inch distances by painting the track white and laying on strips of black scotch tape one inch wide every other inch.   To improve the accuracy of the measurement a vernier scale was painted on the cart so it would move along the track markings.   Thus a reading every tenth of an inch could be made.

The time record on the film was made by means of a 200-cps spark originating in a vibrating-reed timer built for the purpose by our organization.   A vibrating reed has its output voltage stepped up by a transformer to a point where it trips the grid of a Strobotron tube. The output of the Strobotron is put through a spark coil on the camera which is connected to the sparking electrode in the camera body.   A spark flashes against the film sprocket, the light of the discharge making a small fog mark on the edge of the film every 5 milliseconds.

Thus time and distance were recorded on the same film from which velocity may be calculated.   By drawing the curve of velocity against time it is possible to take the slope of the curve at any point and so calculate acceleration.

In this way a complete record is obtained not only of velocity and acceleration but of the appearances of the action in slow motion for visual study.

Lighting of the subjects to the required high intensity is provided by *R-2* photofloods of small objects and up to 10,000-w units for

larger areas. In bright sunlight, a maximum of 2000 frames per sec is all that the light will permit and still produce adequate exposure from light-colored subjects. For higher camera speeds, the subject must be illuminated with additional lighting units. A light truck equipped with four 3200-w floodlighting units and provided with its own generator was found to be a useful item for work in the field.

Processing.—Because the exposure per frame of films made with the Fastax or Eastman Type III cameras is of the order of $1/5000$ sec or less, the films are normally on the underexposed side. Special processing to obtain a printable film density is usually required. A fresh *D-76* formula gives good density provided the development is carried from 30 to 60 min. To reduce the time of development, a more energetic print type of developer will cut the time to about 7 to 10 min. With this stronger developer it is necessary to use an anti-foggant to hold down the background fog; 6-nitrobenzimidazole has been found very effective for this purpose.

Removal of the opaque backing from the film has been found relatively easy with Eastman Kodak Super XX by a simple squeegeeing with a viscose sponge during final washing. The film must be doubly perforated similarly to "double eight," as usually supplied for 8-mm cameras. It is spooled in 100-ft lengths and is a reversible-type film although we develop it as a negative for convenience and extra speed

In the laboratory, rack and tank development has proved more practical than machine processing because of the long developing time required to obtain sufficient image density. In the field a *G-3* tank is capable of producing good results. The roller in this tank is replaced with a viscose sponge to aid in removing the backing from the film. A collapsible drying rack designed for the Air Corps is a convenient accessory to hold the film while the moisture is evaporating from it.

Analysis of the Film.—After processing, the film must be studied for information that will enable performance curves to be drawn for the subject under analysis. The timing marks along the edge of the film are usually reduced to a frames-per-second figure for important parts of the film where the action occurs. Where the whole film is to be analyzed, a curve is drawn of film length measured in feet from the beginning of the film against frames per second. In this way, the time interval measured from one frame to the next may be taken off the curve for any part of the reel while it is measured on a footage counter.

The action is viewed frame by frame with special projectors originally designed to analyze gun sight aiming point camera records. The image may be projected on a screen up to exactly original size and measurements of distance thus made directly on the screen.   By interposing a mirror in the beam of the projector and reflecting the image back toward a translucent screen near the projector, the analyst may operate the projector and measure the screen without leaving his chair.   A scale on the floor along which to slide the mirror enables the operator to consult a table and so enlarge the image to any desired extent without trial and error by setting the mirror at predetermined distances from the screen.

Large transparent protractors and scales to use on the screen enable the analyst to work quickly and accurately.   After the points for the velocity curve have been plotted, a special tangent scale devised by our chief analyst is used to obtain the points to plot the curve of acceleration.

Achievements with the High-Speed Cameras.—While the films made with high-speed motion picture cameras often appear spectacular, it is usually the more prosaic looking picture that produces the most significant results.   The close-up of a wheel on the landing gear of a *B-24* during the process of making contact with the ground during an actual landing is very dull screen fare, but it yielded curves and figures that explained a great deal about the flexures a tire undergoes during the violent impact at landing.

Studies have been made of aircraft machine gun malfunctioning which proved the correctness of the theory of one of Wright Field's experts and revised the thinking of the gun manufacturers.

Under the analytical eye of the high-speed camera have come aerial camera shutters, jet propulsion engines, bursting propellers, exploding oxygen containers, explosively operated radio antennae, electrical relay actions, manual gun charging operations, aircraft launching devices, and a host of other engineering projects.

Intermittent Light High-Speed Motion Pictures.—Another important piece of equipment in use is the Edgerton flashing light high-speed camera.   As is well known to most engineers in this field, this camera utilizes special gaseous discharge lamps whose flash is so short that it stops the action not only of the subject but of the continuous moving film in the camera as well.   The film is 35-mm in width and 100 ft long.   The film passes through the camera in $1^{1}/_{2}$ sec when the driving motor is set to full speed, taking 1500 pictures per sec.   A

contactor on the main sprocket wheel fires the lamps every time a new frame is in position back of the aperture plate.

A spark electrode in the Edgerton camera places a time record on the film so that time duration, velocity, and acceleration may be measured.

Incidentally, a comparison of the 3 types of high-speed cameras—the Fastax, the Eastman, and the Edgerton—brings to light the fact that 100 ft of film passes through each in $1^1/_2$ sec at full speed. The linear film velocity is the same, therefore, in each camera, the different frames per second rates being a result of the difference in frame size.

The Edgerton camera can be used only in subdued light because the lens is open all the time; therefore its operation is restricted to laboratory applications. The shortness of the flash, which amounts to $1/_{100,000}$ sec, and the relatively large frame size compared to the 8- or 16-mm films made by the other cameras make possible the recording of greater detail in the pictures. Single frame enlargements up to 8×10 in. of the important phases of the action are readily made for inclusion in reports, a valuable aid in explaining data.

Because of the shortness of the flash, normal speed films are barely exposed. Even the fastest films leave a great deal to be desired because the severe reciprocity failure of the film reduces the effective exposure considerably. The blue color of the discharge lamp's flash utilizes only a portion of the wide spectral sensitivity of the fast panchromatic emulsion.

Adding all these restrictions together pointed to the need for finding a high-speed blue-sensitive emulsion that could be developed vigorously. A blue-sensitive film made especially for recording the fluoroscopic screen of x-ray apparatus was finally adopted as incorporating all the features desired. This film still has to be developed for 30 to 60 min but the results are reasonably satisfactory.

The coolness of the flashing light technique, as contrasted to the incandescent glare of the continuous light camera, indicates that for biological pictures and subjects whose actions would be affected by temperature rise, the Edgerton equipment would prove superior It can, however, photograph only relatively small objects because of the low light output.

The continuous light cameras are lighter, smaller, cheaper, and simpler to operate and will make pictures in daylight. Each type of apparatus has its particular advantage and application.

Sequence Flashing.—Some actions are too fast for even the high-speed cameras to catch. What is more, the bursting of an airplane propeller under increasing speeds cannot be anticipated, so it is impossible to start a motion picture camera in time to be operating at full speed at the exact moment required. Even if the camera were operating at the proper time, it is doubtful if more than 2 frames would record the action. A different technique had to be evolved to handle problems of this nature.

If a series of electrical discharge lamps were lined up and their condensers charged, they may be fired in sequence at almost any rapidity desired. For relatively small but fast subjects such as bullets, 6 Edgerton microflash units were assembled. These units emit a flash of light whose duration is $1/_{500,000}$ sec. The condensers in each unit require several seconds to charge from a 7000-v supply, but once charged the units may be fired one after the other in rapid succession.

A sequencing device was designed and constructed that would fire each lamp in turn electronically from $1/_{12}$ sec to $1/_{20,000}$ sec between flashes. By means of a microphone feeding into an amplifier, the sound of the gun initiates the sequence and the lights flash in succession. Of course, the picture is made in darkness, the flashes of light exposing the film. The picture is taken on an ordinary still camera loaded with fast blue-sensitive film which is developed vigorously. In this way pictures of bullets may be photographed striking armor plate and shedding their jackets. A series of bullet images appear in one picture showing successive stages of the action.

Although the microflash units have a relatively short range and angle of spread, helicopter rotors up to 38 ft across have been successfully photographed during rupture. To accomplish this end, the blades were painted white, a fluoride-coated $f/2.5$ lens was used on the camera, and the fast fluorographic film developed to completion. Ten minutes in straight *D-72* with an antifoggant added is not unusual to bring up an image adequate for printing.

In the case of the helicopter propeller rupture, a wire was cemented to the blades and brought out through a slip-ring device normally used to connect strain gauges to recording instruments. The wires were connected to a transformer and battery in series. The secondary of the transformer was close to and connected into the input of the triggering amplifier. The transformer enabled the circuit comprising the rotor and slip-ring to retain a low impedance and so

be relatively free from pickup disturbances. The rupturing of the rotor broke the wires and initiated the sequence of flashes.

Because the camera with its fast lens and film was set for time exposure to catch the moment of rupture, the whole propeller test laboratory had to be darkened completely. Windows that could not be covered in the enclosing structure made it necessary to perform the test only after darkness fell. One of the first pictures made with this equipment shows pieces of the fabric blade flying away from the rotor. The success of the results obtained so far has warranted the building of a new sequence flasher of far greater light output to be permanently installed in the propeller test laboratory for continuing research.

Flash Techniques.—In some cases where the action is continuous, pictures are required at intervals that do not approach motion picture frequency and yet each picture must be made with extremely short exposure. An actual case was a helicopter hovering above the ground. Pictures of the blades were required to determine coning angle and bending.

An aerial night photographic flash unit was adapted to ground operation for this purpose. This unit emitted an extremely powerful flash of light whose duration was only $1/5000$ sec. The flash could be repeated 3 times a sec. An aerial camera taking a 5×7-in. picture had its shutter removed and its mechanism altered to move the film continuously. The lens was set into a focusing mount and the camera set upon a Mitchell tripod. A contactor was installed in the camera to flash the light every time a fresh 5-in. length of film came into position.

When darkness fell on the flying field and everything was in readiness, the helicopter pilot was given the signal to make the aircraft rise to a hovering position. At the same moment, the camera was started and the light was fired by the film metering rollers inside. A series of pictures was thus obtained showing the blades of the helicopter sharply defined against a black sky. Measurements could then be easily made of the angle and deformation of the blades.

Individual flash pictures may, of course, be made with the same equipment. An example of such an application was the request made by the Propeller Laboratory to photograph the successive stages of the building up of ice on a propeller. The request stated that this was not to be done in the wind tunnel but must be accomplished under actual icing conditions in the air. To complicate matters further,

it was considered too dangerous to make the flight at night, sufficient hazard being encountered during daylight operations in icing clouds.

The problem was finally solved by the combination of several techniques and the development of a new discharge lamp. The regular lamp of the night photographic unit was replaced with a short duration tube. This tube flashed in about $1/20,000$ sec. To make the picture, a wide-angle camera was constructed which could be operated entirely from the rear and so rigid that it would keep its focus despite the vibration of the airplane. A contactor was fitted to the shutter to fire the flash when the blades were wide open. In this way, the effect of daylight would be kept to a minimum with a high shutter speed.

The camera and lamp were installed in the cockpit of the *B-25* Mitchell bomber directly behind the pilot, viewing the blades of the propeller perpendicular to their axis of rotation. The success of the whole project depended upon 3 factors: (*1*) overpowering the daylight with the flash, (*2*) a fast enough flash to stop the propeller, and (*3*) sufficient contrast to be obtained between the cloud background and the propeller blade to show the latter to its best advantage.

To achieve the last requirement, color contrast was tried and found to be of considerable help. Ansco Color Film was loaded into the camera and the propeller blades of the airplane painted bright red. The name of the *B-25, Flaming Mamie,* was no meaningless term as one glance at the flaming color of the propeller would prove.

The photographs obtained with this equipment showed the white ice crystals on the red propeller blade against the blue cloud background, a colorful and successful solution to a difficult problem.

Motion Picture Theodolites.—Recording theodolites are used effectively at Wright Field for the location in space of moving aircraft, parachutes, and slow-moving missiles. The recording theodolites are essentially motion picture cameras whose azimuth (panorama from the north point) and site (tilt from the horizontal) are recorded on the film simultaneously with the picture. A clock is also recorded for the purpose of matching pictures taken at the same time from 2 stations. The theodolites are always used in pairs so that triangulation from their 2 positions defines the position of the subject. The clocks on the 2 instruments may be synchronized by radio so that accuracy in timing is assured. From the observations recorded by these theodolites, three-dimensional space graphs may be plotted to depict the exact motion of an object in the air.

With these instruments, the flight path of a helicopter was recorded and plotted to prove that such an aircraft requires some wind to produce vertical ascent. The oscillations and drift of a parachute were also measured.

Conclusion.—Motion picture technique has been put to work in the ways enumerated to aid in the solution of engineering problems at Wright Field, the experimental center of aircraft development for the Army Air Forces. Under the pressure of war, the satisfactory solutions to these design problems had to be found quickly. The success which attended the application of these new photographic analytical methods was so complete that this work is expanding to an ever-increasing extent.

COLORED TRACE OSCILLOGRAMS*

L. S. TRIMBLE AND F. W. BOWDEN**

Summary.—*Aerial Kodacolor has been found suitable as a cure for trace entangled, illegible, oscillographic recordings. A 5¹/₂-in. width film is available that in combination with filtered light beams is productive of distinctly differing color traces at recording speeds up to 20 in. per sec.*

It is often found necessary to study a function that changes rapidly with time; a convenient method of measuring this variation is to convert it to an electrical impulse and record the corresponding variation by means of an oscillograph. A simple form of this instrument employs a sensitive galvanometer capable of causing deflections in a beam of light by virtue of being coupled electrically to the variable whose time function it is desired to study. In the usual case the light beam is reflected from a mirror on a galvanometer and impinges and records on a photosensitive film or paper driven uniformly with time. The narrow light beam is then deflected normal to this direction of travel so that the processed photosensitive material carries a continuous line trace representing the function variation with time.

In many cases several light beams are caused to record on the same photosensitive material, and often these beams will be simultaneously deflected so that trace entanglement results, making the final study of an individual line practically impossible. This condition is accentuated in aircraft flight test recordings where, because of space and weight considerations, as many as 12 oscillating traces are recorded on a 6-in. width of photographic paper. Fig. 1 illustrates such an entanglement as the result of flight stresses recorded on the Lockheed, 60-passenger, high-speed *Constellation.* As can be seen, considerable time is required to follow each trace and determine its frequency, amplitude, and slope characteristics.

Mechanical alterations of line width or continuity have not been successful in positive identification. Compact light-weight instru-

---

ments capable of equivalent individual recording are not currently available. One method of simplifying this problem is to utilize a color sensitive and reproductive photo-recording material thus allowing the reproduction of traces as separate and distinct hues, preferably upon a white background. The oscillograph needs altering only in the proper filtering of the light beams and the substitution of a suitable color sensitive photographic material for the orthochromatic type of bromide paper normally used.
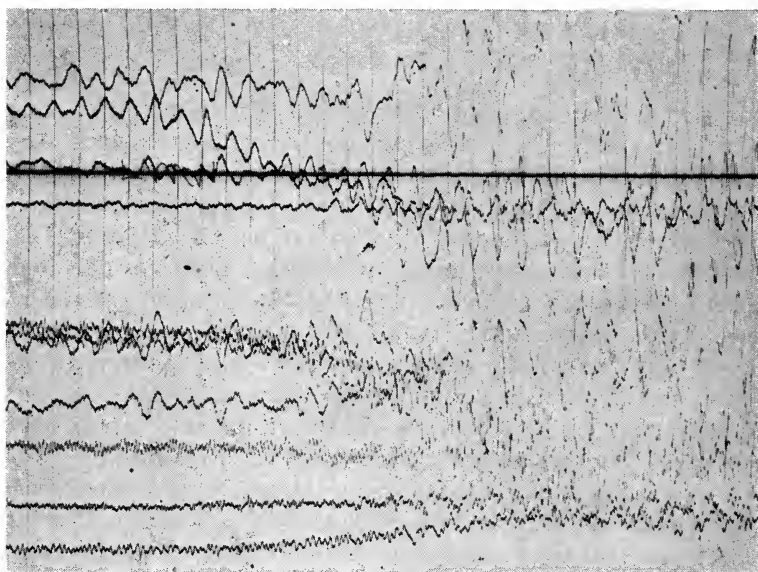

Fig. 1.   Black and white entangled traces.

A gelatin or glass filter having transmission characteristics similar to one of those shown in Fig. 2 is placed in each beam so that the light passes through it only once. The exact location of the filter will depend upon the instrument used as well as the optical system of the instrument. Since there are but 6 major colors in the visible spectrum, and there are 12 traces to filter, sharp, clear, visual color distinction between all lines is difficult to attain. Two blue lines, for instance, differing in density or differing but slightly in hue, will form closely identical traces as one beam is rapidly modulated, thus altering photographic exposure and thereby color density, and to some

extent, hue. In addition, certain limitations in the color reproduction mediums available at the present time serve to narrow the reproducible color range. It is possible, however, to select Wratten filters differing in spectral transmissions so that corresponding variations in hue will be evident on the recording medium. Widely spaced traces may be in duplicate hues since the probability of their complete intermodulation would be slight. The quality and thickness of the filters should be chosen so that the over-all transmissions are of about the same order, thus insuring light intensities within the latitude range of the recording medium.
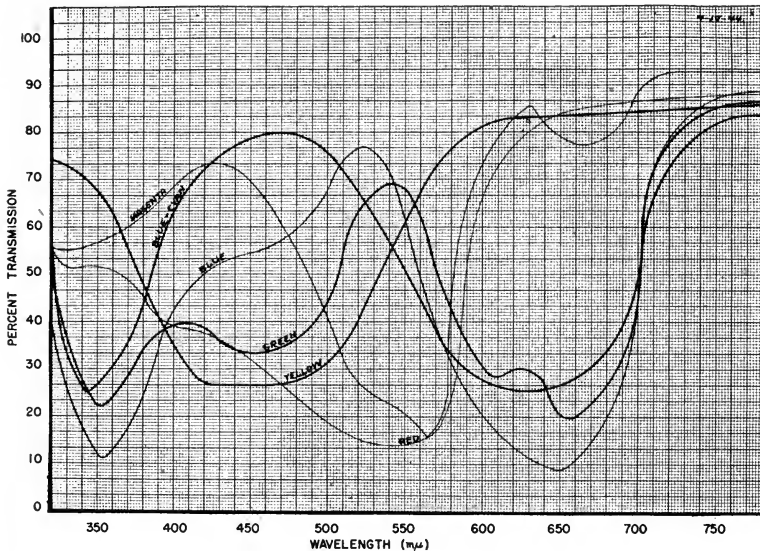

FIG. 2.   Filter characteristics.

Flight test records, particularly on new model airplanes, are often secured in a few moments of flight time, but represent many hours of planning. Modifications or additional tests are considered only after interpreting first performance data, so that speed of processing records as well as reading the records is important. For this reason, those color photographic products easily processed by the customer have received the most attention. Most of the available photographic materials comprise 3 light sensitive emulsions which record the 3 color aspects of the impinging light beam. During processing of certain of these materials the exposed silver is reduced in the normal

manner followed by the coupling of the partially oxidized form of the developing agent with substances incorporated in each emulsion such that dye images are formed of a hue complementary to the wavelength band responsible for the emulsion exposure. A blue-violet beam, therefore, will produce a yellow line on the photographic medium, whereas a green beam will produce a magenta line. Certain other color products are designed to be treated by a reversal process, such that the reproduced hue will substantially match that of the filtered light beam.
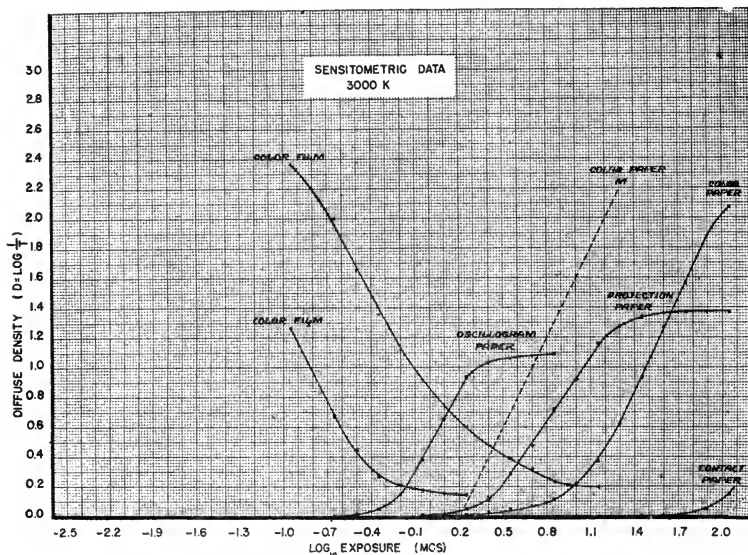

FIG. 3.   Comparison of available recording materials.

Comparison of color paper and film speeds was made by means of sensitometric IIb exposures at 3000 K, a color temperature specified for product color balance; processing was conducted utilizing packaged chemicals supplied with the recording material in accordance with the manufacturer's instructions. Fig. 3 shows typical sensitometric curves of the paper and film recording mediums available. Diffuse density, transmission or reflection, is plotted against log exposure in the normal manner. The slope of the straight line portion of the curve provides a comparison of contrast; and for a given density and contrast, a change of 0.3 log exposure represents 100 per cent, or one stop, change in exposure.

Data on 2 commercial blue-sensitive papers are shown for reference, a chloride type of contact paper, and a bromide projection or enlarging paper.   It can be seen that the commercial black-and-white oscillogram paper is about 2 stops faster than the projection paper, whereas the available color paper is about 4 stops slower than the oscillogram paper.   By limiting the bromide concentration in the color developer of the nonreversal process, it is possible to gain 2 to 3 stops in speed, as shown by the dotted curve, without appreciable gain in fog level.   This allows the complementary color rendition of line images at a linear paper speed of one to 2 in. per sec.   Although this

FIG. 4.   Developing pans and chemicals.

is satisfactory, the margin of speed is not great, the color distinction is not particularly good, and the thick paper tends to bind and surface crack in passing through the oscillograph.

Photographic films are faster than any of the photographic papers available; they must be viewed by projection or over a light box, but have substantially increased exposure latitude, are capable of good color separation, and have the ability to be duplicated in the form of paper prints for detailed study or report purposes.

Satisfactory results were obtained up to a linear recording speed of 20 in. per sec through the use of Aerial Kodacolor supplied in $5^1/_2$-in. by 40-ft rolls.   The 6-w tungsten lamp in the oscillograph, a Miller model H, provided a satisfactory light source, and the individual light

beams were filtered using Wratten gelatin squares Nos. *23, 29, K2, 34, 38, 40, 45, 47,* and *61N*.   The rolls were processed in about $1^1/_2$ hr by winding the film on a Steinman-type spiral and immersing in $4^1/_2$ gal of the processing solutions prepared from the chemicals supplied with each roll, Fig. 4.   Exposure for reversal was accomplished with the film on the spiral by traversing the spiral path between the film planes with a glowing relatively heat-free light source comprising a mercury arc in the form of a $^3/_{16}$-in. glass U-tube.   Air circulation from a fan hastened drying of the film on the spiral.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y., at prevailing rates.

American Cinematographer
27, 1 (Jan., 1946)
Orthicon Pickup Tube for Television Cameras (p. 6)
Pointers on Use of New Ansco 16-Mm Color Film (p. 7)
Automatic Follow-Focus Device for Use in Cinematography (p. 8) — J. T. STROHM AND W. G. HECKLER

Sixteen Goes Hollywood (p. 12) — R. FERNSTROM
No Cherry Blossoms in a Factory (p. 16) — W. WISE
Using Your Movie Camera as a Motion Picture Step Printer (p. 24) — J. R. OSWALD

British Kinematograph Society, Proc. Sub-Standard Division
(1944–45)
Sub-Standard Motion Picture Practice (p. 2) — I. D. WRATTEN
Professional Sub-Standard Projection (p. 11) — W. HINE
Screen Brightness in Sub-Standard Projection (p. 16) — G. H. SEWELL
American Standards for 16-Mm Service Projectors (p. 19) — R. H. CRICKS
Sound Recording for Sub-Standard Films (p. 24) — N. LEEVERS

Electronic Engineering
18, 215 (Jan., 1946)
A Continuous Film-Recording Camera for Use with Standard Cathode-Ray Oscilloscopes (p. 10) — A. H. SIMONS

Ideal Kinema, The
12, 126 (Jan., 1946)
Westrex Sound System (p. xxv) — G. S. APPELGATE

International Photographer
17, 12 (Jan., 1946)
The Strobolight (p. 9) — F. J. SCHERSCHEL
Rotocolor is Something Different (p. 11) — R. FERNSTROM

238   Current Literature

International Projectionist
            21, 1 (Jan., 1946)

A Post-War 16-Mm Projector: The Ampro Premier 10
(p. 7)   L. Chadbourne

Sharp Heat Reduction, Better Color Rendition Claimed for
New Glass (p. 12)

Projectionists' Course on Basic Radio and Television—Pt.
19, Vacuum Tubes (p. 20)   M. Berinsky

The Stratovision System for Television, FM—Pt. 2 (p. 24)   C. E. Nobles

Technique Cinematographique, La
            16, 12 (Dec., 1945)

Standards of the Characteristic Dimensions of Auditoriums
(Russian Standards) (p. 221)

Television
            3, 1 (Jan., 1946)

Film Projection Equipment (p. 13)   J. L. Caddigan

59th SEMI-ANNUAL TECHNICAL CONFERENCE

Hotel Pennsylvania, New York

May 6-10, 1946

Directory of Committee Chairmen

Atlantic Coast Section and Local Ar-
  rangements........................FRANK E. CAHILL, JR., *Chairman*
Registration and Information...........W. C. KUNZMANN
Luncheon and Dinner-Dance Commit-
  tee................................E. I. SPONABLE, *Chairman*
Hotel and Transportation...............O. F. NEU
Membership and Subscription Commit-
  tee................................JAMES FRANK, JR., *Chairman*
Ladies Reception Committee Hostess.....MRS. O. F. NEU
Papers Committee......................BARTON KREUZER, *Chairman*
                                      C. R. DAILY, *Vice-Chairman*
Publicity Committee...................HAROLD DESFOR, *Chairman, assisted by*
                                      LEONARD BIDWELL
Projection Programs—35-mm............H. F. HEIDEGGER, *Chairman, assisted
                                      by* Members New York Projection-
                                      ists Local 306
                  16-mm............J. E. STEOGER

HOTEL RESERVATIONS AND RATES

No hotel room reservation cards will be mailed to the membership for this Con-
ference.   Therefore, members and others must book and reserve desired room ac-
commodations early and direct with Joseph Troise, Front Office Manager, Hotel
Pennsylvania, New York 1, N. Y., prior to April 20.   Mention that the reserva-
tion is in connection with the SMPE Technical Conference.   No rooms will be
assured or available unless confirmed by the hotel management.

Note: Out-of-town members who can schedule their New York arrival for Sunday, May 5, are more apt to get immediate room assignment on this date than if arrival is on Monday, May 6.

The following per diem room rates, European plan, are extended to SMPE members and guests when booking accommodations direct with the Hotel Pennsylvania:

```
Room with bath, one person..........$3.85, $4.40, $4.95, $5.50, $6.05, $6.60
Room with bath, 2 persons, double bed......$5.50, $6.05, $6.60, $7.15, $7.70
Room with bath, 2 persons, twin beds........$6.60, $7.15, $7.70, $8.25, $8.80
Parlor suits for one or 2 persons............$10.00, $11.00, $13.00, and $18.00
```

REGISTRATION

The Conference registration headquarters will be located on the 18th floor of the hotel adjacent to the *Salle Moderne*, where all business and technical sessions will be held during the 5-day Conference.   Members and guests are expected to register.   The fee is used to defray Conference expenses.

TECHNICAL SESSIONS

SMPE members and others contemplating presentation of papers at this Technical Conference can greatly assist the Papers Committee in the early assembly of the program by mailing in title and author of papers together with an abstract by April 1, 1946.   Complete manuscripts should be sent to the Chairman or Vice-Chairman of the Papers Committee not later than April 15.

Only through your earnest co-operation will it be possible to draft and announce the papers program prior to the opening of the Conference.

SMPE GET-TOGETHER LUNCHEON

The Society will again hold its regular pre-war social functions, and accordingly a Get-Together Luncheon is scheduled in the *Penn Top* (formerly the *Roof Garden*) on the 18th floor of the hotel, on Monday, May 6, at 12:30 P.M.   Ladies are invited to attend this luncheon.   Tickets must be procured at the registration desk prior to noon on May 6, so that adequate hotel accommodations may be provided accordingly.

The Board of Governors cordially invites the holders of Dinner-Dance tickets to spend a social hour with the Board in the hotel *Georgian Room* between 7:15 P.M. and 8:15 P.M., on May 8, preceding the Conference dinner.   (Refreshments.)

The informal Dinner-Dance (dress optional) will be held in the *Georgian Room* promptly at 8:30 P.M., on May 8.   Dancing until 1:30 A.M.

Note: It is imperative that Dinner-Dance tickets be procured and table reservations made at the registration headquarters prior to noon on May 8.   Your earnest co-operation with the Arrangements Committee is requested.

LADIES' PROGRAM

A reception parlor will be provided in the hotel for the ladies' daily get-together and open house.   The ladies' entertainment program will be announced later.

MOTION PICTURES AND RECREATION

Conference identification cards issued to registered members and guests will be honored at New York *deluxe* motion picture theaters which will be listed in later issues of the JOURNAL.

Those interested in other entertainment while in New York should consult the hotel information bureau, or the SMPE registration headquarters.

Technical Sessions Scheduled

Monday, May 6, 1946

Open Morning.

9:30 a.m.   *Hotel, 18th Floor*:   **Registration.**   Advance sale of Luncheon and Dinner-Dance tickets.

12:30 p.m.   *Hotel Penn Top:* (formerly *Roof Garden*), *18th Floor:* **Get-Together Luncheon.** (Eminent Speakers.)   *Note:* Luncheon tickets must be procured before noon on May 6, at the registration desk.

2:00 p.m.   *Salle Moderne:* **Opening session of the Conference.   Business and Technical Session.**

8:00 p.m.   *Salle Moderne:* **Evening Session.**

Tuesday, May 7, 1946

9:00 a.m.   *Hotel, 18th Floor:* **Registration.**   Advance sale of Dinner-Dance tickets.

9:30 a.m.   *Salle Moderne:* **Morning Session.**

2:00 p.m.   *Salle Moderne:* **Afternoon Session.**

Open Evening.

Wednesday, May 8, 1946

Open Morning.

10:00 a.m.   *Hotel, 18th Floor:* **Registration.**   Advance sale of Dinner-Dance tickets.

2:00 p.m.   *Salle Moderne:* **Afternoon Session.**

7:15 p.m.   *Georgian Room* (**Reception Foyer**):   A social hour with your Board of Governors preceding the Dinner-Dance.   (Refreshments.)

8:30 p.m.   *Georgian Room:* **Fifty-Ninth Semi-Annual Technical Conference Dinner-Dance.**   Social get-together, entertainment, and dancing until 1:30 A.M.

Note: Tickets must be procured and tables reserved prior to noon on May 8, for this function.

Thursday, May 9, 1946

Open Morning.

2:00 p.m.   *Salle Moderne:* **Afternoon Session.**

8:00 p.m.   *Salle Moderne:* **Evening Session.**

Friday, May 10, 1946

9:30 a.m.   *Salle Moderne:* Morning Session.
2:00 p.m.   *Salle Moderne:* Afternoon Session.   Adjournment of the Fifty-
               Ninth Semi-Annual Technical Conference.

Note: All sessions during the 5-day Conference will open with an interesting
35-mm motion picture short.

IMPORTANT

Those desiring hotel rooms *must* book their accommodations *direct* with the
Hotel Pennsylvania management prior to *April 20*, which are subject to cancella-
tion prior to May 1.

Owing to the acute travel conditions, it is imperative that out-of-town members
and guests who contemplate attending the May Technical Conference consult
their local railroad passenger agent regarding rail and Pullman accommodations,
within the existing Pullman reservation period.

W. C. KUNZMANN
Convention Vice-President

EMPLOYMENT SERVICE

POSITIONS OPEN

Designer and engineer experienced in optics, lighting, and microphotog-
raphy, capable of designing microfilm reading equipment and products
related to microfilm industry.   Reply to Microstat Corporation, 18
West 48th St., New York 19, N.Y.

Position available for Optical Designer, capable of handling the calcula-
tion and correction of aberrations in photographic and projection lens
systems.   Junior designers or engineers will be considered.   Write
fully giving education, experience, and other qualifications to Director
of Personnel, Bell and Howell Company, 7100 McCormick Road, Chi-
cago 45, Ill.

POSITIONS WANTED

Sound recording engineer, 16- or 35-mm equipment, studio or location
work, single or double system.   Free to travel.   For details write J. J. K.,
354 Ninth Ave., New York 1, N.Y.

Honorably discharged veteran with 15 years' experience in all phases of
motion picture production, including film editing, directing, producing.   For
details write F. A., 30-71 34th St., Long Island City 3, N.Y.   Telephone
AStoria 8-0714.

Projectionist-newsreel editor with 15 years' experience just released
from service.   Willing to locate anywhere.   Write P. O. Box 152, Hamp-
den Station, Baltimore 11, Maryland.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

CONTENTS

JOURNAL

OF THE

SOCIETY of MOTION PICTURE ENGINEERS
HOTEL PENNSYLVANIA • NEW YORK 1, N·Y· • TEL. PENN. 6 0620

HARRY SMITH, JR., EDITOR

Board of Editors

ARTHUR C. DOWNES, *Chairman*

JOHN I. CRABTREE   ALFRED N. GOLDSMITH   EDWARD W. KELLOGG
CLYDE R. KEITH   ALAN M. GUNDELFINGER   CHARLES W. HANDLEY
ARTHUR C. HARDY

Officers of the Society

President: DONALD E. HYNDMAN,
    350 Madison Ave., New York 17.
Past-President: HERBERT GRIFFIN,
    133 E. Santa Anita Ave., Burbank, Calif.
Executive Vice-President: LOREN L. RYDER,
    5451 Marathon St., Hollywood 38.
**Engineering Vice-President:* JOHN A. MAURER,
    37–01 31st St., Long Island City 1, N. Y.
Editorial Vice-President: ARTHUR C. DOWNES,
    Box 6087, Cleveland 1, Ohio.
**Financial Vice-President:* M. R. BOYER,
    350 Fifth Ave., New York 1.
Convention Vice-President: WILLIAM C. KUNZMANN,
    Box 6087, Cleveland 1, Ohio.
Secretary: CLYDE R. KEITH,
    233 Broadway, New York 7.
Treasurer: EARL I. SPONABLE,
    460 West 54th St., New York 19.

Governors

*†FRANK E. CAHILL, JR., 321 West 44th St., New York 18.
**FRANK E. CARLSON, Nela Park, Cleveland 12, Ohio.
**ALAN W. COOK, Binghamton, N. Y.
*JOHN I. CRABTREE, Kodak Park, Rochester 4, N. Y.
*CHARLES R. DAILY, 5451 Marathon St., Hollywood 38.
**JOHN G. FRAYNE, 6601 Romaine St., Hollywood 38.
**PAUL J. LARSEN, 1401 Sheridan St., Washington 11, D. C.
**WESLEY C. MILLER, Culver City, Calif.
*PETER MOLE, 941 N. Sycamore Ave., Hollywood.
*‡HOLLIS W. MOYSE, 6656 Santa Monica Blvd., Hollywood.
*WILLIAM A. MUELLER, 4000 W. Olive Ave., Burbank, Calif.
*REEVE O. STROCK, 111 Eighth Ave., New York 11.

---

*Term expires December 31, 1946.   †Chairman, Atlantic Coast Section.
**Term expires December 31, 1947.   ‡Chairman, Pacific Coast Section.

THE ILLUSION OF DEPTH IN MOTION PICTURES*

HOWARD T. SOUTHER**

Summary.—*Motion pictures are not realizable as such until they are perceived by the brain through the eye. The manner in which the eye operates is dealt with, particularly those functions having to do with perceiving objects as solids. The intelligent employment of motion picture taking equipment now in use, in making it conform to the requirements of the eye, can result in an important contribution to three-dimensional perception from the screen. Some 15 aids in promoting the illusion of depth are dealt with in this paper.*

Foreword.—Leonardo da Vinci said that pictures were the result of "giving corporeal shape to the three dimensions on a flat surface." In the execution of his masterpieces, Leonardo the *artist* used Leonardo the *scientist* to fix his design, to project his true perspectives, to mix his colors, and to imprison light like Ariel in his web. This paper presumes to deal with the methods by which the three-dimensional illusion is evoked by calling attention to some 15 contributing factors.

But before going further, it is well that we understand that any pictorial effect is not realizable as such until perceived by the brain through the eye. In a simple and general way, the camera, projector, and associated equipment serve as a delay mechanism for the presentation to an audience of an occurrence which it is desired that they should see. We must keep in mind at all times that the eye and its peculiarities of perception should govern the steps by which this delay is accomplished.

Two broad corrections in lighting treatment are needed to achieve this delay. The first is a considerable compression of the range of light intensities falling on the subject. This is necessary in order

---

245

that the exposure limits of the camera may be met.   These are much
less than those of the eye and generally call for an increase in the
normal amount of light present.   Second, a correction for color is
necessary.   The eye and the film are not linear with respect to each
other.   For instance, yellow affects the eye more violently than the
film; blue affects the film more violently than the eye.   There are
many other differences which call for compensation.   We shall take
up these points of variance more completely later.

The Illusion of Three Dimensions.—One of the aims of motion
picture presentation is to achieve the illusion of reality.   Optically
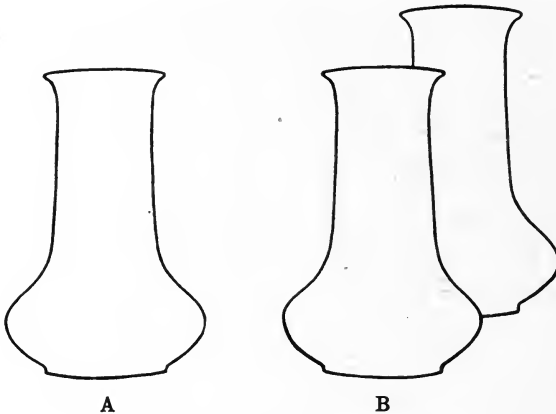

FIG. 1.   *A*—The shape of contours; *B*—Overlap.

speaking, we must duplicate wherever possible in the minutest
detail the actual experience of vision.   Paradoxically, the require-
ments of perfection should not be too strongly emphasized.   The
human being is capable of considerable psychological adjustment to
his environment in general; in this case, to the screen in particular.

The screen portrays its subjects many times oversize.   We all
realize that there is an easy adjustment to this seeming gigantism.
There is also the adjustment which permits comfortable observation
from the unnatural angle of the viewer.

In viewing a motion picture, the eye observes the scene in only 2
planes actually.   By employing the proper technique, an illusion of
three dimensions may be evoked.

Methods of Portraying Solidity.—The illusion of three dimensions

is built up upon the screen in a number of different ways.   The following methods are employed universally at present:

The Shape of Contours.—We view in Fig. 1*A* the outline of a vase. The drawing means to suggest merely the feeling of an enclosure separated from its background by only a line.

Overlap.—In Fig. 1*B* we observe a slight increase in the feeling of form.   The outlines of the 2 vases complement each other by virtue of the overlapped position.

Cast Shadows.—The cast shadows of the 2 vases, in Fig. 2, on the

FIG. 2.   Cast shadows.

background and the shadow of the first vase on the second have contributed tremendously to the feeling of form.   Note also that the *shape* of the shadows has a contributing effect.   Interest increases. Observe the contrast of light and shade.   As the shadows are lightened the beneficial effect decreases.   Heavy contrast results in more powerful delineation and perception of rounded form.

Perspective.—The simulation of an actual viewpoint and the normal decrease in size because of distance have resulted in an increased effect, seen in Fig. 3.   We are impressed psychologically by the duplication of an effect observed in everyday life.

Reflections.—The shape and position of the reflection of the vase in the water below in Fig. 4 is something we would expect in normal existence.   This is another duplication of the actual which increases interest and illusion.

Elevation and Light Reflections.—In Fig. 5 the form of the vase has changed in shape because of the changed viewpoint.   The phenomenon of foreshortening is experienced in graphic form.

The tempering of the shadow by reflected light produces another simulation of reality.   Daily experience again repeats in this figure.

Fig. 3.   Perspective.

All of these phenomena help in the three-dimensional illusion to a marked degree.   The most important aid to this illusion, none the less, would be one which we miss in motion pictures almost without exception;   that is, the function of the eyes in a stereoscopic manner. A more complete understanding of this important function of the eye may be achieved if we engage in a digression on the phenomenon of vision.

Definition of Sight.—Sight may be termed the perception by the brain through the eye of varying intensities of wavelengths of light, radiated or reflected from a substance or object.   Radiation may take place from generation within the object, in which case it incandesces, or glows, or by reflection of light by an objec- from the original source.   Varying intensities of reflection from port

tions of the object impinge themselves upon the retina of the eye, and cause the object to assume form in our brain.

Sensitivity of the Eye.—The sensitivity of the eye to different amounts of light can be measured.   In the same manner, the sensitivity to various degrees of light on motion picture films can also be measured.   However, the human eye is a wonderful device.   It is much more sensitive in ordinary ways than the film.

The eye can detect changes of light of one in a million.   The camera cannot.   The ability of the eye to define an object is infinitely more acute.   When we see a motion picture we must look through the eye

Fig. 4.   Reflections.

of the camera.   Whereas the retina of the eye consists of microscopic cells over 8,000,000 in number to the square inch, the finite granular structure of the film and the focusing limits of the camera decrease the definition of the object whose reflected light has caused an exposure upon its surface.   This phenomenon results in a distortion of the perceived image.   The sensitivity of the film to color does not at present correspond with that of the eye.   This results in a further distortion.

Distortion by the Eye.—The knowledge of the manner in which these distortions take place, and in what degree, are important in our work.   Distortions necessarily need not be bad.   If they are controlled they can be very useful and may contribute materially to the artistic effect of a scene.   A paper flower may be distorted so as to

appear more beautiful than a real one by proper lights and a camera. The converse is also true. A real flower may be distorted by bad lighting and camera operation so as to appear like a paper one. The difference in achieving the desired effect and the opposite bad effect lies in the proper use by the various technical departments of their equipment.

The Analogue of the Camera and the Eye.—The camera and the eye partake of a number of mutual properties. The first of these is the physical one of construction. Fig. 6 shows that both the camera and the eye possess lenses which focus or gather the light rays

FIG. 5. Elevation and light reflections.

and concentrate them upon the desired spot. In the eye this spot is the fovea of the retina. In the camera it is the film. If the eye and the camera reacted in the same manner in every way, our problems would be simplified. But it is the difference between the eye and the camera which concerns us. The operations and adjustments necessary to make the camera react like the eye, or in any manner which we may desire, are the reasons for the further study on this subject.

Convergence and Divergence of the Eyes.—The higher vertebrates are able to converge the axes of the eyes on nearer points. This enables the images of the point to coincide with the central spots of both retinas. This ability of the eye, and others, is associated with the development of the higher faculties of the mind. The

normal position of the human eyes is convergent or parallel, but it is possible also for the eyes to diverge.

The movement of the eyes is complex. When they move together to one side or the other, up or down in a vertical plane, there is no rotation of the optical axes, i. e., no torsion. When the visual plane is elevated and the eyes move to the right, they rotate to the right. When they move to the left, they rotate to the left. When the visual
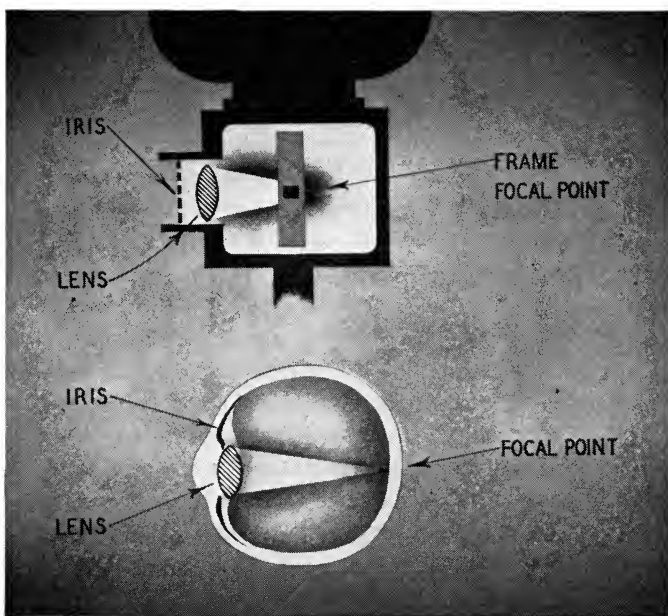

FIG. 6. The analogue of the camera and the eye.

plane is depressed and the eyes turn to the right, they rotate to the left, and vice versa. We constantly evaluate these complex muscular stresses, and *through experience* we interpret size, shape, and distance of objects. We must believe from this that a baby newly born must *learn* to see in 3 planes. They learn how far to reach for an object through evaluating muscular stress in the eye, and through actually evaluating the physical effort required in comparison to reach for it with their arm.

Accommodation by the Eye.—Objects at different distances cannot be seen clearly at the same time. However, by interpreting the

eye movements as the point of sight is focused forward and back-
ward, the intellect automatically appraises size, form, and the dis-
tance of each object.   This is the result of the ability of the eyes to
focus upon a particular object and the ability of the observer's mind
to determine from focus, and from previous experience in viewing
other objects, the approximate distance of the object viewed from the
eyes.   This is part of the factor of accommodation.

The combination of convergence and accommodation, carried out
unconsciously and automatically, produces the major depth effect.

Norling[1] says that the fundamental problem in projecting three-
dimensional pictures is that of "projecting a 'right eye' image which
will reach the right eye, and projecting a 'left eye' image which will
reach the left eye."

If we were to assume that each eye was capable of independent
scanning in the human being, the necessity of a particular picture
for the right eye and a particular picture for the left eye would be
eliminated.   We know that stereoscopic effects are achieved by the
camera today occasionally in the monoptical manner.

The premise is proved further by medical research.   Ives[2] says
that the old-time stereopticon photos resulted in a strain on the part
of the eyes when viewed for more than a short period of time.   This
would tend to prove the idea of independent, or monoptical scanning.
This would tend to prove, also, that the 2 eyes, scanning point for
point at the same time, are doing an unnatural thing when they
observe views in a stereopticon which keep them from scanning
independently.

Scanning.—The eyes constantly scan a scene being viewed.
When we dolly a camera, or when we follow with our eyes the actor
as he walks across the screen, we are increasing the feeling of three
dimensions very materially by scanning.   We are injecting arti-
ficially one of the stereoscopic effects of which the eyes are capable
when viewing the object in real life.

Monocular Stereoscopic Vision Versus Binocular Stereoscopic
Vision.—Now, a great deal is not known of the exact manner in
which the eye functions.   Most authorities agree that stereoscopic
vision implies binocular vision.   But this point is open to question.
If this were true, it would hold that animals, the axes of whose eyes
are spaced 180 degrees apart, would have considerable difficulty in
perceiving near objects because of the inability to converge.   The
actions and acuity of a deer, for instance, as far as distance is

concerned, would preclude such restriction. In this case, the animal would have no more advantage than the human in viewing the present motion picture with only those previously exposed aids to viewing depth. *This gives rise to the idea that distance can be realized very well monoptically.*

The writer is inclined to believe that those stereoscopic effects achieved at times accidentally on the screen have as their basis a *scanning* operation by the camera. In effect, the camera duplicates a normal function of the eyes.

This, if true, would tend to show that stereoscopic vision is not entirely, if at all, a matter of effect achieved binocularly. Among other things, it means that we have room for unlimited improvement in our work with present equipment. Perhaps our problems are largely concerned with the refinement of technique.

Psychology of the Eye.—Suggestion plays a great role in the art of seeing. Always we must hold in mind that we see with our *brain* through the eye. What the mind believes, the eye will see. We may hide the method, and the eye will believe the result, however achieved.

It has been the writer's intention in the foregoing paragraphs to show that a knowledge of the biology and psychology of seeing are very important. The intelligent use of equipment in conforming to the requirements of the eye will result in a great step toward our goal—*"corporeal shape to the three dimensions on a flat surface."*

[*Ed. Note.*—A 16-mm Kodachrome motion picture was shown illustrating a number of the various points discussed in the foregoing, emphasis being placed on the relative apparent motion of objects when the camera was moving. The demonstration is referred to in the Discussion section following.]

REFERENCES

[1] NORLING, J. A.: "Three-Dimensional Motion Pictures," *J. Soc. Mot. Pict. Eng.*, **XXXIII**, 6 (Dec., 1939), p. 612.

[2] IVES, CHARLES E., Eastman Kodak Company.

THE THEORY AND PRACTICE OF LIGHTING FOR THE CAMERA*

HOWARD T. SOUTHER**

Summary.—*It is the purpose of proper lighting to mold the dimensions, transmit the plane, and give to motion pictures the necessary mood and beauty. The screen image is a modified light reflection of reality, and light is the main source of photographic construction. This paper deals with the all important necessity of successful production, the exposition of lighting as a method. The theory and its application in practice are discussed. The employment of the principles of illusion in achieving photographic presentation is considered.*

Foreword.—The apparent mission of the cameraman is to flatter the senses with an illusion of reality. His secret and true aim is to purvey a psychical effect. The various methods of distortion, whether they be a soft presentation of the image or the sharp transmission of linear optics, all require subjective and stylistic motivation. If initiative and imagination are not used boldly, the camera loses its significance and means of expression. It becomes merely a tool of technique and artisanship.

But here we are faced with a problem. Although we may be artists at heart, we must be technicians in fact, in order that we may employ the technology of our art to paint the soul of the subject. And so the paragraphs which follow will seem intricately and trivially concerned with processes. Yet even miracles must have processes of some kind, however instantaneous.

In a given object, we may concede that the linear and graphic details are inherent in the thing itself. But it is the purpose of proper lighting to mold the dimensions, to transmit the plane, to provide spatial depth, and to give to the picture necessary mood and beauty. Taking into account the laws of optics and photographic transmission, the screen image is a modified light reflection of reality. Light is the main source of photographic construction. Without its primary organizational activity the screen image is impossible.

Lighting Theory.—Photographically speaking, there are 2 types of lighting, each producing a different visual effect:

(1) Direct, concentrated, or "hard" lighting, which produces a harshly contrasting distribution of light and shade. It reveals sharply the details of the object and the outline of its contours. It transmits the *volume* of the object through linear definition of its perspective. This type of illumination implies lighting from a very intense, single-point source.

(2) Diffused "soft" lighting, which reveals an easy plastic distribution of light and shade. Deep, bright, clear lights are almost entirely absent, while half-tones predominate in the image. It suggests space in the form of air—as vaguely plastic, fluid. It is the tool of *aerial* perspective, and tends to pictorial beauty with an evanescent quality. This lighting method implies illumination from a multiple-point light source, each point having a relatively low intensity.

The General Plan of Lighting for the Camera.—The basic idea in lighting for the camera is to cause the object being photographed to register on the film a *different* intensity of light from as many planes of the object as is possible. This plan may be modified by the compositional and emotional requirements of the scenario. The vignette, the silhouette, and the various demands of individual "shot" motivation can make necessary wide deviation from this precept. However, we shall maintain this basic idea because it develops for us the all important necessity of successful motion picture production— *method.*

Development of the Lighting Method.—One of the most important means of accomplishing the cinematic illusion is through lighting our object with the thought in mind that it is a series of planes. These planes are reflecting surfaces. Apparently each surface forms a projecting image when contrasted with a light of different intensity than that of the neighboring surface. Through the progression of a number of these seemingly opposing planes our conciousness builds the illusion on film of the third dimension when reality discloses only two.

Because the head is a commonly accepted subject for photography, and in view of the fact that it contains a complex series of planes, protuberances, and hollows, we shall use this difficult symbol for illustration. The mediums with which we illuminate this subject will be controllable sources of light. Some of these lighting elements will be beams and others will be lamps providing soft broad sources. Usage has given these units various names which are indicative of their function.

FIG. 1. Standard lighting setup illustrating positioning of the key-light.

The Main-Light or Key-Light.—The interception of light by an object in everyday life is from above.   Our key-light simulates the direction of the light source.   Usual composition places the object in a position facing the light source, and at an angle of 45 degrees below and around it.   The standard lighting set up is shown in Fig. 1. Later we shall take up the use of the other lights shown one by one.

This results in the casting of certain shadows.   It is well that we digress for a moment and consider that there are shadows of 3 general classifications, seen graphically in Fig. 2:

(1)   *Primary Shadows*—which are shadows on the object itself, consisting of those portions which receive no light from the source.   This is the simplest form of
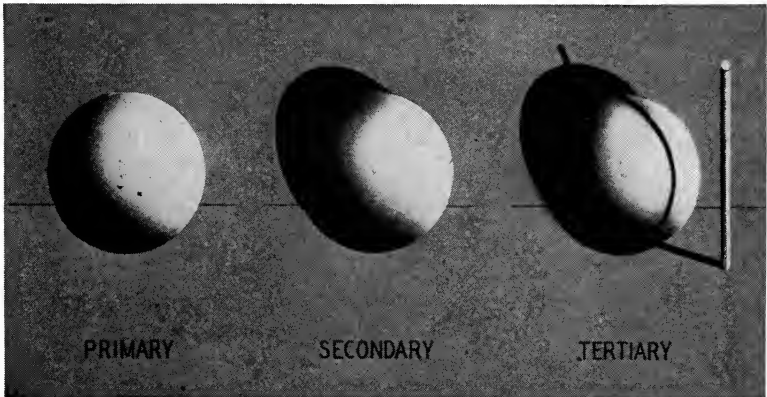
FIG. 2.   Diagram showing primary, secondary, and tertiary shadows.

shadow manifestation, but contributes materially to the modeling of the subject.

(2)   *Secondary Shadows*—Reference to the figure reveals this shadow to be the one thrown on the background by the interception of the object itself with the light source.   This shadow adds to the modeling effect, but is not nearly as important as those of the primary type in achieving an illusion of depth.

(3)   *Tertiary Shadows*—which are those caused on the object itself by other objects intervening between itself and the light source.   The importance of this shadow varies with the circumstances and form of the intervening objects.   In those cases where it may be employed, modeling is materially enhanced.   It can be seen that these shadows can be used to relieve a broad expanse illuminated by the key-light and assist in perceiving irregular contour.

Observe in Fig. 3 the phenomenon caused by the key-light of primary and secondary shadows under the eyes, the nose, on the

neck, and part of the chin. When employed in this manner, the key-light assumes the following attributes:

(1) It is generally the *hottest* or warmest light.
(2) The key-light simulates the light source.

FIG. 3.   Shadows which are a resulting phenomenon of the key-light.

(3) It is that light which concentrates the attention of the audience.
(4) It determines by its intensity the general *tonal accent* of the composition.

In exteriors, this light might be the actual sun. In some cases this light may impinge from the extreme side angle. Sometimes it may come as a three-quarter back-light. This latter condition will not so clearly reveal the character of the image in a physical way as in an emotional way, after the manner of an effect.

The Back-Light.—The back-light is placed in some region more or less behind the object. Physical requirements of the element placement in the shot most often require that this light be situated up and out of the range of the lens.

FIG. 4. Pseudo back-lighting—the use of a spot on the background to "blow out" the head contours.

At other times, it may be advantageous, under certain set conditions, to hide the back-light directly behind the subject's head. In other cases, it may be necessary to resort to a method known as pseudo back-lighting; the contrast of a brilliant spot on the background with the darker edge of the head area, seen in Fig. 4.

This last method can be used when the set placement is such that a back-light can not be positioned upon the subject.

The use of back-lighting presents the linear outline of the image. The contour is sharply defined. Used alone, the frontal plane assumes the character of the silhouette, a dark expanse of low tonal value.

FIG. 5.   The effect of employing fill-light.

Front-Light or Filler (Fill-Light).—This light is of the unconcentrated type. Fig. 5 will show that its broad, vague-point source serves to eliminate small creases and shadows. It has the effect of flattening out and making less apparent irregularities.

An important function of this light is to determine, in a way, the lower limit of the tonal scale in our compositional structure, so far as it concerns exposure. At times, this light is used to establish a "photographic black"—a phrase used to connote a dark tone, but

FIG. 7.   The effect of adding a camera-right kicker.

FIG. 6.   The addition of a camera-left kicker.

not one so definitely underexposed on the film that it assumes a muddy texture.

The more intense the front-light is, the lower the contrast of the picture. We experience a decrease in dynamism but observe an increase in the pictorial quality. In addition, this important light establishes the range of *tonal* gradations. It is very important in determining the elusive factor of quality in the lighting composition.

The length of exposure of the negative also plays a great part in achieving a given tone to the image. By underexposing (shortening the exposure time of the subject) we accomplish a general reduction in tone and a compression of the tonal scale. The image becomes contrasted in nature. By overexposing the image becomes higher in over-all tone value and loses the quality of contrast. The laboratory may control this factor in printing, also.

The name of the light—front-light—denotes its occupational position. It emanates from the region of the camera lens, frontally.

The 3 lights mentioned above are the most important lights used in the construction of our compositional product. However, there are other lights which are variations of the above. They have functions of lesser importance, but certain conditions of shot construction find them necessary and invaluable.

Three-Quarter Crosslight, or "Kicker."—The "kicker" partially assumes the nature of the back-light. It "limns" the object as does the light from which it is derived, but with a much thicker edge. It lines one side of the object only, shown in Fig. 6.

Sometimes two of these lights are used, one for each side, as seen in Fig. 7. It can be situated lower than the back-light. Because it is to one side, it may be moved over far enough to escape the camera line.

The name of the light is significant. It literally "kicks" the object out of the background, and makes it seem dimensionally forward in the shot.

Employment of Lighting Method.—The thought now presents itself that the camera might be able to photograph the subject from any angle with a given lighting setup. This variation of shooting angle might affect the editorial composition, but pictorially, and from the standpoint of plastic interpretation, the subject should translate itself very satisfactorily to the screen.

This conception involves the necessity for "taking the bull by the horns." Given a starting point for the beginning of the lighting proc-

ess, it behooves us to light the first unit, set it definitely in its position, adjust its intensity, and then proceed to work completely around the subject until we return to our starting point.

Adhering to our basic precept of achieving a difference of intensity for every plane of the subject, we must at all times bear in mind the following points:

(1)   From our study of color we have found that all colors have a difference in actinic quality.   Some colors require more light to bring them up to the required exposure level, some require less.
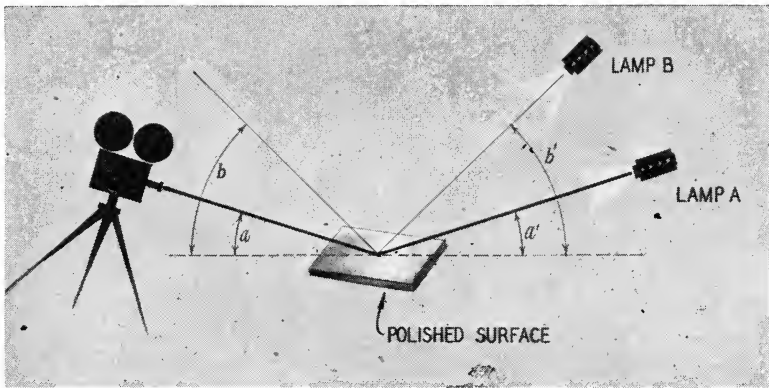
Fig. 8.   The effect of light reflection from an object to the camera with changing position.

(2)   The texture of the material of which the subject is composed may lend itself to a facile or a difficult transmission of light.   Inasmuch as exposure depends on light transmission *from the object*, this factor is most important in determining the intensity with which we illuminate that particular area.

(3)   The *angle of incidence* of the light has a very decided bearing on the intensity with which it reaches the camera lens by reflection.   If the angle of reflection to the lens exactly equals the angle of incidence upon the subject, the transmission is much more effective.   This means that the actual intensity of the light upon the subject must be gauged by sight from the lens position.   Substances with sheen or polish, therefore, require much more light if these 2 angles do not coincide, and much less if they do.   This is shown graphically in Fig. 8.

Water is the most difficult of subjects to light.   We may only photograph the halations and reflections on the water or, of course, those things which can be seen through the water.

A mirror represents impossibility.   We may photograph only those objects which are reflected into the mirror.

Portraiture.—In connection with the art of motion pictures, it is well to realize that emotion in the mind of the audience is based on visual sensation. This sensation is a process that has for its foundation the material reality of the actual things, and the human beings, before the camera. The nearer these things are to the camera, the nearer are they to the audience. This closeness promotes a stimulus which is in direct ratio to the size of the image on the screen.
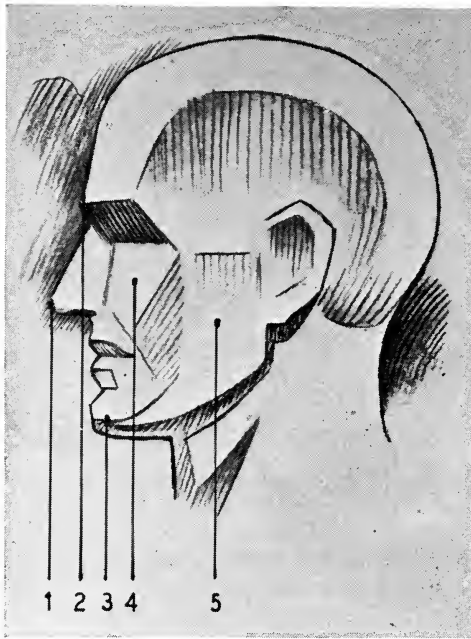

Fig. 9. Diagram listing the planes of the face.

Thus, a close-up of the face offers a prime means of communicating emotion to the audience. Through a near view of the subject, we may observe the *generation* of an idea, the *reaction* to a given occurrence, or the *pictorial qualities* of the idealized form.

This last brings us face to face with one of the most important creative problems of the cameraman. It consists in portraying in a close-up of the subject, either the *realized* form or the *idealized* form through the subtle mechanics of lighting.

Idealization.—We shall brook no argument with those who claim

that photogenics engender a false or superficial standard of beauty, nor will we agree wholly with those who claim that the subject being photographed must be characterized by a socially or historically significant treatment (the realized form).

It follows that we cannot exclude the possibility of looking at a subject from a certain standpoint with a measure of objectivity even though the illusion of perfection has been the result of, perhaps, an aesthetic formula or recipe.   It is perfection for which we strive, and this should result in pictures attaining true beauty.   This ephemeral quality we achieve through scientific and realistic motivation creatively applied to the camera.

The basis of formal beauty lies in an involved ideological complex. For hundreds of years, since the time of the Greeks, the ideal frontal contour of the human head has been subconsciously accepted as being egg shaped.

It would seem extreme to say that if the head did not assume this egg shape, it could not be beautiful, but we must understand that the concept of facial perfection is not indigenous to a group of people, it is peculiar to the individual.   It may not be easily fitted into the vise of uniformity.   The monstrous lips of African women charm their men.   Cleopatra by present standards is not what one would term attractive.   The tyranny of fashion once embraced the "wasp waist" (17th century).   The Romans had their noses.

In the pictorial synthesis of the face, the mind unconsciously takes those forms which deviate from the norm and attempts to make them conform in the mind's eye with this accepted ideal of the individual.

The less effort entailed in making the subject conform, the more pleasurable is the emotional reaction of the audience.   It is the cameraman's duty to promote this rationalizing process on the part of the viewer with every means at his command.   These means are based on the phenomenon of optical illusion.

The Planes of the Face.—As seen from the frontal position, the face offers a series of 5 planes.   If we interpret the face through the lighting treatment given these planes, shown in Fig. 9, we achieve the maximum in plastic rendering of the physiognomies.

The Necessity for a Standard.—Now, no doubt, there are as many conceptions of the ideal facial form as there are individuals to imagine them.   But for purposes of illustration, we may not equivocate.   We shall assume the Greek form as our standard of beauty. Given a starting point, we can be left to indulge ourselves in any

change, and we please our artistic side by preserving a subjective
approach to beauty.

Horizontal Divisions of the Face.—This arbitrary facial contour,
as set forth before, we shall assume to be egg shaped.   Next we shall
assume this form to be divided into 3 major equisections, seen in Fig.
10.   We then divide this form in half by a line.

The intersection of the first sectional line is the place where the
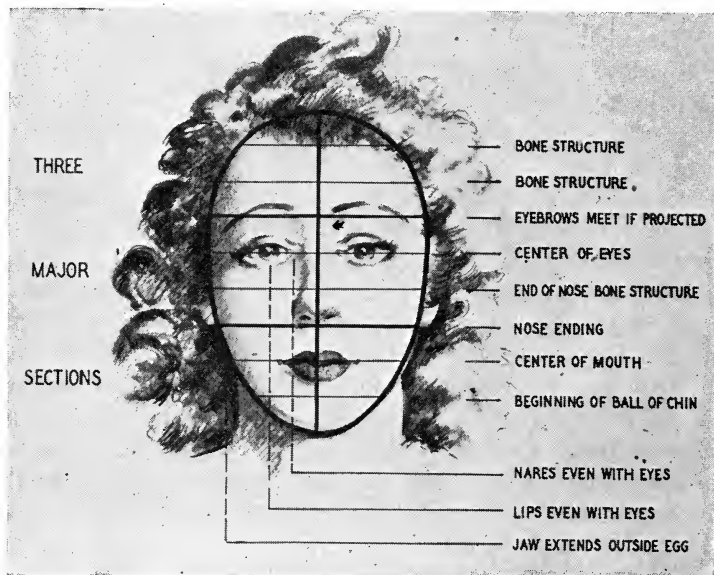eyebrows would meet, if they continued.

FIG. 10.   The divisions of the face.

The intersection of the vertical line at the next dividing line de-
termines the tip of the nose.

Each of these 3 major divisions is subdivided into 3 minor ones.
In the first case, the added horizontal lines determine the 2 ridges of
the bone structure which compose the brow.

The next division is more important.   The first intersection hori-
zontal line runs through the centers of the eyes.   The second line
intersects the end of the bone structure in the nose, and the beginning
of the cartilaginous portion.

The next line crosses the middle of the mouth.   The last line establishes the declivity which marks the beginning of the ball of the chin.

Vertical Divisions of the Face.—The vertical divisions of the ideal physiognomy are these:

At that line where the eyes are placed, the lateral space is 4 eyes wide.   The distance between the eyes is one eye in width.
The corners of the mouth extend to a point directly underneath the pupil.
The nares of the nostrils extend one-half this distance.
The jaw extends slightly outside of the confines of the head contour.
The hair areas assume an optional dimension.

Formation of the Side of the Face.—From the side of the face we observe that the ears are level with the eyes.

The cheek is a flat plane (sometimes slightly protruding, sometimes slightly hollow) and extends almost up to the frontal region of the eye.

The jaw line connects with the lobe of the ears.

Application of Principles to the Idealization Process.—The application of these principles to achieving the idealized form photographically is, of course, dependent upon the manner in which the subject differs from our individual concept of the ideal.   We classify below some of the more important deviations, and their correction through the manipulation of lighting.

Corpulence.—The presence of excess adipose in the face may be corrected in several ways:

(*1*)   Raising the Key-light.   The key-light may be raised and thus increase the downward thrust of the shadows on the face.   The effect is to compress the width of the subject seemingly through increasing its length.   (Lines and angles promote the illusion of length in the direction taken by them.)
(*2*)   Cross Key-lighting.   Taking the key-light more *around* the subject helps very materially in this respect through our illusion phenomenon.   The more cross positioned the key-light, the less area is illuminated from the camera position. (Dark is less noticeable with respect to area than light.   Most of the face is in mezzotone.)

Forehead Area Too Large.—Subduing the light incident upon the brow apparently decreases its size.   (Again dark is less pronounced than light.)

Double Chin.—Once more we have cause for a higher than normal

position of the key-light.   This throws the underside of the chin into darkness.   Less attention is directed to the fault.

Nose Faults.—Retrousse and beak noses require frontal composition in regard to camera position.   Profile composition is fatal.

The Eyes.—The eyes, because of the active muscles surrounding them, are the most expressive feature of the face.   In area, however, they do not possess the amount their importance would seem to demand in relation to other physiognomical elements.   We may direct attention to the eyes in various ways so that they will appear to be as really significant as they are.   Except for deformity, the eyes never seem too large.   In fact, size characterizes their beauty.

(1) · *Diminutive Eyes.*—Except for make-up, illusory lighting perhaps does more for the features in general and the eyes in particular, than movement, expression, or any other artifice employed by the individual.

(2)   *The Eye-Light.*—A special light consisting of a small unit situated near the camera lens will reflect back into the film as 2 pronounced points of hot light.   The halation commands attention and is very pleasing in effect.

(3)   *Focus.*—Sharp focus on the eyes is always important, but in portraiture, is absolutely essential.

(4)   *Masking the Eye-Light.*—If the eye-light is masked off from the rest of the face and allowed to impinge only as an elongated rectangle horizontal with the plane of the eyes, the law of illusion will manifest itself in a definite enlargement of this area.   A correlative result of this operation is to widen the head, subdue an otherwise unphotogenic facial composition, and direct the attention of the viewer to a specific reaction of the eyes alone.

Photographing Blue Eyes.—Blue eyes are very high in actinic value.   The iris tends to photograph much lighter than would be ordinarily observed in everyday life.   This results in a "washed out" and unexpressive appearance.   The use of a magenta or red gelatin on the eye-light assists in photographing subjects with eyes of this type.   These act as a filter and result in a much darker exposure. The result is a truer rendition of the subject characterization or, at least, control over the effect.

Wrinkles.—Wrinkles are the enemy of idealized photographic interpretation.   The remedy lies in the employment of reduced contrast.   This requires frontal placement of the key-light, increase of fill-light, and the use of optical filters over the lens of the camera.

The Illusion of Depth in Motion Pictures

QUESTION: The question is asked as to how the monocular method might be used.

LT. SOUTHER: The paper as presented means to suggest that the "monocular method" is currently employed in the taking of motion pictures, but not to the fullest extent possible. The thought implied by present-day use of the term "stereoscopic perception" includes as a prerequisite for viewing the use of spectacles or a mechanical device to cause a "right-eye picture" to reach the right eye and a "left-eye picture" to reach the left eye, and it was the purpose of this paper to present for consideration the fact that binocular perception by the brain of two disparate views of an object is not altogether necessary in achieving a superior illusion over that commonly obtained today.

The Fuller patents make use of the precepts exposed in this paper; that is, that three-dimensional perception is possible monocularly. Working on this premise, a dual image is imposed on the screen. By placing a line grating in front of the screen, the patent presumes to prevent the eyes or eye from scanning the image and thus duplicating the function which has already been performed by the camera. This line grating also presumes to prevent the eyes or eye from focusing on the image, thus duplicating another function already performed by the camera. Through the prevention of such duplication, the brain is allowed to perceive normally, through the eyes, the intent of the illusion originated by the camera.

QUESTION: The impression was given that the line-grating process ordinarily used 2 cameras and twin projectors, and that the grating prevented the image of one projector from being seen by both eyes.

LT. SOUTHER: That is an obvious method of purveying a right-eye image to the right eye, and vice versa. However, a complication is involved in that either movement of the head from side to side is necessary or, obviously, movement of the screen from side to side. The line grating as employed, with the intention propounded by the patent previously mentioned, serves a different function, namely that of preventing the eyes from duplicating actions already performed by the camera and thus spoiling the three-dimensional effect. This is rather an obtuse subject, I must admit. It requires considerable study and undoubtedly will receive a great deal of attention by experimenters in the future. I do feel, however, that the solution is not too far off, although it is not here at the present.

QUESTION: Do we get the same effect in viewing a motion picture with one eye as we do with 2 eyes?

LT. SOUTHER: I believe that the three-dimensional effect, observable through the line-grating method we have been discussing, would be increased not more than 50 per cent by viewing it with 2 eyes, providing the second eye was equally efficient as the first eye during the observation. In the reel that we have just seen, no special process was used other than an attempt to employ all the possible aids to roundness perception possible with current production methods. In the making of this reel everything was done to include as many foreground objects framing the picture as possible, in order to show one of the important aids to achieving illusion that we can use at present; that is, the relative apparent movement of objects when the camera is in motion. To answer your question

specifically, I do not think that there would be any vastly superior effect in viewing the usual motion picture with 2 eyes instead of one.

QUESTION: I have observed, in viewing Grandeur film, a pronounced increase in three-dimensionality when it was being shown some years ago. Have you any idea why this was so?

LT. SOUTHER: I believe that the increase in three-dimensional perception in this case was caused by the fact that the usual unnatural angle of the viewer was less pronounced because of the increased image size on the screen. We must realize that today, in viewing a motion picture with an aspect ratio of 3 to 4, we are more violently violating our visual continuity by confining the angle of view. We place ourselves in the theater in what would appear to be a long black tunnel, and view a scene transpiring in what would seem to be an opening at the end of this tunnel. Certainly this is something we are not used to in everyday life, and calls for a particular type of accommodation on the part of the viewer which must result in some irritation. I believe that this irritation reduces, unconsciously, the viewer's ability to perceive solidity. I would say that in my opinion the larger Grandeur screen, because it does not limit the angle of view so much, gives a greater three-dimensional effect, but only for that reason.

QUESTION: Could we have that reel run again? I would like to ask the members to confine their observation to the screen with one eye this time. I would also suggest that the members make a viewing tube out of their hands in order to exclude observation of the rest of the room. The purpose of this is to see if an increase in the three-dimensional effect is caused by such viewing.

[*Ed. Note.*—The film was re-run, and a show of hands was called for to indicate whether an increase in solidity had resulted from this observation with one eye and through the exclusion of the room in the field of view through the viewing "hole" formed by the hand. The show of hands indicated that approximately 80 per cent of the members present had experienced an increase in the feeling of three-dimensionality.]

QUESTION: Can we have the film run once more, and this time ask the members to cover one eye only and view the film without the tube formed by their hand?

[*Ed. Note.*—When the film was run, a show of hands was called for as to whether the effect was more pronounced or less pronounced than in the last test. Approximately 75 per cent of the members believed that there was less effect than before. The film was then run once more upon request, and viewed again with both eyes.]

The Theory and Practice of Lighting for the Camera

QUESTION: How is the intensity of the key-light controlled on the actor's face, particularly in a "two-shot?"

LT. SOUTHER: If I understand your question properly, I would say that the intensity of the key-light on an actor's face is determined by tests before the start of the production. The reflectiveness of certain make-ups differs, and the addition or decrease of key-light for a certain make-up must be predetermined. For all normal scenes thereafter throughout the picture the key-light intensity is adjusted to this same tested level. This presupposes the use of a controlled

standardized development process, such as that employed by Twentieth Century-Fox.   It is not unusual to have an entire day's shooting print on a single light setting.   Where two actors, both using make-ups of different reflectiveness, are illuminated by a single key-light, scrims must be employed on that side of the lamp to adjust the particular make-up to the degree of light transmission determined upon by tests before the start of the production.

It was pointed out during the demonstration that the use of dimmers on incandescent units calls for judgment in the choice of the power of the illumination unit. A unit too large, dimmed to the required intensity for a close subject, results in illumination of poor spectral quality, which in printing causes muddy texture owing to its low actinic value.   The proper regulation of arcs, when used as key-lights, calls for extreme care in placement of the illuminating unit and the precise application of scrims to control intensity.   Dimmers are not currently practical on arcs.

[*Ed. Note.*—The set shown in Fig. 1 was duplicated at the Conference with model for purposes of demonstration.   The units were lighted one by one, and their names and purposes explained.]

WESTREX STANDARD SOUND FILM REPRODUCER*

G. S. APPELGATE** AND J. C. DAVIDSON†

Summary.—A simplified sound film theater reproducer is described. The machine holds the film under constant tension and has a minimum of moving parts.

A review of the theater field for sound film reproducers has indicated a definite need for a machine that will fulfill the requirements of the relatively large field where equipment cost is a prime factor. Since the requirements permit no compromise on quality or performance, the need for a new basic design was indicated. Accordingly, the development of a machine was undertaken on this basis and each part was given a careful scrutiny to justify its use from the viewpoints of either assured performance or operating necessity. This work has resulted in a reproducer whose component parts are surprisingly few and yet whose film propulsion performance falls well within the recommended standards of the Research Council of the Academy of Motion Picture Arts and Sciences.

A front view of the machine is given in Fig. 1, showing the film, lamp, and photocell compartments. The film path is perhaps as simple as has been offered to the theater industry and approaches a straight vertical line from the holdback sprocket in the projector head to the lower magazine with no free loops to be set. The film is under a tension of approximately 300 grams from the lower sprocket in the projector to the sound sprocket in the reproducer.

The threading operation is both quick and simple. The film is passed under the upper filter arm roller, over the scanner drum, and over the lower filter arm roller. Before engaging the sound sprocket the film is pulled down until the arrow and line on the filter arm assembly are in approximate registry. The film is then engaged around and under the sound sprocket and over the idler roller which guides it into the fire trap of the lower film magazine.

The film filtering mechanism consists of a solid flywheel mounted on the scanner shaft which supplies the inertia element, 2 filter arms and rollers connected together by a spring, which furnish the compliance element where rates of flutter below 10 cycles are concerned, and viscous dashpot connected to the lower arm, which provides the damping element. Above 10 cycles the attenuation of disturbing frequencies by the film compliance gradually exceeds that furnished by the spring. While the filter parts are simple, an explanation of how they function involves a rather complicated electrical analogy and is covered in detail elsewhere.[1] It is sufficient here to state that
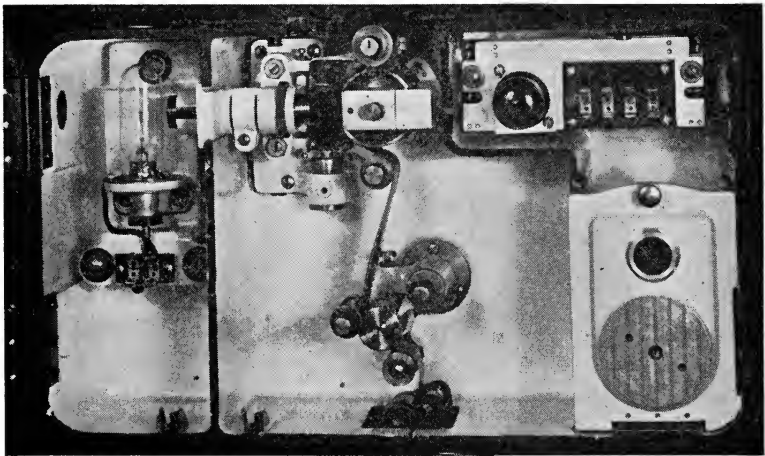
FIG. 1.   Front view of Westrex standard sound film reproducer.

the upper filter arm, which is not directly damped by the dashpot, supplies an attenuation of the order of 12 db per octave against disturbances arising in the projector head. This permits the elimination of the free loop between picture and sound head with a reasonable factor of safety. A further factor of safety against slow rates of disturbances occurring in either the projector head or take-up magazine has been provided by the use of a new sprocket tooth with a relatively wide base.

In the present film path where the film operates between 2 sprockets under a relatively fixed tension, it is desirable that the tension beyond the 2 sprockets be maintained at either a greater or lesser value than that existing between the sprockets. The tension of the film on the

incoming side of the upper sprocket, which is in the projector, is substantially zero, so that the requirement is met at this point.

The film leaving the lower, or sound sprocket, is at substantially the same tension as the take-up.   As long as the take-up tension is maintained at a higher value than that in the filtered path, the holdback sprocket can be eliminated with reasonable safety.   In the event the take-up tension approaches the same value as that in the filtered film path the variations in take-up tension may cause the film to travel between the limits of free play between the tooth and sprocket hole. The effect is, of course, attenuated by the belt action of the film on the sprocket and on the lower idler roller.

To minimize the amount of disturbance that might occur from this source, a new sprocket tooth has been developed which more nearly fits the sprocket hole, with due consideration for film shrinkage, *etc.*

The scanner assembly consists of a scanner drum, shaft, and flywheel and mounts in the main frame as a unit.   The filter arm assembly also mounts as a unit and consists of 2 arms and rollers mounted on cone pivots operating in ball races to produce a minimum of bearing friction and lateral play.   The upper roller is provided with a lateral adjustment to provide means for aligning the sound track with respect to the principal axis of the optical system.   The dashpot is easily removed for inspection.   The liquid used in the dashpot has been chosen for its small viscosity change with temperature to insure a sufficiently uniform damping characteristic.

The optical system consists of a flexibly mounted lamp bracket which takes the theater prefocused base $7^{1}/_{2}$-amp, 10-v exciter lamp, the Bausch and Lomb *41-87-35* objective, a collective lens, and a photocell.   The collective lens images the aperture of the objective lens onto the cathode of the photocell and gives approximately a uniform area of variable-intensity illumination on the cathode with modulation of the light beam.

The photocell is flexibly mounted and is coaxially coupled to a remotely located photocell amplifier.   The photocell mounting plate is so designed that it is interchangeable with a 2-stage photocell amplifier, should that arrangement be preferred to the coaxial cable coupling.

The drive arrangement is somewhat different from current practice and contains some interesting features, particularly when considered from the standpoint of ease of assembly and alignment.   It is shown in Fig. 2.   With the exception of the scanner assembly, the sound

sprocket shaft is the only one that is mounted in the main frame casting. This shaft is driven by the motor through double vee-belts. Since the motor is flexibly mounted, the vee-belts provide a coupling that transmits very little motor vibration to the film drive mechanism. Double belts are used to minimize the effect of belt irregularities on the machine's performance. The belt drive also simplifies the motor alignment problem. Different motor speeds are accommodated by a change of pulleys. If synchronous interlock operation is desired, the vee-belts are replaced by a silent chain drive.
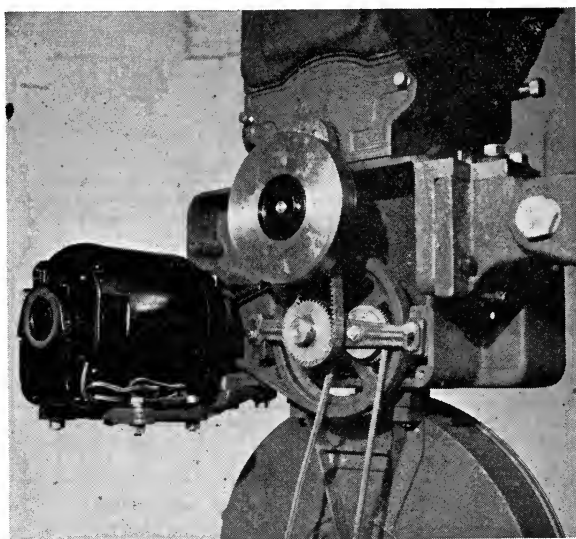
FIG. 2.   Drive gear assembly.

Also mounted on the sprocket shaft are the silent chain sprocket for driving the projector head and a gear to couple with the take-up pulley shaft. The take-up pulley and its driven gear are located by means of a stub shaft on a spider that centers on the sprocket shaft and is locked by 2 screws to bosses on the main frame. An idler to tension the projector drive chain is also mounted on the spider. The take-up belt tension is adjusted by loosening 2 screws and rotating the spider.

Fig. 3 shows a chart of flutter as measured on a preproduction model of the reproducer. It will be observed that the total integrated flutter from 2–200 cycles does not exceed ± 0.09 per cent, while no dis-

crete disturbance between $2^1/_2$ and 200 cycles is greater than ± 0.05 per cent.   Occasional irregular disturbances in the bands between 0–1 and 1–$2^1/_2$ cycles reach as high as ± 0.06 and ± 0.08 per cent, respectively.   This results from the fact that full advantage of the new sprocket tooth could not be taken because a few laboratories still release on film that does not have standard positive perforations.

The type of film path and filter system used in this reproducer is substantially identical with that used in several designs of studio recorders and rerecorders.   Tests set up to simulate operation under
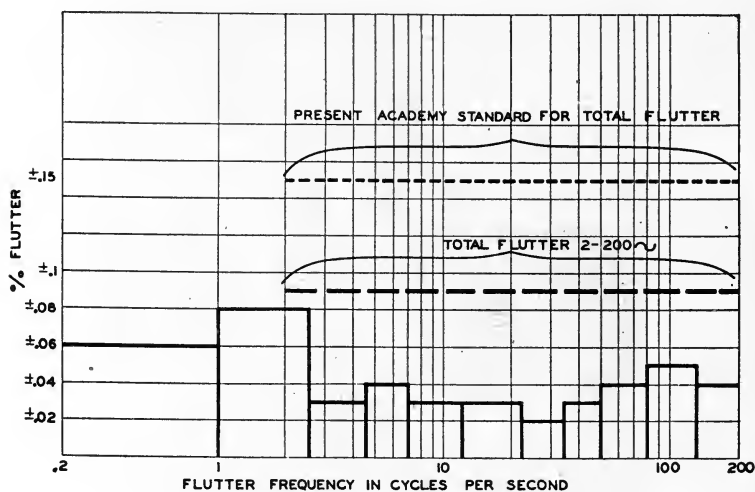
Fig. 3.   Flutter performance chart.

adverse conditions indicated that little or no effect was discernible in the reproduced sound.

Film weave in this system appears to be negligible.   In one test, sprocket eccentricity to the extent of 18 mils was introduced and while the filter arms were set into considerable motion, only a very small increase in measured flutter was found.   A piano recording was reproduced under this condition and the listeners were unable to detect the effect of the sprocket eccentricity.   The photocell network and coaxial cable pick up no machine noise that is audible under any normal condition of operation.

In conclusion, it is felt that the performance as well as the simplicity of this reproducer have fully met the design expectancy.

The authors desire to take this opportunity to acknowledge the contributions to this design made by the engineering department of the Century Projector Corporation.

REFERENCE

[1] DAVIS, C. C. "An Improved Film Drive Filter Mechanism," to be published in a forthcoming issue of *J. Soc. Mot. Pict. Eng.*

WESTREX MASTER SOUND FILM REPRODUCER*

G. S. APPELGATE** AND J. C. DAVIDSON†

Summary.—The following article describes a new design of film reproducer which has brought the flutter content to a minimum, and which will maintain its low flutter rate regardless of ordinary wear and tear. Other unique features embodied in the design are a new optical system, rugged construction and ease of maintenance.

Over 7 years have elapsed since the Western Electric Company developed its last theater sound film reproducer. The interval of time has been sufficiently long to permit a well-considered evaluation of how much has been accomplished as well as to point the direction that future development should take.

When the former machines were in good adjustment and the film was in good condition, the performance obtained appeared to meet the needs of the theater industry rather satisfactorily. The machines, however, were subject to two vagaries which sometimes affected their performance to a point that was discernible to a critical listener. These may be summed up as scanner-bearing trouble and the physical condition of the film. Either resulted in an increase in the low rates of flutter.

It seemed, therefore, that future endeavor should point first toward the attainment of assured stability of operation and then toward such further improvement in performance as may seem to be justified.

In the new reproducer a film path and filter system have been developed wherein the film compliance is utilized to obtain attenuation of high-frequency disturbances while at the same time means are provided to minimize the possibility of the vagaries of the film from setting up low rates of flutter sometimes referred to as "wows." The theoretical basis for the filter system is discussed in detail elsewhere.[1]

A front view of the machine is given in Fig. 1, with the doors open and with the photocell amplifier cover plate removed. Film has been threaded to show the film path.

Film Path.—The film is received from the projector head as a free loop and is held in contact with the scanning drum by a pressure roller. It leaves the drum under controlled tension, passes over the damped spring compliance roller, and is then engaged by the sound sprocket. There is a free film loop between the sound sprocket and
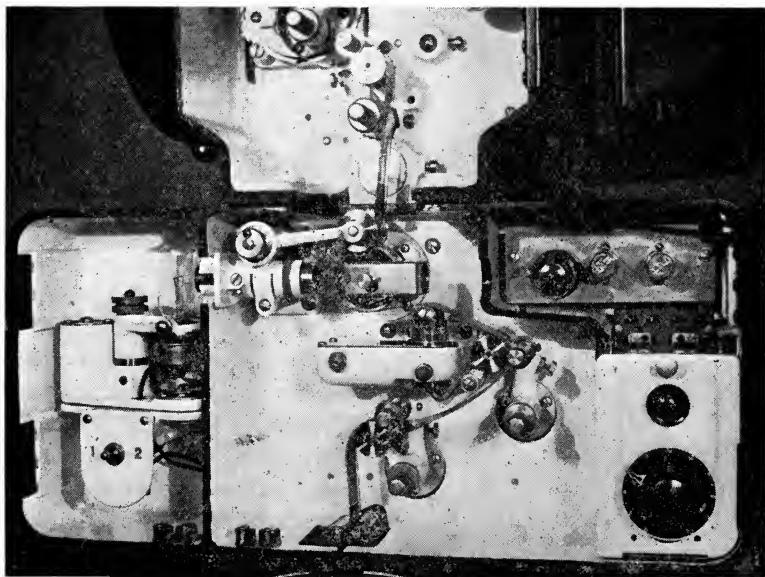
FIG. 1. Front view of Westrex master sound film reproducer.

the holdback sprocket. Thus it is seen that the film path between the scanner and the sound sprocket is isolated from disturbances originating in either the picture head or take-up magazine by free loops. The pressure roller is provided with means for lateral movement to align the sound track with the optical axis. This adjustment is provided with an indexed head so the correction for a misplaced sound track can be preset and the alignment can be returned to normal without requiring special attention.

With the machine running it is desired that the film between the scanner drum and the sound sprocket be under a tension of approxi-

mately 300 grams.   Since there is a free loop above the scanner drum, this requires that a constant load be applied to the latter. This is accomplished by associating an eddy current drag with the scanner flywheel.   The eddy current drag is obtained by a copper ring rotating in a magnetic field produced by permanent magnets. The amount of drag is controlled by altering the position of the magnets and it, in turn, determines the amount of tension in the film be-

tween the scanner drum and the sound sprocket.
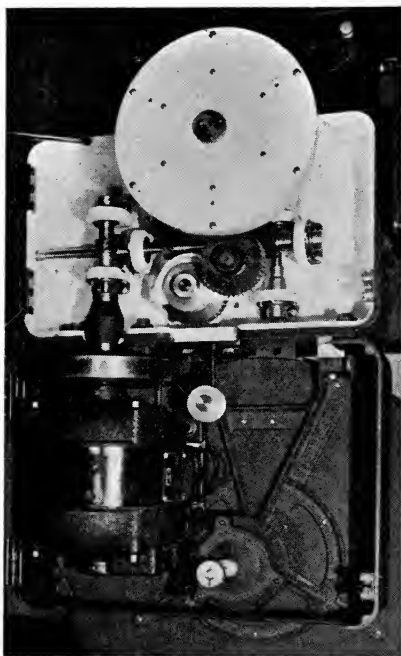
Scanner Assembly.—The scanner assembly consists of a scanner drum, a solid flywheel, and an eddy current ring and permanent magnets mounted in a closed casting. It mounts as a complete assembly in the main frame wall by means of 3 cap screws.   Its radial position is determined by a dowel pin, thus facilitating its removal and replacement without adjustment change.   In the previous scanner designs irregular bearing friction has been a major source of trouble, particularly since the film was under relatively light tension.   In the present design, the scanner shaft is supported in 2 small $^3/_8$-in. outboard ball bearings

Fig. 2.   Drive gear assembly.

and as a result, disturbances from the scanner bearings have been practically eliminated.

Compliance Damper Assembly.—The compliance damper assembly consists of a casting in which is mounted a pivoted arm.   The arm is spring tensioned and has a viscous damper attached to it. The arm supports a ball-bearing mounted roller over which the film rides.   The arm pivots have been designed to have a minimum of friction and lateral play and consist of cone points operating in ball races.   The spring tension is adjustable by means of a locknut and

screw.   The cup containing the damping fluid is readily removed for inspection by loosening a thumbscrew.   The damping fluid has been chosen to have a minimum of viscosity change with temperature.

Optical System.—The optical system consists of the prefocused base, 9-v, 4-amp exciter lamp, the Bausch and Lomb *41-87-35* objective, a pair of collective lenses, and a photocell.   The lamp assembly is flexibly mounted and contains the usual lamp and an auxiliary lamp with means for adjustment of the filament in the vertical plane.   In case of an emergency burn-out, the auxiliary lamp can readily be
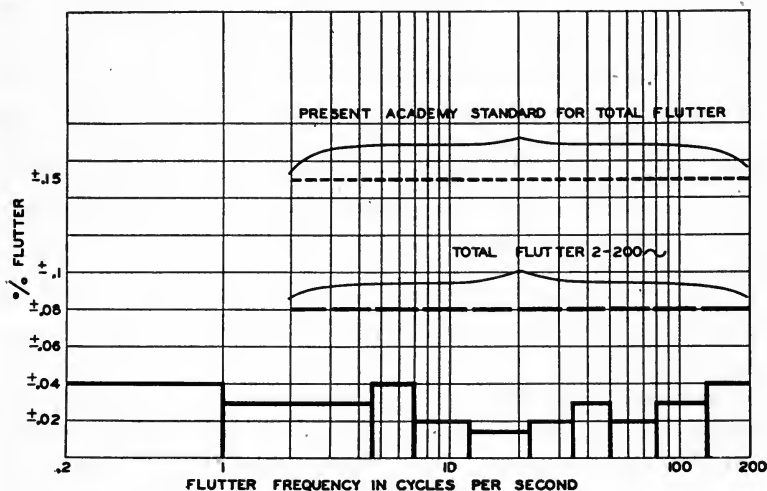
FIG. 3.   Flutter performance chart.

moved into its correct position on the optical axis, and power transferred to it by operating the auxiliary lamp switch.   The Bausch and Lomb lens tube has been widely used in the theater field and needs no description.

Between the film plane and the photocell is a doublet lens followed by a single lens.   The doublet images the film plane in the aperture of the single lens, thus providing a plane in which separator lenses may be placed for scanning 100-mil push-pull or double track should this requirement arise.   The single lens images the aperture of the doublet onto the cathode of the photocell.   Under this condition the photocell cathode sees a spot of light of uniform area and variable in intensity, irrespective of the nature of the modulation on the film.

The collective lens system assembly is removable by means of a thumbscrew for cleaning.

Drive Mechanism.—Fig. 2 shows a rear view of the machine with the rear cover and motor cover removed. It shows the drive gear assembly.

The drive mechanism has a vertically mounted motor that is flexibly coupled to a vertical shaft. This shaft drives a horizontal shaft through a pair of right-angle helical gears. The horizontal shaft contains 2 helical drive gears which drive 2 cross shafts. · One cross shaft supports the sound sprocket. The second supports the holdback sprocket and the chain sprocket for driving projector heads other than the Century head. A third cross shaft provides the drive for the take-up and is gear coupled to the holdback sprocket shaft.

When the sound head is set up with a Century projector a new type of coupling has been provided. This consists of a second vertical shaft in line with and coupled to the vertical shaft in the projector head by a flexible shaft. This eliminates the relatively expensive chain or pinion drive in current use with other types of projector heads.

A flywheel is provided on the motor shaft to insure a sufficiently slow starting time and a hand brake is available for a quick stop in case of a film break.

Transmission System.—The photocell and a 2-stage photocell amplifier are assembled on a small flexibly mounted chassis which is removable for inspection. Two Western Electric *6AK5* tubes are used. The first stage is a gain stage, while the second is an impedance transforming stage of the cathode follower type. A separate gain attenuator is mounted on each machine. The attenuator is located beyond the photocell amplifier at a point of relatively high level.

Performance.—Fig. 3 shows a chart of the performance from the flutter standpoint as measured on a preproduction model of the reproducer. It will be noted that at no flutter rate does the amount of flutter exceed ± 0.04 per cent, while the total integrated flutter from 2 to 200 cycles does not exceed ± 0.08 per cent. This performance is considerably better than the flutter requirements of the present standard of the Research Council of the Academy of Motion Picture Arts and Sciences. The time of recovery after the passage of a film splice is less than one second. There is little tendency for the film to weave in this tensioned system. Sufficient studies have been made to indicate that this performance will be realized in commercial

production and will be maintained in the field with a minimum of service.

The transmission system has been sufficiently isolated so that no machine noise can be heard above photocell hiss with the machine running, the lamp on, and no film in the optical path.

The authors wish to take this opportunity to acknowledge the numerous contributions of machine design that have been made by the engineering department of the Century Projector Corporation.

REFERENCE

[1] DAVIS, C. C.: "An Improved Film-Drive Filter Mechanism," to be published in a forthcoming issue of *J. Soc. Mot. Pict. Eng.*

AMERICAN STANDARDS ON MOTION PICTURES

FOREWORD

Industrial standards are by nature not static rigid limits that once established must be adhered to religiously for all time. They are subject to change as are the changing times and so must be reviewed, revised, and brought up to date periodically, if the industry that prepared them is to continue to look on them with favor.

Once each year, Sectional Committee on Motion Pictures Z22 of the American Standards Association reviews all *American Standards* on Motion Pictures, determining whether the substance and form of presentation are still suitable to continue serving their original purpose.

Following the October 17, 1945, meeting of Committee Z22, eight American Standards were reaffirmed, subsequently approved by the ASA and will remain active for the present time.

The war procedure of the ASA requires that all *American War Standards* shall be reviewed after the end of hostilities to determine whether they should be:

(1) Reapproved and continued as *American Standards*.
(2) Revised, if necessary; or
(3) Dropped if they have outlived their usefulness.

Consequently all published *American War Standards* on Motion Pictures were also reviewed. Fifteen were approved to continue now as *American Standards*. They have been assigned Z22 numbers and are published here in American Standard format.

Three of the reaffirmed Z22 Standards, Z22.37, Z22.,38, Z22.39, were published previously in the August, 1944 JOURNAL, and since these are of comparatively recent date they are not reprinted here.

The published *American Standards* are the result of effective collaboration over a long period by a large number of important groups in the motion picture industry. The continued and valued co-operation of the many individual members of the Armed Forces, the Re-

search Council of the Academy of Motion Picture Arts and Sciences, and the Society of Motion Picture Engineers is gratefully acknowledged.

With the exception of the 3 Standards appearing in the August, 1944 JOURNAL, the publication of the 20 Standards listed here supersedes all previous publication of these *American Standards* on Motion Pictures.

AMERICAN STANDARDS

Z22.2-1946	35-Mm Sound Film; Emulsion and Sound Record Positions in Camera—Negative
Z22.3-1946	35-Mm Sound Film; Emulsion and Sound Record Positions in Projector—Positive (for Direct Front Projection)
Z22.9-1946	16-Mm Silent Film; Emulsion Position in Camera—Negative
Z22.15-1946	16-Mm Sound Film; Emulsion and Sound Record Positions in Camera—Negative
Z22.21-1946	8-Mm Silent Film; Emulsion Position in Camera—Negative
Z22.40-1946	Sound Records and Scanning Area of 35-Mm Sound Motion Picture Prints
Z22.41-1946	Sound Records and Scanning Area of 16-Mm Sound Motion Picture Prints
Z22.42-1946	Sound-Focusing Test Films for 16-Mm Sound Motion Picture Projection Equipment, Specification for
Z22.43-1946	3000-Cycle Flutter Test Film for 16-Mm Sound Motion Picture Projectors, Specification for
Z22.44-1946	Multifrequency Test Film Used for Field Testing 16-Mm Sound Motion Picture Projection Equipment, Specification for
Z22.45-1946	400-Cycle Signal Level Test Film for 16-Mm Sound Motion Picture Projection Equipment, Specification for
Z22.46-1946	16-Mm Positive Aperture Dimensions and Image Size for Positive Prints Made from 35-Mm Negatives
Z22.47-1946	Negative Aperture Dimensions and Image Size for 16-Mm Duplicate Negatives Made from 35-Mm Positive Prints
Z22.48-1946	Printer Aperture Dimensions for Contact Printing 16-Mm Positive Prints from 16-Mm Negatives
Z22.49-1946	Printer Aperture Dimensions for Reversal and Color Reversal Duplicate Prints
Z22.50-1946	Reel Spindles for 16-Mm Motion Picture Projectors
Z22.51-1946	Intermodulation Tests on Variable-Density 16-Mm Sound Motion Picture Prints, Method of Making
Z22.52-1946	Cross-Modulation Tests on Variable-Area 16-Mm Sound Motion Picture Prints, Method of Making
Z22.53-1946	Resolving Power of 16-Mm Motion Picture Projector Lenses, Method of Determining
Z22.54-1946	Freedom from Travel Ghost in 16-Mm Sound Motion Picture Projectors, Method of Determining

One other group of 25 *American Standards* has been referred back to the SMPE for disposition. Two *American Standards* have been referred back to the Research Council of the Academy of Motion Picture Arts and Sciences, and 3 *American Standards* are being revised by a subcommittee of Z22. These 30 Standards will also be published in the JOURNAL as soon as they are formally approved through the procedure of the Research Council of the Academy of Motion Picture Arts and Sciences, the Society of Motion Picture Engineers, and the American Standards Association.

American Standard
Emulsion and Sound Record Positions in Camera for 35-Millimeter Sound Motion Picture Film*

Drawing shows film as seen from inside the camera looking toward the camera lens.

1. Emulsion Position

1.1 The emulsion position in the camera shall be toward the lens, except for special processes.

2. Speed of Projection

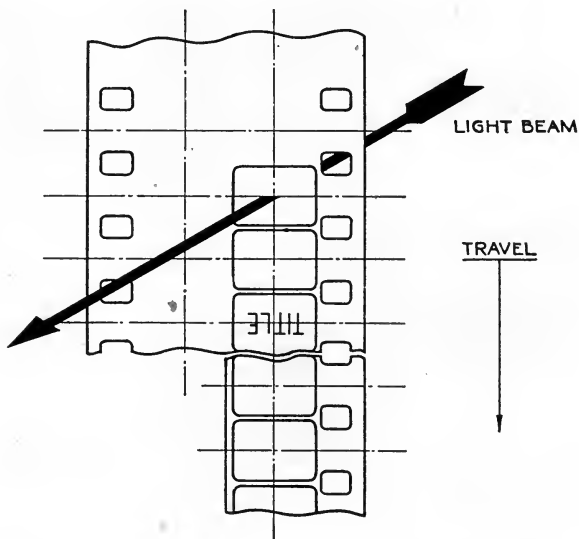**2.1** The speed of projection shall be 24 frames per second.

3. Distance Between Picture and Sound

3.1 The distance between the center of the picture and the corresponding sound shall be 20 frames.

*The title of this standard is the only revision from the 1941 edition.

American Standard
Emulsion and Sound Record Positions in Projector for 35-Millimeter Sound Motion Picture Film*
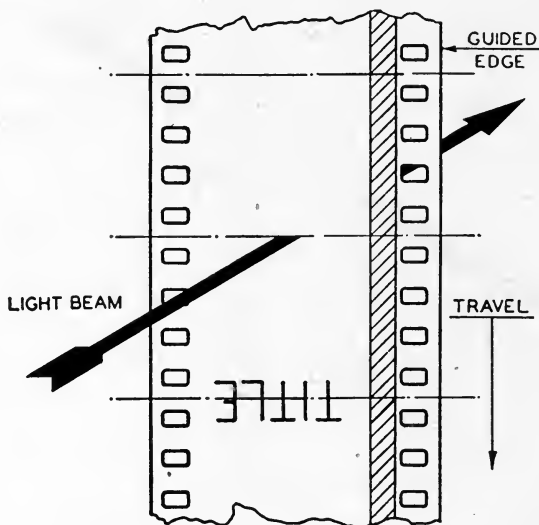
Drawing shows film as seen from the light-source in the projector.

1. Emulsion Position

1.1 The emulsion position in the projector shall be toward the light-source, except for special processes.

2. Speed of Projection

2.1 The speed of projection shall be 24 frames per second.

3. Distance Between Picture and Sound

3.1 The distance between the center of the picture and the corresponding sound shall be 20 frames.

*The title of this standard is the only revision from the 1941 edition.

American Standard
Emulsion Position in Camera for
16-Millimeter Silent Motion Picture Film*

ASA
Reg. U. S. Pat. Off.
Z22.9-1946
First Edition
Z22.9-1941
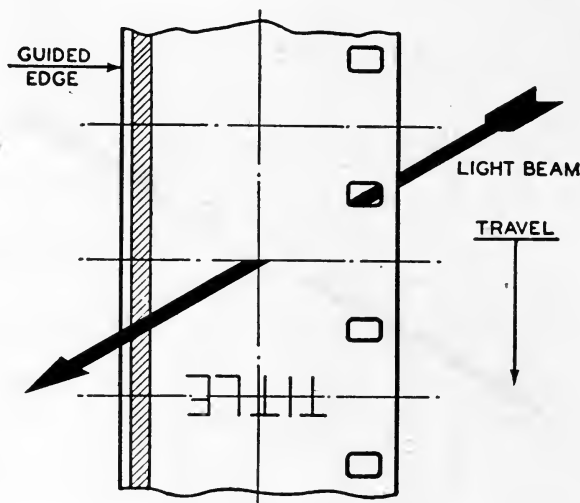
Drawing shows film as seen from inside the camera looking toward the camera lens.

1. Emulsion Position

1.1 The emulsion position in the camera shall be toward the lens, except for special processes.

2. Normal Speed of Exposure

2.1 The normal speed of exposure shall be 16 frames per second.

*The title of this standard is the only revision from the 1941 edition.

American Standard
Emulsion and Sound Record Positions in Camera For 16-Millimeter Sound Motion Picture Film*

Drawing shows film as seen from inside the camera looking toward the camera lens.

1. Emulsion Position

1.1 The emulsion position in the camera shall be toward the lens, except for special processes.

2. Speed of Projection

2.1 The speed of projection shall be 24 frames per second.

3. Distance Between Picture and Sound

3.1 The distance between the center of the picture and the corresponding sound shall be 26 frames.

*The title of this standard is the only revision from the 1941 edition.

American Standard
Emulsion Position in Camera for
8-Millimeter Silent Motion Picture Film*

Drawing shows film from inside the camera, looking toward the camera lens.

1. Emulsion Position

1.1 The emulsion position in the camera shall be toward the lens, except for special processes.

2. Normal Speed of Exposure

2.1 The normal speed of exposure shall be 16 frames per second.

*The title of this standard is the only revision from the 1941 edition.

American Standard
Sound Records and Scanning Area
of 35-Millimeter Sound Motion Picture Prints

ASA
Reg. U. S. Pat. Off.
Z22.40-1946
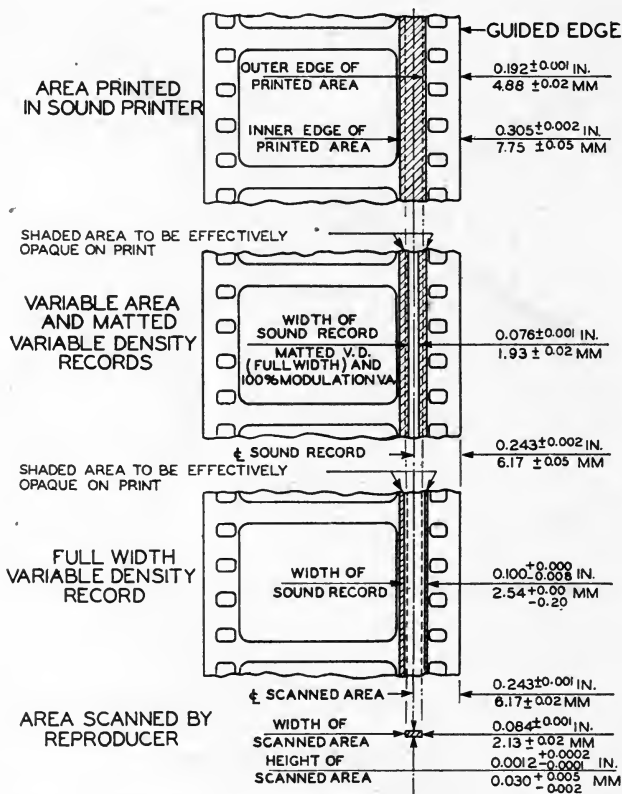
Distance Between Sound and Corresponding Picture — The sound shall precede the center of the corresponding picture by a distance of 20 ± ½ frames.

These Dimensions and Locations Are Shown Relative to Unshrunk Raw Stock

American Standard
Sound Records and Scanning Area
of 16-Millimeter Sound Motion Picture Prints

ASA
Reg. U. S. Pat. Off.
Z22.41-1946

GUIDED EDGE

0.018 IN. MAX
0.457 MM MAX

0.110 IN. MAX, 0.098 IN. MIN
2.794 MM MAX, 2.489 MM MIN

OUTER EDGE OF PRINTED AREA

INNER EDGE OF PRINTED AREA

PRINTED AREA

0.058 ± 0.002 IN.
1.473 ± 0.051 MM

¢ SOUND RECORD

$* \ 0.060^{+0.006}_{-0.001}$ IN.
$1.524^{+0.152}_{-0.025}$ MM

* WIDTH OF SOUND RECORD
V.D. SQUEEZE OR 100% MODULATION V. A.

VARIABLE AREA AND VARIABLE DENSITY SQUEEZE RECORDS

0.058 ± 0.002 IN.
1.473 ± 0.051 MM

¢ SOUND RECORD

0.080 ± 0.001 IN.
2.032 ± 0.025 MM

WIDTH OF SOUND RECORD

FULL WIDTH VARIABLE DENSITY RECORD

0.058 ± 0.002 IN.
1.473 ± 0.051 MM

¢ SOUND RECORD

0.072 IN. MAX, 0.070 IN. MIN
1.829 MM MAX, 1.778 MM MIN

WIDTH OF SCANNED AREA

SCANNED AREA

0.058 ± 0.001 IN.
1.473 ± 0.025 MM

¢ SCANNED AREA

These Dimensions and Locations Are Shown Relative to Unshrunk Raw Stock

*This dimension for the width of the sound record of variable density squeeze tracks and of variable area tracks at 100 percent modulation is based on present day equipment design. It is recommended that all future equipment be designed for a record width of 0.060 ± 0.001 inch. It is also recommended that existing equipment be modified to produce prints having variable density squeeze and 100 percent modulation variable area records with a width as close as practicable to 0.060 ± 0.001 inch.

American Standard Specifications for **Sound-Focusing Test Films** for 16-Millimeter Sound Motion Picture Projection Equipment	ASA Reg. U. S. Pat. Off. **Z22.42-1946**

1. Scope and Purpose

1.1 This specification describes test films to be used for checking the focus of the scanning beam of 16-mm sound motion picture projectors.

2. Test Films

2.1 The test films shall have an originally recorded variable-density sound track, heavily overmodulated and developed to high contrast so that the resultant track is essentially a square-wave track.

2.1.1 The test films shall be of 2 types:

Type A — 7000-cycle recording for manufacturing and precision adjustment of sound focusing;

Type B — 5000-cycle recording for quick field adjustment of focusing.

2.2 The sound track shall have correct azimuth within $\pm$ 5 minutes of arc.

2.3 Each test film shall be provided with a suitable leader, title, and trailer.

2.4 The standard length of the test films shall be 100 feet.

NOTE: A test film in accordance with this standard is available from the Society of Motion Picture Engineers.

American Standard Specifications for
3000-Cycle Flutter Test Film
for 16-Millimeter Sound Motion Picture Projectors

1. Scope and Purpose

1.1 This specification describes a 3000-cycle sound test film for use in determining the presence of flutter in 16-mm sound motion picture projectors.

2. Test Film

2.1 Recording. The test film shall have either an originally recorded, direct-playback positive variable-area sound track or an originally recorded variable-density sound track developed as a toe record. The recorded frequency shall be within ± 25 cycles of the nominal 3000-cycle frequency. The modulation of the recording shall be 80 ± 5 percent. The output level of the film shall be constant within ± ¼ db. (This is equivalent to an amplitude tolerance of ± 0.0015 inch when recording variable-area sound track with a nominal amplitude of 0.055 inch.) The recording shall be accomplished in a recorder so constructed as to keep the flutter content to the absolute minimum consistent with the state of the art. The total rms flutter content of the film shall be less than 0.1 percent upon shipment by the test film manufacturer. The wave-form distortion of the recording shall not exceed 5 percent.

2.2 Film Stock. The film stock used for the test film shall be cut and perforated in accordance with the American Standard 16-Mm Sound Motion Picture Film; Cutting and Perforating for Negative and Positive Raw Stock, Z22.12-1941, or latest revision thereof.

2.2.1 *Resistance to Shrinkage.* The film stock used for the test film shall have a maximum lengthwise shrinkage of 0.50 percent when tested as follows: At least 20 strips of film approximately 31 inches in length shall be cut for measurement of shrinkage. After normal development and drying (not over +80 F [+26.7 C]), the strips shall be placed at least ¼ inch apart in racks and kept for seven days in an oven maintained at +120 F (+49 C) and a relative humidity of 20 percent. The strips shall then be removed, reconditioned thoroughly to 50 percent relative humidity at +70 F (+21.1 C), and the shrinkage measured by an adaptation of the pin-gage method outlined in Research Paper RP-1051 of the National Bureau of Standards. The percent shrinkage shall then be calculated on the basis of deviation from the nominal dimension for the length of 100 consecutive perforation intervals given in American Standard Z22.12-1941, or latest revision thereof.

2.3 Standard Length of Film. The standard length of the flutter test film shall be 380 feet.

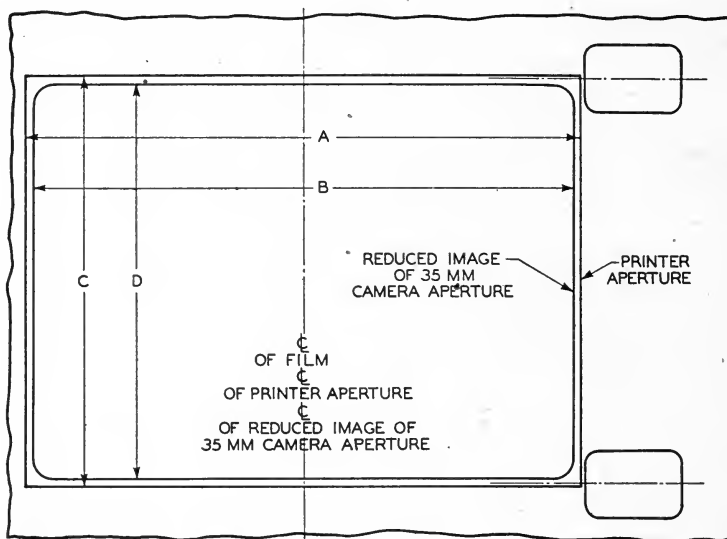**2.4 Leader and Trailer.** Each test film shall be furnished with a suitable leader, title, and trailer.

NOTE: A test film in accordance with this standard is available from the Society of Motion Picture Engineers.

American Standard Specification for
Multi-Frequency Test Film for Field Testing
16-Millimeter Sound Motion Picture Projection Equipment

ASA
Reg. U. S. Pat. Off.
Z22.44-1946

1. Scope and Purpose

1.1 This standard describes a multi-frequency sound test film used for testing and adjusting the sound systems of 16-mm sound motion picture projection equipment. The test frequencies on this film are adequate for normal field and general laboratory use.

2. Test Film

2.1 Frequencies. The test film shall contain the following series of frequencies, each preceded by spoken announcement recorded at approximately 10 db below full modulation:

Frequency Cycles	Tone Footage Feet
400	12
50	6
100	6
200	6
300	6
500	6
1000	6
2000	6
3000	6
4000	6
5000	6
6000	6
7000	6
400	12

2.1.1 *Frequency Tolerance.* The frequency tolerance of the recorded signals shall be ± 2 percent of the nominal frequency of each portion of the test track.

2.2 Recording. The test film shall be an originally recorded, splice-free, direct playback, positive variable-area sound track, recorded so that the modulated light is substantially constant when the film is reproduced with a scanning beam of negligible width. Modulation of the recording shall be 95 ± 5 percent at 7000 cycles. The level within any one frequency of each reel shall be constant to within ± 0.5 db. The recording shall be accomplished on a recorder so constructed as to keep the flutter content of the film to the absolute minimum consistent with the state of the art. The distortion of the recorded wave, up to a frequency of 3000 cycles, shall not exceed 5 percent.

2.3 Film Stock. The film stock used for the test film shall be cut and perforated in accordance with the American Standard 16-Mm Sound Motion Picture Film; Cutting and Perforating Negative and Positive Raw Stock, Z22.12-1941, or latest revision thereof.

2.3.1 *Resistance to Shrinkage.* The film stock used for the test film shall have a maximum lengthwise shrinkage of 0.50 percent when tested as follows: At least 20 strips of film approximately 31 inches in length shall be cut for measurement of shrinkage. After normal development and drying (not over + 80 F [+ 26.7 C]), the strips shall be placed at least ¼ inch apart in racks and kept for 7 days in an oven maintained at + 120 F (+ 49 C) and a relative humidity of 20 percent. The strips shall then be removed, reconditioned thoroughly to 50 percent relative humidity at + 70 F (+ 21.1 C), and the shrinkage measured by an adaptation of the pin-gage method outlined in Research Paper RP-1051 of the National Bureau of Standards. The percent shrinkage shall then be calculated on the basis of deviation from the nominal dimension for the length of 100 consecutive perforation intervals given in American Standard Z22.12-1941, or the latest revision thereof, referred to in 2.3 above.

2.4 Film Identification. Each test film shall be provided with a suitable leader, title, and trailer, and shall be accompanied by a calibration of the level of the frequency recordings.

2.4.1 *Calibration.* The calibration shall be in terms of light modulation at the photocell with a scanning beam of negligible width, and shall be correct to within ± ¼ db up to and including 3000 cycles, and within ± ½ db above 3000 cycles up to and including 7000 cycles. The correction for each frequency shall be so stated that it will give the true level when the correction is added algebraically to the output level measured using the film.

NOTE: A test film in accordance with this standard is available from the Society of Motion Picture Engineers.

American Standard Specifications for
400-Cycle Signal Level Test Film
for 16-Millimeter Sound Motion Picture Projection Equipment

ASA
Reg. U. S. Pat. Off.
Z22.45-1946

1. Scope and Purpose

1.1 This specification describes a 400-cycle signal level test film for use in testing 16-mm sound motion picture projection equipment.

2. Test Film

2.1 Recording. The test film shall have an originally recorded direct playback positive variable-area sound track recorded at an amplitude of 0.048 ± 0.0015 inch. The frequency of the recording shall be within ± 8 cycles of nominal frequency.

The density of the dark portion of the sound track shall be between 1.7 and 2.0. The density throughout the length of the film shall be as uniform as is consistent with the state of the art.

The combined base and fog density, measured as visual diffuse density, shall be 0.05 ± 0.01 when measured on an integrating sphere densitometer or a polarization densitometer.

The wave form distortion of the recording shall not exceed 5 percent.

2.2 Film Stock. The film stock used for the test film shall be cut and perforated in accordance with the American Standard 16-Mm Sound Motion Picture Film; Cutting and Perforating for Negative and Positive Raw Stock, Z22.12-1941, or latest revision thereof.

2.2.1 *Resistance to Shrinkage.* The film stock used for the test film shall have a maximum lengthwise shrinkage of 0.50 percent when tested as follows: At least 20 strips of film approximately 31 inches in length shall be cut for measurement of shrinkage.

After normal development and drying (not over +80 F [+26.7 C]), the strips shall be placed at least ¼ inch apart in racks and kept for seven days in an oven maintained at +120 F (+49 C) and a relative humidity of 20 percent. The strips shall then be removed, reconditioned thoroughly to 50 percent relative humidity at +70 F (+21.1 C), and the shrinkage measured by an adaptation of the pin-gage method outlined in Research Paper RP-1051 of the National Bureau of Standards. The percent shrinkage shall then be calculated on the basis of deviation from the nominal dimension for the length of 100 consecutive perforation intervals given in American Standard Z22.12-1941, or latest revision thereof.

2.3 Standard Length. The standard length of the 400-cycle signal level test film shall be 100 feet.

2.4 Measurement Requirements. Each film shall be measured for amplitude of the modulation, for image density, and for combined base and fog density. The measurements shall be made at a point approximately mid-length of the film and at points between 5 and 10 feet from each end. The results of the measurements shall be stated on a card furnished with each test film.

2.5 Leader and Trailer. Each test film shall be provided with a suitable leader, title, and trailer.

NOTE: A test film in accordance with this standard is available from the Society of Motion Picture Engineers.

American Standard
16-Millimeter Positive Aperture Dimensions and Image Size for Positive Prints Made from 35-Millimeter Negatives

* REDUCTION RATIO 2.15 TO 1.00

	Millimeters	Inch
A	10.465 ± 0.051	0.412 ± 0.002
B	10.211 ± 0.051	0.402 ± 0.002
C	7.772 ± 0.051	0.306 ± 0.002
D	7.417 ± 0.038	0.292 ± 0.0015

*The tolerance of the specified reduction ratio is expressed in the tolerance of the reduced image of the area covered by the 35-mm camera aperture. The dimensions of the 35-mm camera aperture being reduced and of the 35-mm aperture of the reduction printer are 0.631 $\times$ 0.868 and 0.662 $\times$ 0.890 inch, respectively.

NOTE 1: The reduced 16-mm image of the 35-mm camera aperture shall be centered in the 16-mm aperture of the printer. With the specified reduction ratio of 2.15, the equality of width of the two black lines (approximately 0.005 inch) produced on the print at the two sides of the aperture is an indication of proper centering.

NOTE 2: Aperture corners may be rounded with a radius of 0.020 inch or less.

American Standard
Negative Aperture Dimensions and Image Size for 16-Millimeter Duplicate Negatives Made from 35-Millimeter Positive Prints

*REDUCTION RATIO 2.15 TO 1.00
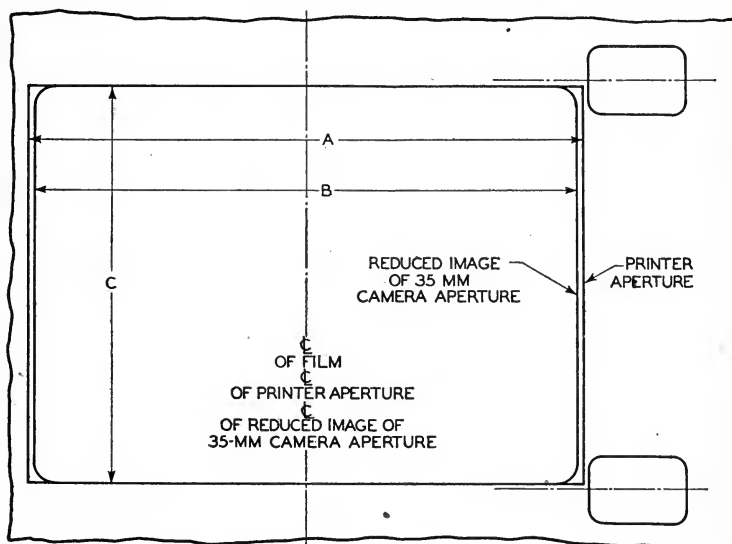
	Millimeters	Inch
A	10.262 ±0.051	0.404 ±0.002
B	10.211 ±0.051	0.402 ±0.002
C	7.417 ±0.038	0.292 ±0.0015

*The tolerance of the specified reduction ratio is expressed in the tolerance of the reduced image of the area covered by the 35-mm camera aperture. The dimensions of the 35-mm camera aperture being reduced and of the 35-mm aperture of the reduction printer are 0.631 × 0.868 and 0.662 × 0.890 inch, respectively.

NOTE 1: The reduced 16-mm image of the 35-mm camera aperture shall be centered in the 16-mm aperture of the printer.

NOTE 2: Aperture corners may be rounded with a radius of 0.020 inch or less.

American Standard
Printer Aperture Dimensions for Contact Printing 16-Millimeter Positive Prints from 16-Millimeter Negatives

ASA
Reg. U. S. Pat. Off.
Z22.48-1946
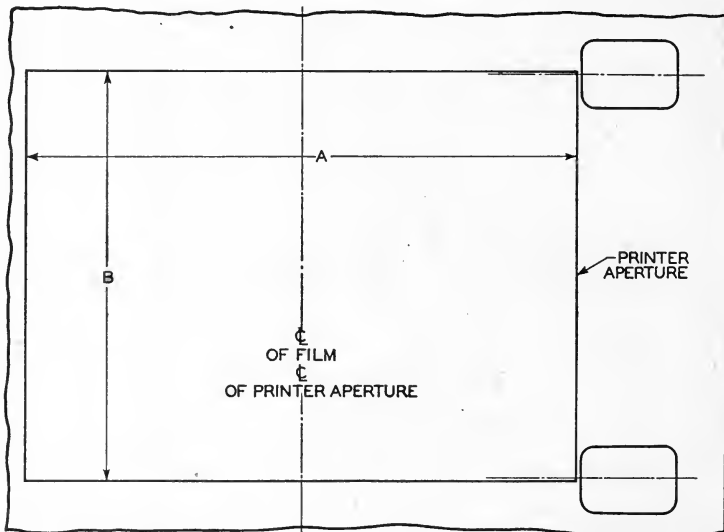
	Millimeters	Inch
A	10.465 ± 0.051	0.412 ± 0.002
*B	7.772 ± 0.051	0.306 ± 0.002

*This dimension is only applicable when using this aperture for contact printing by the step process.

NOTE: Aperture corners may be rounded with a radius of 0.020 inch or less.

American Standard
Printer Aperture Dimensions for Contact Printing 16-Millimeter Reversal and Color Reversal Duplicate Prints

ASA
Reg. U. S. Pat. Off.
Z22.49-1946
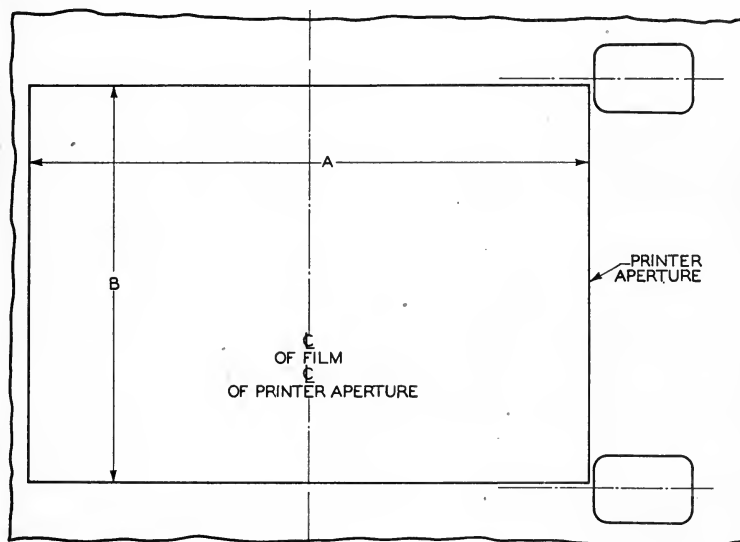
	Millimeters	Inch
A	10.262 ±0.051	0.404 ±0.002
***B**	7.417 ±0.038	0.292 ±0.0015

*This dimension is only applicable when using this aperture for contact printing by the step process.

NOTE: Aperture corners may be rounded with a radius of 0.020 inch or less.

American Standard
Reel Spindles
for 16-Millimeter Motion Picture Projectors

1. Round Section

1.1 The round section of 16-mm motion picture projector reel spindles shall have a finished diameter of 0.312 ± 0.003 inch (7.925 ± 0.076 mm).

2. Square Section

2.1 The square section of 16-mm motion picture projector reel spindles, including finish, shall be 0.312 ± 0.003 inch (7.925 ± 0.076 mm) across the flats. Measurements across the flats shall be made in mutually perpendicular directions.

3. Cumulative Effect of Eccentricity

3.1 The cumulative effect of eccentricity of the round and square sections of the spindles, looseness and misalignment of the bearing, or other mechanical imperfections shall not cause the flange of a tight-fitting reel to depart from the ideal plane by more than 40 minutes of arc.

3.2 A suitable gage for determining the cumulative effect of eccentricity consists of a hub, with coaxial square and round holes whose respective sides and diameter are equal in length, and a flange of suitable stiffness whose diameter is equal to that of an 800-foot reel flange, 10.5 inches (266.7 mm). The flange should be permanently joined to the hub so that its face is perpendicular to the axis of the hub with not more than 0.003 inch (0.076 mm) runout. The hub shall be provided with a thumbscrew for clamping the hub to the reel spindle so that one side of the round and square holes shall come in contact with the corresponding round and square sections of the reel spindle.

4. Reel Position on Spindles

4.1 The design of spindles shall be such that reels are kept under constant lateral pressure against a shoulder on the spindle. The part forming this shoulder need not be integral with the spindle. However, in such event, it shall be securely fastened to the spindle so so that the two parts rotate together.

American Standard Method of Making
Intermodulation Tests on Variable-Density 16-Millimeter Sound Motion Picture Prints

1. Scope and Purpose

1.1 This standard describes the intermodulation method of measuring the sound distortion introduced during the processing of 16-mm variable-density sound motion picture release prints. Through measurements of distortion at various print densities, it is possible to choose a print density which will give sound prints having minimum distortion and hence optimum quality for the particular method of processing employed.

1.2 In general, the intermodulation method of measuring distortion differs from the harmonic method in that the former employs a low frequency and a high frequency at one fourth the amplitude of the low frequency, the combination being simultaneously recorded on the sound negative. Any distortion in the over-all process causes a change in high-frequency amplitude in portions of the low-frequency cycle. The ratio of the average variation in amplitude of the higher frequency in the reproduced wave to its original amplitude is called the intermodulation. Intermodulation test results are not directly proportional to harmonic measurements but in most cases an intermodulation figure of 10 percent corresponds to a harmonic reading of about 2½ percent.

2. Test Method

2.1 The test track, as described in 2.3, is recorded and developed under standard conditions for the process being checked, and a series of prints made at suitable printer lights to give a range of print densities for unmodulated, unbiased tracks above and below the expected optimum density. In most cases this will be in the density range from 0.4 to 0.7. There should be sufficient unspliced film ahead of the test track to permit stabilization of printer speed. The distortion content of the test-track print is then measured using equipment as shown in Fig. 1. In making the measurements, the test-track print is threaded through the sound head of the

film reproducing device in the proper manner according to the position of the sound track (standard or nonstandard position). The distortion of each section of the print is then measured according to the operating instructions for the intermodulation meter used.
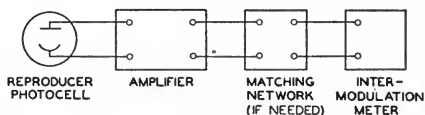
Fig. 1

Arrangement of Intermodulation Test Apparatus to Determine Distortion on Test Track

2.2 Since the method here described measures the over-all distortion for a process involving numerous variables, each of which may affect the total distortion, it is necessary that all such variables (except the print density which is purposely varied to find the optimum) in the recording and processing of the test track be maintained at the same values as they are normally in the process to be checked. These variables include film stock (both sound negative and print), recorder-lamp current, negative gamma, positive gamma, color temperature of printer light, and type of printer (contact or optical).

2.3 Test Track. The test track shall consist of 2 sections, recorded in sequence at the same lamp-current setting.

2.3.1 Section 1. Section 1 shall be a combination of 60 cycles and 1000 cycles having a peak amplitude 2.0 ± 0.5 db below full modulation, in which the 1000-cycle level shall be 12 ± 1 db below the 60-cycle level. The 60- and 1000-cycle waves shall be not more than ± 3 percent from the respective nominal frequencies and neither shall contain more than 5 percent harmonic distortion. This portion of the track should play for about 10 seconds.

2.3.2 Section 2. Section 2 shall be at least 1 foot of unbiased, unmodulated track for density measurement.
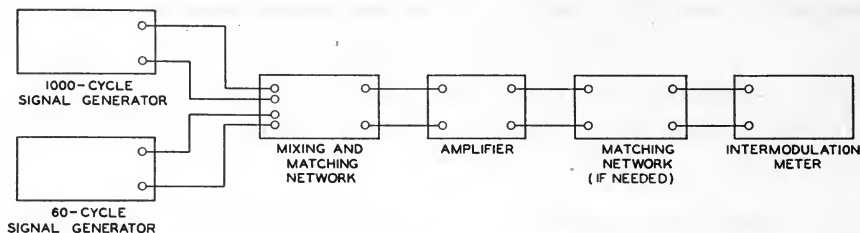
Fig. 2

Arrangement of Intermodulation Test Apparatus
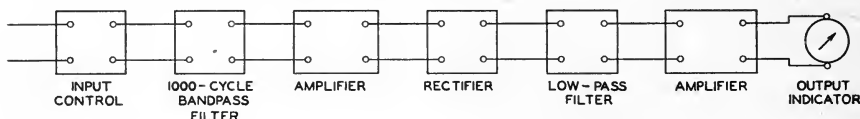to Determine Distortion in Amplifier

Fig. 3

Block Diagram of Intermodulation Meter

3. Test Equipment

3.1 Reproducing System. Care should be taken that the reproducer photocell and its associated coupling circuit to the amplifier input tube do not introduce a significant amount of intermodulation. The complete reproducing system should be checked for indications of distortion by use of a suitable test film, when available.

3.2 Amplifier. The amplifier of the film reproducer in which the test strips are run shall not produce more than 2 percent intermodulation when the intermodulation frequencies are introduced directly into the input, as shown in Figure 2, at approximately the same level as that used when measuring intermodulation on a film.

3.3 Intermodulation Meter. A block diagram of a suitable intermodulation meter* is shown in Figure 3. The attenuation

*The model RA-1107 intermodulation meter made by the Western Electric Company has been found suitable for these measurements.

of the band-pass filter shall not vary more than ± 0.5 db between 880 and 1120 cycles. The attenuation at 60 cycles shall be not less than 50 db and the attenuation at 500 cycles and at 2000 cycles not less than 25 db. The rectifier shall be such that its direct-current output is proportional to the peak amplitude of the wave passed by the band-pass filter. The low-pass filter following the rectifier shall have an attenuation that shall vary not more than ± 0.5 db between 60 and 120 cycles and shall be at least 40 db at frequencies between 1000 and 6000 cycles. The output indicating instrument shall be calibrated to read the average amplitude of the intermodulation components in percentage of the average amplitude of the wave passed by the band-pass filter.

References

Frayne, J. G. and Scoville, R. R.: Analysis and measurement of distortion in variable density recording. *Journal of the Society of Motion Picture Engineers*, **XXXII, No. 6** (June 1939), p 684.

American Standard Method of Making
Cross-Modulation Tests on Variable-Area
16-Millimeter Sound Motion Picture Prints

ASA
Reg. U. S. Pat. Off.
Z22.52-1946

1. Scope and Purpose

1.1 This standard describes the cross-modulation method of measuring high-frequency distortion introduced during the processing of 16-mm variable-area sound motion picture release prints. Through measurements of distortion at various print densities, it is possible to choose a print density which will give sound prints having minimum distortion and optimum quality under the particular method of processing employed.

1.2 Cross-modulation tests are used extensively in establishing and maintaining photographic control of variable-area sound tracks. In consideration of wave form, output level, and noise reduction, it is necessary for variable-area prints to have high density contrast. At satisfactorily high track densities an appreciable amount of image spread occurs, producing partial rectification of high frequencies. To compensate for this, an equal and opposite amount of image spread is introduced into the negative. Therefore, to establish the correct negative and print density combination, amplitude-modulated high frequencies are recorded and printed over a suitable density range. By measuring the rectified component from the prints, the correct density combinations are indicated.

2. Test Method

2.1 The test track, described in 2.3, is recorded and developed under standard conditions for the process being checked. A series of prints is then made at suitable printer lights to give a range of print densities for unmodulated, unbiased tracks above and below the expected optimum density. In most cases this will be in the density range from 0.8 to 1.7. There should be sufficient unspliced film ahead of the test track to permit stabilization of printer speed. The distortion content of the test-track print is then measured using equipment as shown in Fig. 1.
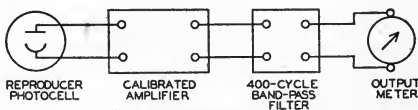
Fig. 1

Basic Arrangement of Cross-Modulation
Test Equipment to Determine Distortion
on Test Track

In making the measurements, the test-track print is threaded through the sound head of the film reproducing device in the proper manner according to the position of the sound track (standard or non-standard position). The distortion of each section of the print is then measured according to the operating instructions for the cross-modulation meter used if one is available.

2.1.1 If measurements are made using individual pieces of equipment, as shown in Fig. 1, the gain is adjusted to 0 db output reading on the 400-cycle section of the test track, so that the output meter will properly read the db output from the 4000-cycle section of test track which is modulated by the 400-cycle signal. The difference in output for the 2 sections of the cross-modulation test track is the cross-modulation for the process being checked.

2.2 Since the method here described measures the over-all distortion for a process involving numerous variables, each of which may affect the total distortion, it is necessary that all such variables (except the print density which is purposely varied to find the optimum) in the recording and processing of the test track be maintained at the same values as they are normally in the process to be checked. These variables include film stock (both sound negative and print), recorder-lamp current, negative gamma, color temperature of printer light, and type of printer (contact or optical).

2.3 Test Track. The test track consists of 3 sections, recorded in sequence at the same lamp-current setting:

2.3.1 Section 1. 400 ± 10 cycles constant amplitude at 2 ± ½ db below full modulation.

2.3.2 Section 2. 4000 ± 200 cycles amplitude modulated 2 ± ½ db below full modulation at 400 ± 10 cycles. The peak amplitude of this modulated wave shall be 2 ± ½ db below that required for full modulation of the sound track.

2.3.3 Section 3. Unmodulated, unbiased track, or track fully modulated at approximately 30 cycles, or less, for density measurement.

2.3.4 Sections 1 and 2 should have a running time of 10 seconds and section 3 at least 1 second. Neither the 400- or 4000-cycle waves shall contain more than 5 percent harmonic distortion. The modulated wave of section 2 must not contain a 400-cycle component greater than 50 db below the average 4000-cycle amplitude of the modulated wave. The recorder should be correctly adjusted for slit azimuth, track location, and focus.

NOTE: This test track should also be used in the case of 35-mm negatives prepared for a study of optical reduction printing, instead of the tracks commonly used in checking regular 35-mm print production.

3. Test Equipment

3.1 Reproducing Equipment. The reproducing equipment shall consist of a 16-mm sound film reproducer, amplifier, 400-cycle band-pass filter and volume indicator.

3.2 Amplifying System. The amplifying system should have approximately 110 db gain and should be adjustable in 1 db steps over a range of 40 db. When the modulated wave described in 2.3.2 is applied to the input of the amplifier at sufficient amplitude to produce normal output, the 400-cycle component of the amplifier output shall be at least 50 db below the average 4000-cycle amplitude of the same modulated wave. The gain of the amplifying system shall be calibrated at 400 and 4000 cycles. The relative gain at these frequencies shall vary not more than ± 1 db for any setting of the gain adjustment. The attenuation of the 400-cycle band-pass filter shall vary not more than ± 0.5 db between 375 and 425 cycles and shall be at least 50 db at 4000 cycles.

3.3 Distortion. Care should be taken that the reproducer photocell and its associated coupling circuit to the amplifier input tube do not introduce a significant amount of cross-modulation. The complete reproducing system should be checked for indications of distortion by use of a suitable test film when available.

References

Baker, J. O. and Robinson, D. H.: Modulated high-frequency recording as a means of determining conditions for optimal processing. *Journal of the Society of Motion Picture Engineers*, **XXX, No. 1** (Jan 1938), p 3.

The Quality Control of Variable Area Sound Tracks. RCA Victor Division, Radio Corporation of America, Camden, N. J. (1938)

The Modulated Carrier Oscillator, RCA Victor Division, Radio Corporation of America, Camden, N. J. (1939)

Method of Determining Resolving Power

of 16-Millimeter Motion Picture Projector Lenses

1. Scope and Purpose

1.1 This standard describes a method of determining the resolving power of projection lenses used in 16-mm motion picture projectors. The resolving power shall be measured in lines per millimeter.

2. Test Method

2.1 The lens to be tested shall be mounted in a special test projector. A glass plate test object, carrying patterns of lines, shall be then projected upon a white matte grainless screen located at such a distance from the projector that the projected image of the border of the test object measures 30 x 40 inches. The resolving power of the lens is the largest number of lines per millimeter in the test object pattern that an observer standing close to the screen sees definitely resolved in both the radial and tangential directions. Lines shall not be regarded as definitely resolved unless the number of lines in the image is the same as the number of lines in the test object.

2.1.1 The patterns of lines shall consist of parallel black lines $2.5/X$ mm long and $0.5/X$ mm wide with a clear space $0.5/X$ mm wide between the parallel lines, where X equals the number of lines per millimeter.

2.2 Care shall be taken to insure that the screen is perpendicular to the projection axis and that the lens is so focused that the image of the center of the test plate is as sharp as possible.

3. Test Projector

3.1 The projector design shall be such that the glass plate test object is held in proper relation to the lens axis. It shall not heat the test plate to a temperature which may cause the plate to be fractured or otherwise damaged. The cone of light supplied by the projector shall completely fill the projection lens.

4. Test Object

4.1 The glass photographic plate used for making the test object and the lens used in making the reduction of the master test chart shall have sufficiently high resolving power to insure clear definition of all lines in the patterns on the test object.

4.2 The photographic reduction of the master test chart shall be such that the test object border has a height of 7.21 mm (0.284 inch) and a width of 9.65 mm (0.380 inch) with a radius of 0.5 mm (0.02 inch) in the corners, and such that the sets of lines in the reduced image are spaced 20, 30, 40, 50, 60, 80, and 90 lines per millimeter.
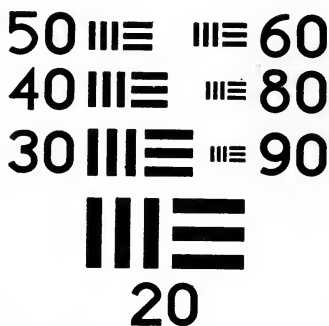
Fig. 1
Resolution Test Patterns

4.3 The patterns on the test object shall be in accordance with Fig. 1.

Fig. 2. Resolving Power Test Object

NOTE: The triangular edge patterns are to facilitate alignment of test plates in the projector.

4.4 The position of the test patterns on the test object shall be in accordance with Fig. 2.

4.5 Identification of the positions of the test patterns on the test object shall be in accordance with Fig. 3.
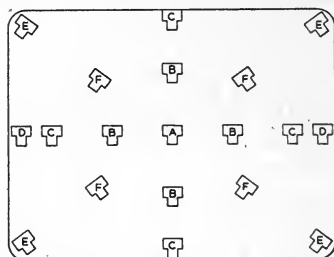
Fig. 3. Identification of Test Patterns in Frame Area

NOTE: When using a 2-inch focal length lens, B corresponds to 2 degrees from the axis, C corresponds to 4 degrees from the axis, D corresponds to 5 degrees from the axis, E corresponds to 6 degrees from the axis, and F corresponds to 3 degrees from the axis.

NOTE: Glass test plates in accordance with this standard are available from the Society of Motion Picture Engineers.

American Standard Method of Determining
Freedom from Travel Ghost
in 16-Millimeter Sound Motion Picture Projectors

ASA
Reg. U S. Pat Off
Z22.54-1946

1. Scope and Purpose

1.1 This standard describes a method of determining freedom from travel ghost in 16-mm sound motion picture projectors.

2. Definition

2.1 Travel ghost is a blurring effect seen on the screen and evidenced by vertical tails or light streaks added to the projected images of the transparent areas on the test film. It is caused by the projector shutter being out of synchronism with the intermittent mechanism, either by faulty adjustment or faulty design.

Fig. 1   Typical Test Pattern

3. Test Film

3.1 The test film used for determining freedom from travel ghost shall carry a pattern of small transparent areas upon a dark background. There shall be at least six transparent areas, three of which shall be located not farther than 1/32 inch from the top of the frame and three not farther than 1/32 inch from the bottom of the frame. Four of the areas shall have their edges 1/32 inch from a side edge and either the top or bottom edge of the frame. The density of the transparent areas shall be less than 0.2 and the density of the dark background shall be greater than 2.2.

3.1.1 *Standard Length of Film.* The standard length of test film shall be 100 feet.

3.1.2 *Leader and Trailer.* Each test film shall have a suitable leader, title, and trailer.

4. Test Method

4.1 A test film in accordance with 2.1 shall be projected at standard sound speed of 24 frames per second (± 2 percent) upon a white matte screen, the projected image of the projector picture aperture being of such size that a screen brightness of 10-foot lamberts is obtained with the projector shutter running, but with no film in the gate. The screen image of the test film shall be viewed from a distance equal to twice its width and the presence or absence of travel ghost noted.

NOTE: A test film in accordance with this standard is available from the Society of Motion Picture Engineers.

REPORT OF THE MEMBERSHIP AND SUBSCRIPTION COMMITTEE*

The membership of the Society of Motion Picture Engineers grew during 1945 from 1676 to 1966. This increase is consistent with the trend during the war years. While it is a healthy, normal growth, the Committee feels that in 1946 it could be materially accelerated. To a large extent the new members acquired during the last several years have consisted of men in the Armed Forces engaged in motion picture activities. However, it is obvious that there are still many competent engineers and scientists working in our industry who are not members and who undoubtedly would like to become members if they knew the requirements of admission.

The recent addition of an Engineering Secretary and staff to the office of the Society will permit a broad expansion in its technical activities and services to the industry.

You are, of course, familiar with the fact that membership in the Society includes a subscription to the JOURNAL which is issued monthly, notices of technical sessions, the opportunity of participating on the various Committees of the Society, and the unusual chance to meet and become acquainted with a large number of men in all phases of the motion picture industry.

The development and improvement of many devices and processes used in our industry, as a result of the war, will stimulate interest in the Society among new companies. One of the most important of these fields is television.

The President and Officers of the Society have been successful recently in increasing the number and amount of financial contributions of Sustaining members. This will result in much greater recognition of the Society by all phases of the industry.

We feel that we are justified in calling upon each member of the Society to assist us in accomplishing our objective by obtaining at least one new member in 1946. A suitable application blank for this purpose is included in each regular issue of the JOURNAL and we

---

* Submitted Mar. 28, 1946.

earnestly ask you to cut it out and mail it promptly to a prospective member with whom you are acquainted.   In doing this, be sure to offer to sponsor their application.   If everyone will perform this obligation, the report of the Committee a year hence will show the type of results that we all are convinced can be performed.

James Frank, Jr.,
Chairman

OFFICERS AND GOVERNORS OF THE SOCIETY

HERBERT GRIFFIN
Past-President

JOHN A. MAURER
Engineering Vice-President

LOREN L. RYDER
Executive Vice-President

DONALD E. HYNDMAN
President

M. RICHARD BOYER
Financial Vice-President
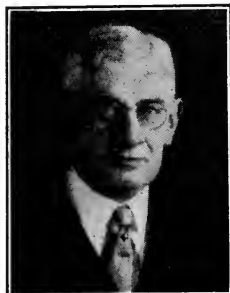
ARTHUR C. DOWNES
Editorial Vice-President

WILLIAM C. KUNZMANN
Convention Vice-President

CLYDE R. KEITH
Secretary
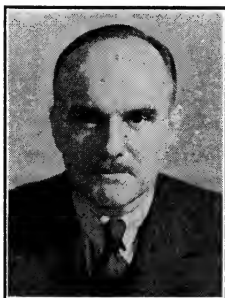
EARL I. SPONABLE
Treasurer

JOHN I. CRABTREE
Governor

FRANK E. CARLSON
Governor

ALAN W. COOK
Governor
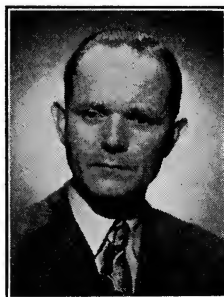
CHARLES R. DAILY
Governor

JOHN G. FRAYNE
Governor

PAUL J. LARSEN
Governor
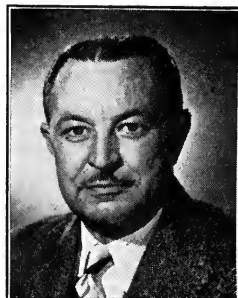
WESLEY C. MILLER
Governor

PETER MOLE
Governor

REEVE O. STROCK
Governor

WILLIAM A. MUELLER
Governor

FRANK E. CAHILL, JR.
Chairman,
Atlantic Coast Section

HOLLIS W. MOYSE
Chairman,
Pacific Coast Section

ATLANTIC COAST SECTION

*FRANK E. CAHILL, JR., *Chairman*
*CLYDE R. KEITH, *Past-Chairman*
*JAMES FRANK, JR., *Sec.-Treas.*

| **HERBERT BARNETT | *G. T. LORANCE | *W. H. OFFENHAUSER, JR. |
| **H. D. BRADBURY | **J. A. NORLING | *H. E. WHITE |

PACIFIC COAST SECTION

*HOLLIS W. MOYSE, *Chairman*
*CHARLES W. HANDLEY, *Past-Chairman*
*S. P. SOLOW, *Sec.-Treas.*

| **G. M. BEST | **P. E. BRIGANDI | *H. W. REMERSCHEID |
| *J. W. BOYLE | *F. L. EICH | **G. E. SAWYER |

* Term expires December 31, 1946; ** Term expires December 31, 1947.

COMMITTEES OF THE SOCIETY

(Correct to March 26, 1946)

◄ ►

ADMISSIONS.—To pass upon all applications for membership, applications for transfer and to review the Student and Associate membership list periodically for possible transfers to the Associate and Active grades, respectively. The duties of each committee are limited to applications and transfers originating in the geographic area covered.

(East Coast)

A. S. DICKINSON, *Chairman*
28 West 44th St.
New York 18, N. Y.

M. R. BOYER	JAMES FRANK, JR.	HARRY RUBIN
F. E. CAHILL, JR.	J. A. MAURER	E. I. SPONABLE

(West Coast)

H. W. REMERSCHEID, *Chairman*
716 N. LaBrea St.
Hollywood, Calif.

C. R. DAILY	PETER MOLE
EMERY HUSE	H. W. MOYSE

BOARD OF EDITORS.—To pass upon the suitability of all material submitted for publication, or for presentation at conventions, and publish the JOURNAL.

A. C. DOWNES, *Chairman*
Box 6087
Cleveland 1, Ohio

J. I. CRABTREE	A. M. GUNDELFINGER	C. R. KEITH
A. N. GOLDSMITH	C. W. HANDLEY	E. W. KELLOGG
	A. C. HARDY	

CINEMATOGRAPHY.—To make recommendations and prepare specifications for the operation, maintenance, and servicing of motion picture cameras, accessory equipment, studio and outdoor set lighting arrangements, camera technique, and the varied uses of motion picture negative films for general photography.

J. W. BOYLE, *Chairman*
1207 N. Mansfield Ave.
Hollywood, Calif.

C. G. CLARKE	*ARTHUR MILLER	ARTHUR REEVES
KARL FREUND		JOSEPH RUTTENBERG

COLOR.—To make recommendations and prepare specifications for the operation, maintenance, and servicing of color motion picture processes, accessory equipment, studio lighting, selection of studio set colors, color cameras, color motion picture films, and general color photography.

J. A. BALL, *Chairman*
12720 Highwood St.
Los Angeles 24, Calif.

M. R. BOYER	R. M. EVANS	A. C. HARDY
G. A. CHAMBERS	J. L. FORREST	W. C. MILLER
L. E. CLARK	J. G. FRAYNE	L. L. RYDER
R. O. DREW	L. T. GOLDSMITH	J. G. WHITE
	A. M. GUNDELFINGER	

---

* Advisory Member.

CONVENTION.—To assist the Convention Vice-President in the responsibilities pertaining to arrangements and details of the Society's technical conventions.

W. C. KUNZMANN, *Chairman*
Box 6087
Cleveland 1, Ohio

*JULIUS HABER	C. R. KEITH	H. W. MOYSE
H. F. HEIDEGGER	R. H. McCULLOUGH	O. F. NEU

EXCHANGE PRACTICE.—To make recommendations and prepare specifications on the engineering or technical methods and equipment that contribute to efficiency in handling and storage of motion picture prints, so far as can be obtained by proper design, construction, and operation of film handling equipment, air-conditioning systems, and exchange office buildings.

(Under Organization)

FELLOW MEMBERSHIP.—To consider qualifications of Active members as candidates for elevation to Fellow members, and to submit such nominations to the Board of Governors.

HERBERT GRIFFIN, *Chairman*
133 E. Santa Anita Ave.
Burbank, Calif.

M. R. BOYER	D. E. HYNDMAN	H. W. MOYSE
A. S. DICKINSON	C. R. KEITH	L. L. RYDER
A. C. DOWNES	W. C. KUNZMANN	E. A. WILLIFORD
	J. A. MAURER	

FILM PROJECTION PRACTICE.—To make recommendations and prepare specifications for the operation, maintenance and servicing of motion picture projection equipment, projection rooms, film storage facilities, stage arrangement, screen dimensions and placement, and maintenance of loudspeakers to improve the quality of reproduced sound and the quality of the projected picture in the theater.

G. T. LORANCE, *Chairman*
63 Bedford Road
Pleasantville, N. Y.

HENRY ANDERSON	L. W. DAVEE	C. F. HORSTMAN
*C. J. BACHMAN	A. S. DICKINSON	L. B. ISAAC
T. C. BARROWS	J. K. ELDERKIN	E. R. MORIN
H. D. BEHR	JAMES FRANK, JR.	M. D. O'BRIEN
H. J. BENHAM	R. R. FRENCH	HARRY RUBIN
M. F. BENNETT	G. GAGLIARDI	J. J. SEFING
KARL BRENKERT	E. R. GEIB	R. O. WALKER
F. E. CAHILL, JR.	ADOLPH GOODMAN	V. A. WELMAN
D. W. COLLINS	HERBERT GRIFFIN	H. E. WHITE
C. C. DASH	SYLVAN HARRIS	A. T. WILLIAMS
	J. J. HOPKINS	

HISTORICAL AND MUSEUM.—To collect facts and assemble data relating to the historical development of the motion picture industry, to encourage pioneers to place their work on record in the form of papers for publication in the JOURNAL, and to place in suitable depositories equipment pertaining to the industry.

J. E. ABBOTT, *Chairman*
11 West 53d St.
New York 19, N. Y.

O. B. DEPUE	RICHARD GRIFFITH	TERRY RAMSAYE

HONORARY MEMBERSHIP.—To diligently search for candidates who through their basic inventions or outstanding accomplishments have contributed to the advancement of the motion picture industry and are thus worthy of becoming Honorary members of the Society.

EMERY HUSE, *Chairman*
6706 Santa Monica Blvd.
Hollywood 38, Calif.

NATHAN LEVINSON	L. L. RYDER
A. J. MILLER	E. I. SPONABLE

* Advisory Member.

JOURNAL AWARD.—To recommend to the Board of Governors the author or authors of the most outstanding paper originally published in the JOURNAL during the preceding calendar year to receive the Society's Journal Award.

F. E. CARLSON, *Chairman*
Nela Park
Cleveland 12, Ohio

C. R. DAILY	G. E. MATTHEWS
P. J. LARSEN	W. V. WOLFE

LABORATORY PRACTICE.—To make recommendations and prepare specifications for the operation, maintenance, and servicing of motion picture printers, processing machines, inspection projectors, splicing machines, film cleaning and treating equipment, rewinding equipment, any type of film handling accessories, methods, and processes which offer increased efficiency and improvement in the photographic quality of the final print.

H. E. WHITE, *Temporary Chairman*
Room 813
350 Madison Ave.
New York 17, N. Y.

J. R. ALBURGER	F. L. EICH	J. M. NICKOLAUS
A. C. BLANEY	G. H. GIBSON	N. F. OAKLEY
L. A. BONN	EMERY HUSE	W. H. OFFENHAUSER, JR.
A. W. COOK	T. M. INGMAN	V. C. SHANER
O. B. DEPUE	C. L. LOOTENS	J. H. SPRAY
R. O. DREW	A. J. MILLER	J. F. VAN LEUVEN

MEMBERSHIP AND SUBSCRIPTION.—To solicit new members, obtain nonmember subscriptions for the JOURNAL, and to arouse general interest in the activities of the Society and its publications.

(East Coast)

JAMES FRANK, JR., *Chairman*
356 West 44th St.
New York 18, N. Y.

T. C. BARROWS	L. T. GOLDSMITH	G. E. MATTHEWS
J. G. BRADLEY	SYVAN HARRIS	G. C. MISENER
KARL BRENKERT	L. B. ISAAC	H. B. SANTEE
G. A. CHAMBERS	W. C. KUNZMANN	E. O. WILSCHKE
E. R. GEIB	S. A. LUKES	C. R. WOOD, SR.

(West Coast)

H. W. REMERSCHEID, *Chairman*
716 N. LaBrea St.
Hollywood, Calif.

L. W. CHASE, JR.	HERBERT GRIFFIN	L. L. RYDER
J. P. CORCORAN	EMERY HUSE	G. E. SAWYER
C. R. DAILY	K. F. MORGAN	W. L. THAYER
J. G. FRAYNE	H. W. MOYSE	W. V. WOLFE
	W. A. MUELLER	

NOMINATIONS.—To recommend nominations to the Board of Governors for annual election of officers and governors.

E. M. HONAN, *Chairman*
6601 Romaine St.
Hollywood 38, Calif.

E. A. BERTRAM	EMERY HUSE	W. C. MILLER
M. R. BOYER	D. B. JOY	PETER MOLE
HERBERT GRIFFIN	J. A. MAURER	E. A. WILLIFORD

PAPERS.—To solicit papers, and provide the program for semi-annual conventions, and make available to local sections for their meetings papers presented at national conventions.

BARTON KREUZER, *Chairman*
RCA Victor Division
Radio Corp. of America
Camden, N. J.

C. R. DAILY, *Vice-Chairman*
5451 Marathon St.
Hollywood 38, Calif.

A. R. DAVIS
F. L. EICH
JAMES FRANK, JR.
J. G. FRAYNE

L. T. GOLDSMITH
C. R. KEITH
E. W. KELLOGG
G. E. MATTHEWS
P. A. McGUIRE

H. W. MOYSE
V. C. SHANER
S. P. SOLOW
W. V. WOLFE

PRESERVATION OF FILM.—To make recommendations and prepare specifications on methods of treating and storage of motion picture film for active, archival, and permanent record purposes, so far as can be prepared within both the economic and historical value of the films.

J. G. BRADLEY, *Chairman*
The Library of Congress
Washington 25, D. C.

J. E. ABBOTT
*H. T. COWLING
J. I. CRABTREE
A. S. DICKINSON

J. L. FORREST
*J. E. GIBSON
*ORVILLE GOLDNER
C. L. GREGORY

*C. A. LINDSTROM
G. S. MITCHELL
TERRY RAMSAYE
V. B. SEASE

PROCESS PHOTOGRAPHY.—To make recommendations and prepare specifications on motion picture optical printers, process projectors (background process), matte processes, special process lighting technique, special processing machines, miniature set requirements, special effects devices, and the like, that will lead to improvement in this phase of the production art.

(Under Organization)

PROGRESS.—To prepare an annual report on progress in the motion picture industry.

W. V. WOLFE, *Chairman*
1016 N. Sycamore Ave.
Hollywood 38, Calif.

(Under Organization)

PROGRESS MEDAL AWARD.—To recommend to the Board of Governors a candidate who by his inventions, research, or development has contributed in a significant manner to the advancement of motion picture technology, and is deemed worthy of receiving the Progress Medal Award of the Society.

E. A. WILLIFORD, *Chairman*
230 Park Ave.
New York 17, N. Y.

M. R. BOYER
F. E. CARLSON

NATHAN LEVINSON
G. F. RACKETT

PUBLICITY.—To assist the Convention Vice-President in the release of publicity material concerning the Society's semi-annual technical conventions.

*HAROLD DESFOR, *Chairman*
RCA Victor Division
Radio Corp. of America
Camden, N. J.

*LEONARD BIDWELL
*E. O. BLACKBURN

C. R. DAILY
BARTON KREUZER

P. A. McGUIRE
HARRY SHERMAN

SCREEN BRIGHTNESS.—To make recommendations, prepare specifications, and test methods for determining and standardizing the brightness of the motion picture screen image at various parts of the screen, and for special means or devices in the projection room adapted to the control or improvement of screen brightness.

E. R. GEIB, *Chairman*
National Carbon Company, Inc.
Fostoria Works
Fostoria, Ohio

* Advisory Member.

HERBERT BARNETT	W. F. LITTLE	H. E. WHITE
F. E. CARLSON	W. B. RAYTON	A. T. WILLIAMS
SYLVAN HARRIS	C. M. TUTTLE	R. J. ZAVESKY
	C. R. UNDERHILL	

16-MM AND 8-MM MOTION PICTURES (Formerly Nontheatrical Equipment).—To make recommendations and prepare specifications for 16-mm and 8-mm cameras, 16-mm sound recorders and sound recording practices, 16-mm and 8-mm printers and other film laboratory equipment and practices, 16-mm and 8-mm projectors, splicing machines, screen dimensions and placement, loudspeaker output and placement, preview or theater arrangements, test films, and the like, which will improve the quality of 16-mm and 8-mm motion pictures.

D. F. LYMAN, *Chairman*
333 State St.
Rochester 4, N. Y.

E. W. D'ARCY	R. C. HOLSLAG	L. T. SACHTLEBEN
WILLIAM BALCH	H. J. HOOD	A. SHAPIRO
W. C. BOWEN	R. KINGSLAKE	D. G. SMITH
F. L. BRETHAUER	L. R. MARTIN	RAYMOND SPOTTISWOODE
*F. E. BROOKER	W. C. MILLER	*J. B. STREIFFERT
F. E. CARLSON	*A. H. NICOL	HARRY STRONG
G. A. CHAMBERS	V. J. NOLAN	*A. L. TERLOUW
S. L. CHERTOK	W. H. OFFENHAUSER, JR.	LLOYD THOMPSON
JOHN CHRISTIE	M. W. PALMER	M. G. TOWNSLEY
G. W. COLBURN	A. G. PETRASEK	L. E. VARDEN
R. O. DREW	S. READ, JR.	J. E. VOLKMANN
*J. WALTER EVANS		A. G. ZIMMERMAN

SOUND.—To make recommendations and prepare specifications for the operation, maintenance, and servicing of motion picture film, sound recorders, rerecorders, and reproducing equipment, methods of recording sound, sound film processing, and the like, to obtain means of standardizing procedures that will result in the production of better uniform quality sound in the theater.

J. G. FRAYNE, *Chairman*   C. R. KEITH, *Vice-Chairman*
6601 Romaine St.   233 Broadway
Hollywood 38, Calif.   New York 7, N. Y.

D. J. BLOOMBERG	L. B. ISAAC	OTTO SANDVIK
B. B. BROWN	J. P. LIVADARY	G. E. SAWYER
F. E. CAHILL, JR.	G. T. LORANCE	S. P. SOLOW
C. R. DAILY	W. C. MILLER	E. I. SPONABLE
R. J. ENGLER	W. A. MUELLER	R. T. VanNIMAN
L. D. GRIGNON		J. E. VOLKMANN

STANDARDS.—To constantly survey all engineering phases of motion picture production, distribution, and exhibition, to make recommendations and prepare specifications that may become proposals for SMPE Recommended Practices and/or American Standards. This Committee should carefully follow the work of all other committees on engineering and may request any committee to investigate and prepare a report on the phase of motion picture engineering to which it is assigned.

F. T. BOWDITCH, *Chairman*
Box 6087
Cleveland 1, Ohio

J. M. ANDREAS	L. T. GOLDSMITH	H. W. MOYSE
HERBERT BARNETT	IRL GOSHAW	W. H. OFFENHAUSER, JR.
M. F. BENNETT	HERBERT GRIFFIN	J. D. PHYFE
E. A. BERTRAM	A. C. HARDY	G. F. RACKETT
M. R. BOYER	R. C. HOLSLAG	W. B. RAYTON
F. L. BRETHAUER	J. K. HILLIARD	A. C. ROBERTSON
F. E. CARLSON	C. S. PERKINS†	L. T. SACHTLEBEN
E. K. CARVER	D. B. JOY	OTTO SANDVIK
G. A. CHAMBERS	C. R. KEITH	J. A. SCHBIK
J. S. CHANDLER	R. KINGSLAKE	R. R. SCOVILLE
A. W. COOK	P. J. LARSEN	J. H. SPRAY
E. D. COOK	C. L. LOOTENS	MONROE SWEET
L. W. DAVEE	D. F. LYMAN	LLOYD THOMPSON

* Advisory Member; † Alternate.   (See next page.)

A. A. DURYEA   PIERRE MERTZ   M. G. TOWNSLEY
A. F. EDOUART   W. C. MILLER   J. F. VAN LEUVEN
P. C. GOLDMARK   G. S. MITCHELL   D. R. WHITE
A. N. GOLDSMITH   H. E. WHITE

STUDIO LIGHTING.—To make recommendations and prepare specifications for the operation, maintenance, and servicing of all types of studio and outdoor auxiliary lighting equipment, tungsten light and carbon arc sources, lighting effect devices, diffusers, special light screens, *etc.*, to increase the general engineering knowledge of the art.

C. W. HANDLEY, *Chairman*
1960 West 84th St.
Los Angeles 44, Calif.

J. W. BOYLE   F. C. COATES   KARL FREUND
H. J. CHANON   R. E. FARNHAM   W. W. LOZIER

TECHNICAL NEWS.—To survey the fields of production, distribution, and exhibition of motion pictures, and allied industries, to obtain technical news items for publication in the JOURNAL.

A. C. BLANEY, *Chairman*
1016 N. Sycamore St.
Hollywood 38, Calif.

J. W. BOYLE   C. W. HANDLEY   H. W. REMERSCHEID
J. I. CRABTREE   EMERY HUSE   EDWARD SCHMIDT
A. M. GUNDELFINGER   H. R. LUBCKE   WILLIAM THOMAS
                      K. F. MORGAN

TELEVISION.—To study the television art with special reference to the technical inter-relationships of the television and motion picture industries, and to make recommendations and prepare specifications for equipment, methods, and nomenclature designed to meet the special problems encountered at the junction of the two industries.

D. R. WHITE, *Chairman*
Redpath Laboratories
E. I. du Pont de Nemours & Co.
Parlin, N. J.

R. B. AUSTRIAN   J. P. LIVADARY
*G. L. BEERS   C. F. HORSTMAN   H. B. LUBCKE
A. W. COOK   L. B. ISAAC   J. R. POPPELE†
E. D. COOK   A. G. JENSEN   PIERRE MERTZ
C. E. DEAN   P. J. LARSEN   W. C. MILLER
BERNARD ERDE   C. C. LARSON   *PAUL RAIBOURN
P. C. GOLDMARK   NATHAN LEVINSON   OTTO SANDVIK
A. N. GOLDSMITH   F. E. CAHILL, JR.† G. E. SAWYER
T. T. GOLDSMITH   R. E. SHELBY
HERBERT GRIFFIN   E. I. SPONABLE
*F. P. GOLDBACH†   H. E. WHITE

TELEVISION PROJECTION PRACTICE.—To make recommendations and prepare specifications for the construction, installation, operation, maintenance, and servicing of equipment for projecting television pictures in the motion picture theater, as well as projection room arrangements necessary for such equipment, and such picture-dimensional and screen-characteristic matters as may be involved in high-quality theater television presentation.

P. J. LARSEN, *Chairman*
1401 Sheridan St., N. W.
Washington 11, D. C.

F. E. CAHILL, JR., *Vice-Chairman*   JAMES FRANK, JR., *Secretary*
321 West 44th St.   356 West 44th St.
New York 18, N. Y.   New York 18, N. Y.

R. B. AUSTRIAN   L. W. DAVEE   H. E. KALLMANN
C. F. HORSTMAN†   JOHN EBERSON   E. R. MORIN
HERBERT BARNETT   *H. B. FANCHER   A. H. ROSENTHAL
*F. P. GOLDBACH†   *P. M. GARRETT†   *ARTHUR LEVEY†
M. C. BATSEL   JAMES FRANK, JR.   HARRY RUBIN
F. G. ALBIN†   G. T. LORANCE†   *PAUL RAIBOURN†
*G. L. BEERS   E. P. GENOCK   R. E. SHELBY

* Advisory Member;   † Alternate.

F. G. ALBIN†   A. J. RICHARD†   *E. D. GOODALE†
*THOMAS BILLS   P. C. GOLDMARK   E. I. SPONABLE
F. T. BOWDITCH   G. R. TINGLEY†   *H. E. BRAGG†
PAUL RIES†   T. T. GOLDSMITH   C. S. SZEGHO
A. BROLLY   *RUDOLPH FELDT†   NICHOLAS GLYPTIS†
*W. BROCK†   L. B. ISAAC   V. A. WELMAN
F. E. CAHILL, JR.   M. D. O'BRIEN†   H. E. WHITE
M. F. BENNETT†   A. G. JENSEN   D. E. HYNDMAN†
                        H. B. SANTEE†
                        J. J. KOHLER
                        PIERRE MERTZ

TEST FILM QUALITY.—To supervise, inspect, and approve all print quality control of sound and picture test films prepared by any committee on engineering before the prints are released by the Society for general practical use.

F. S. BERMAN, *Chairman*
111–14 76th Ave.
Forest Hills, N. Y.

C. F. HORSTMAN   F. R. WILSON

THEATER ENGINEERING, CONSTRUCTION AND OPERATION.—To make recommendations and prepare specifications on engineering methods and equipment of motion picture theaters in relation to their contribution to the physical comfort and safety of patrons, so far as can be enhanced by correct theater design, construction, and operation of equipment.

HENRY ANDERSON, *Chairman*
1501 Broadway
New York 18, N. Y.

HERBERT BARNETT   *W. L. FLEISHER   C. F. HORSTMAN
H. J. BENHAM   JAMES FRANK, JR.   E. R. MORIN
F. E. CARLSON   T. T. GOLDSMITH   BEN SCHLANGER
*W. B. CUTTER   ADOLPH GOODMAN   J. J. SEFING
                       J. J. HOPKINS

SMPE REPRESENTATIVES TO OTHER ORGANIZATIONS

American Documentation Institute....................J. E. ABBOTT
American Standards Association:
  Sectional Committee on Standardization of Letter
    Symbols and Abbreviations for Science and
    Engineering, Z10.............................L. A JONES
  Sectional Committee on Motion Pictures, Z22..C. R. KEITH, *Chm.*
                                    A.N. GOLDSMITH, *Hon.Chm*
                                    F. T. BOWDITCH
                                    E. K. CARVER
                                    D F. LYMAN†
  Sectional Committee on Acoustical Measurements
    and Terminology, Z24........................J. E. VOLKMANN
  Sectional Committee on Photography, Z38..........J. I. CRABTREE
European Advisory Committee.....................DONALD McMASTER, *Chm*
Inter-Society Color Council........................R. M. EVANS, *Chm*
                                    J. A. BALL
                                    RONALD BINGHAM
                                    F. T. BOWDITCH
                                    M. R. BOYER
                                    A. M. GUNDELFINGER
                                    G. F. RACKETT
National Fire Protection Association...............A. S. DICKINSON
Radio Technical Planning Board...................P. J. LARSEN
                                    E. I. SPONABLE†

---

* Advisory Member; † Alternate.

CONSTITUTION AND BY-LAWS*

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

CONSTITUTION

Article I

Name

The name of this association shall be SOCIETY OF MOTION PICTURE ENGINEERS.

Article II

Object

Its objects shall be: Advancement in the theory and practice of motion picture engineering and the allied arts and sciences, the standardization of the equipment, mechanisms, and practices employed therein, the maintenance of a high professional standing among its members, and the dissemination of scientific knowledge by publication.

Article III

Eligibility

Any person of good character may be a member in any grade for which he is eligible.

Article IV

Officers

The officers of the Society shall be a President, a Past-President, an Executive Vice-President, an Engineering Vice-President, an Editorial Vice-President, a Financial Vice-President, a Convention Vice-President, a Secretary, and a Treasurer.

The term of office of all elected officers shall be for a period of two years. Of the Engineering, Editorial, Financial, and Convention Vice-Presidents, and the Secretary, and the Treasurer, three shall be elected alternately each year, or until their successors are chosen. The President shall not be immediately eligible to succeed himself in office. Under such conditions as set forth in the By-Laws the office of Executive Vice-President may be vacated before the expiration of his term.

Article V

Board of Governors

The Board of Governors shall consist of the President, the Past-President, the five Vice-Presidents, the Secretary, the Treasurer, the Section Chairmen and

---

ten elected governors.   Five of these governors shall be resident in the area operating under Pacific and Mountain time, and five of the governors shall be resident in the area operating under Central and Eastern time.   Two of the governors from the Pacific area and three of the governors from the Eastern area shall be elected in the odd-numbered years, and three of the governors in the Pacific area and two of the governors in the Eastern area shall be elected in the even-numbered years.   The term of office of all elected governors shall be for a period of two years.

Article VI

Meetings

There shall be an annual meeting, and such other meetings as stated in the By-Laws.

Article VII

Amendments

This Constitution may be amended as follows: Amendments shall be approved by the Board of Governors, and shall be submitted for discussion at any regular members' meeting.   The proposed amendment and complete discussion then shall be submitted to the entire Active, Fellow, and Honorary membership, together with letter ballot as soon as possible after the meeting.   Two-thirds of the vote cast within sixty days after mailing shall be required to carry the amendment.

BY-LAWS

By-Law I

Membership

Sec. 1.—The membership of the Society shall consist of Honorary members, Fellows, Active members, Associate members, Student members, and Sustaining members.

An **Honorary member** is one who has performed eminent services in the advancement of motion picture engineering or in the allied arts.   An Honorary member shall be entitled to vote and to hold any office in the Society.

A **Fellow** is one who shall not be less than thirty years of age and who shall comply with the requirements of either (*a*) or (*b*) for Active members and, in addition, shall by his proficiency and contributions have attained to an outstanding rank among engineers or executives of the motion picture industry. A Fellow shall be entitled to vote and to hold any office in the Society.

An **Active member** is one who shall be not less than 25 years of age, and shall be (*a*) a motion picture engineer by profession.   He shall have been engaged in the practice of his profession for a period of at least three years, and shall have taken responsibility for the design, installation, or operation of systems or apparatus pertaining to the motion picture industry; (*b*) a person regularly employed in motion picture or closely allied work, who by his inventions or proficiency in motion picture science or as an executive of a motion picture enterprise of large scope, has attained to a recognized standing in the motion picture industry.

In case of such an executive, the applicant must be qualified to take full charge of the broader features of motion picture engineering involved in the work under his direction.

An Active member is privileged to vote and to hold any office in the Society.

An **Associate member** is one who shall be not less than 18 years of age, and shall be a person who is interested in or connected with the study of motion picture technical problems or the application of them. An Associate member is not privileged to vote, to hold office or to act as chairman of any committee, although he may serve upon any committee to which he may be appointed; and, when so appointed, shall be entitled to the full voting privileges of a committee member.

A **Student member** is any person registered as a student, graduate or undergraduate, in a college, university, or educational institution, pursuing a course of studies in science or engineering that evidences interest in motion picture technology. Membership in this grade shall not extend more than one year beyond the termination of the student status described above. A Student member shall have the same privileges as an Associate member of the Society.

A **Sustaining member** is an individual, a firm, or corporation contributing substantially to the financial support of the Society.

Sec. 2.—All applications for membership or transfer, except for Honorary or Fellow membership, shall be made on blank forms provided for the purpose, and shall give a complete record of the applicant's education and experience. Honorary and Fellow membership may not be applied for.

Sec. 3.—(*a*) **Honorary membership** may be granted upon recommendation of the Board of Governors when confirmed by a four-fifths majority vote of the Honorary members, Fellows, and Active members present at any regular meeting of the Society. An Honorary member shall be exempt from all dues.

(*b*) **Fellow membership** may be granted upon recommendation of the Fellow Membership Award Committee, when confirmed by a three-fourths majority vote of the Board of Governors. Nominations for Fellow shall be made from the Active membership.

(*c*) Applicants for **Active membership** shall give as references at least one member of Active or of higher grade in good standing. Applicants shall be elected to membership by the unanimous approval of the entire membership of the appropriate Admissions Committee. In the event of a single dissenting vote or failure of any member of the Admissions Committee to vote, this application shall be referred to the Board of Governors, in which case approval of at least three-fourths of the Board of Governors shall be required.

(*d*) Applicants for **Associate membership** shall give as references one member of the Society in good standing, or two persons not members of the Society who are associated with the industry. Applicants shall be elected to membership by approval of a majority of the appropriate Admissions Committee.

(*e*) Applicants for **Student membership** shall give as reference the head of the department of the institution he is attending, this faculty member not necessarily being a member of the Society.

By-Law II
Officers

Sec. 1.—An officer or governor shall be an Honorary, a Fellow, or an Active member.

Sec. 2.—Vacancies in the Board of Governors shall be filled by the Board of Governors until the annual meeting of the Society.

By-Law III

Board of Governors

Sec. 1.—The Board of Governors shall transact the business of the Society between members' meetings, and shall meet at the call of the President, with the proviso that no meeting shall be called without at least seven (7) days' prior notice, stating the purpose of the meeting, to all members of the Board by letter or by telegram.

Sec. 2.—Nine members of the Board of Governors shall constitute a quorum at all meetings.

Sec. 3.—When voting by letter ballot, a majority affirmative vote of the total membership of the Board of Governors shall carry approval, except as otherwise provided.

Sec. 4.—The Board of Governors, when making nominations to fill vacancies in offices or on the Board, shall endeavor to nominate persons who in the aggregate are representative of the various branches or organizations of the motion picture industry to the end that there shall be no substantial predominance upon the Board, as the result of its own action, of representatives of any one or more branches or organizations of the industry.

By-Law IV

Committees

Sec. 1.—All committees, except as otherwise specified, shall be appointed by the President.

Sec. 2.—All committees shall be appointed to act for the term served by the officer who shall appoint the committees, unless their appointment is sooner terminated by the appointing officer.

Sec. 3.—Chairmen of the committees shall not be eligible to serve in such capacity for more than two consecutive terms.

Sec. 4.—Standing committees of the Society shall be as follows to be appointed as designated:

(a) *Appointed by the President and confirmed by the Board of Governors—*
     Progress Medal Award Committee
     Journal Award Committee
     Honorary Membership Committee
     Fellow Membership Award Committee
     Admissions Committees
        (Atlantic Coast Section)
        (Pacific Coast Section)
     European Advisory Committee

(b) *Appointed by the Engineering Vice-President—*
     Sound Committee
     Standards Committee

Studio Lighting Committee
Color Committee
Theater Engineering Committee
Exchange Practice Committee
Nontheatrical Equipment Committee
Television Committee
Test Film Quality Committee
Laboratory Practice Committee
Cinematography Committee
Process Photography Committee
Preservation of Film Committee

(c) *Appointed by the Editorial Vice-President*—
Board of Editors
Papers Committee
Progress Committee
Historical Committee
Museum Committee

(d) *Appointed by the Convention Vice-President*—
Publicity Committee
Convention Arrangements Committee
Apparatus Exhibit Committee

(e) *Appointed by the Financial Vice-President*—
Membership and Subscription Committee

Sec. 5.—Two Admissions Committees, one for the Atlantic Coast Section and one for the Pacific Coast Section, shall be appointed. The former Committee shall consist of a Chairman and six Fellow or Active members of the Society residing in the metropolitan area of New York, of whom at least four shall be members of the Board of Governors.

The latter Committee shall consist of a Chairman and four Fellow or Active members of the Society residing in the Pacific Coast area, of whom at least three shall be members of the Board of Governors.

By-Law V

Meetings

Sec. 1.—The location of each meeting of the Society shall be determined by the Board of Governors.

Sec. 2.—Only Honorary members, Fellows, and Active members shall be entitled to vote.

Sec. 3.—A quorum of the Society shall consist in number of one-fifteenth of the total number of Honorary members, Fellows, and Active members as listed in the Society's records at the close of the last fiscal year.

Sec. 4.—The fall convention shall be the annual meeting.

Sec. 5.—Special meetings may be called by the President and upon the request of any three members of the Board of Governors not including the President.

Sec. 6.—All members of the Society in any grade shall have the privilege of discussing technical material presented before the Society or its Sections.

By-Law VI

Duties of Officers

Sec. 1.—The **President** shall preside at all business meetings of the Society and shall perform the duties pertaining to that office. As such he shall be the chief executive of the Society, to whom all other officers shall report.

Sec. 2.—In the absence of the President, the officer next in order as listed in Article IV of the Constitution shall preside at meetings and perform the duties of the President.

Sec. 3.—The five Vice-Presidents shall perform the duties separately enumerated below for each office, or as defined by the President:

(*a*) The **Executive Vice-President** shall represent the President in such geographical areas of the United States as shall be determined by the Board of Governors and shall be responsible for the supervision of the general affairs of the Society in such areas, as directed by the President of the Society. Should the President or Executive Vice-President remove his residence from the geographical area (Atlantic Coast or Pacific Coast) of the United States in which he resided at the time of his election, the office of Executive Vice-President shall immediately become vacant and a new Executive Vice-President elected by the Board of Governors for the unexpired portion of the term, the new Executive Vice-President to be a resident of that part of the United States from which the President or Executive Vice-President has just moved.

(*b*) The **Engineering Vice-President** shall appoint all technical committees. He shall be responsible for the general initiation, supervision, and coordination of the work in and among these committees. He may act as Chairman of any committee or otherwise be a member ex-officio.

(*c*) The **Editorial Vice-President** shall be responsible for the publication of the Society's JOURNAL and all other technical publications. He shall pass upon the suitability of the material for publication, and shall cause material suitable for publication to be solicited as may be needed. He shall appoint a Papers Committee and an Editorial Committee. He may act as Chairman of any committee or otherwise be a member ex-officio.

(*d*) The **Financial Vice-President** shall be responsible for the financial operations of the Society, and shall conduct them in accordance with budgets approved by the Board of Governors. He shall study the costs of operation and the income possibilities to the end that the greatest service may be rendered to the members of the Society within the available funds. He shall submit proposed budgets to the Board. He shall appoint at his discretion a Ways and Means Committee, a Membership Committee, a Commercial Advertising Committee, and such other committees within the scope of his work as may be needed. He may act as Chairman of any of these committees or otherwise be a member ex-officio.

(*e*) The **Convention Vice-President** shall be responsible for the national conventions of the Society. He shall appoint a Convention Arrangements Committee, an Apparatus Exhibit Committee, and a Publicity Committee. He may act as Chairman of any committee, or otherwise be a member ex-officio.

Sec. 4.—The **Secretary** shall keep a record of all meetings; he shall conduct the correspondence relating to his office, and shall have the care and custody of records, and the seal of the Society.

Sec. 5.—The **Treasurer** shall have charge of the funds of the Society and disburse them as and when authorized by the Financial Vice-President. He shall

make an annual report, duly audited, to the Society, and a report at such other times as may be requested. He shall be bonded in an amount to be determined by the Board of Governors and his bond filed with the Secretary.

Sec. 6.—Each officer of the Society, upon the expiration of his term of office, shall transmit to his successor a memorandum outlining the duties and policies of his office.

By-Law VII

Elections

Sec. 1.—All officers and governors shall be elected to their respective offices by a majority of ballots cast by the Active, Fellow, and Honorary members in the following manner:

Not less than three months prior to the annual fall convention, the Board of Governors shall nominate for each vacancy several suitable candidates. Nominations shall first be presented by a Nominating Committee appointed by the President, consisting of nine members, including a Chairman. The committee shall be made up of two Past-Presidents, three members of the Board of Governors not up for election, and four other Active, Fellow, or Honorary members, not currently officers or governors of the Society. Nominations shall be made by three-quarters affirmative vote of the total Nominating Committee. Such nominations shall be final unless any nominee is rejected by a three-quarters vote of the Board of Governors present and voting.

The Secretary shall then notify these candidates of their nomination. From the list of acceptances, not more than two names for each vacancy shall be selected by the Board of Governors and placed on a letter ballot. A blank space shall be provided on this letter ballot under each office, in which space the names of any Active, Fellow, or Honorary members other than those suggested by the Board of Governors may be voted for. The balloting shall then take place.

The ballot shall be enclosed in a blank envelope which is enclosed in an outer envelope bearing the Secretary's address and a space for the member's name and address. One of these shall be mailed to each Active, Fellow, and Honorary member of the Society, not less than forty days in advance of the annual fall convention.

The voter shall then indicate on the ballot one choice for each office, seal the ballot in the blank envelope, place this in the envelope addressed to the Secretary, sign his name and address on the latter, and mail it in accordance with the instructions printed on the ballot. No marks of any kind except those above prescribed shall be placed upon the ballots or envelopes. Voting shall close seven days before the opening session of the annual fall convention.

The sealed envelope shall be delivered by the Secretary to a Committee of Tellers appointed by the President at the annual fall convention. This committee shall then examine the return envelopes, open and count the ballots, and announce the results of the election.

The newly elected officers and governors of the general Society shall take office on January 1st following their election.

By-Law VIII

Dues and Indebtedness

Sec. 1.—The annual dues shall be fifteen dollars ($15) for Fellows and Active members, seven dollars and fifty cents ($7.50) for Associate members, and three

dollars ($3.00) for Student members, payable on or before January 1st of each year. Current or first year's dues for new members in any calendar year shall be at the full annual rate for those notified of acceptance in the Society on or before June 30th; one-half the annual rate for those notified of acceptance in the Society on or after July 1st.

Sec. 2.—(*a*) Transfer of membership to a higher grade may be made at any time. If the transfer is made on or before June 30th the annual dues of the higher grade is required. If the transfer is made on or after July 1st and the member's dues for the full year has been paid, one-half of the annual dues of the higher grade is payable less one-half the annual dues of the lower grade.

(*b*) No credit shall be given for annual dues in a membership transfer from a higher to a lower grade, and such transfers shall take place on January 1st of each year.

(*c*) The Board of Governors upon their own initiative and without a transfer application may elect, by the approval of at least three-fourths of the Board, any Associate or Active member for transfer to any higher grade of membership.

Sec. 3.—Annual dues shall be paid in advance. A *new* member who has not paid dues in advance shall be notified of admittance but shall not receive the JOURNAL and is not in good standing until initial dues are paid. All Honorary members, Fellows, and Active members in good standing, as defined in *Section 5*, may vote or otherwise participate in the meetings.

Sec. 4.—Members shall be considered delinquent whose annual dues for the year remain unpaid on February 1st. The first notice of delinquency shall be mailed February 1st. The second notice of delinquency shall be mailed, if necessary, on March 1st, and shall include a statement that the member's name will be removed from the mailing list for the JOURNAL and other publications of the Society before the mailing of the April issue of the JOURNAL. Members who are in arrears of dues on June 1st, after two notices of such delinquency have been mailed to their last address of record, shall be notified their names have been removed from the mailing list and shall be warned unless remittance is received on or before August 1st, their names shall be submitted to the Board of Governors for action at the next meeting. Back issues of the JOURNAL shall be sent, if available, to members whose dues have been paid prior to August 1st.

Sec. 5.—(*a*) Members whose dues remain unpaid on October 1st may be dropped from the rolls of the Society by majority vote and action of the Board, or the Board may take such action as it sees fit.

(*b*) Anyone who has been dropped from the rolls of the Society for nonpayment of dues shall, in the event of his application for reinstatement, be considered as a new member.

(*c*) Any member may be suspended or expelled for cause by a majority vote of the entire Board of Governors; provided he shall be given notice and a copy in writing of the charges preferred against him, and shall be afforded opportunity to be heard ten days prior to such action.

Sec. 6.—The provisions of *Sections 1* to *4*, inclusive, of this By-Law VIII given above may be modified or rescinded by action of the Board of Governors.

By-Law IX
Emblem

Sec. 1.—The emblem of the Society shall be a facsimile of a four-hole film reel

with the letter S in the upper center opening, and the letters M, P, and E, in the three lower openings, respectively. The Society's emblem may be worn by members only.

By-Law X

Publications

Sec. 1.—Papers read at meetings or submitted at other times, and all material of general interest shall be submitted to the Editorial Board, and those deemed worthy of permanent record shall be printed in the JOURNAL. A copy of each issue shall be mailed to each member in good standing to his last address of record. Extra copies of the JOURNAL shall be printed for general distribution and may be obtained from the General Office on payment of a fee fixed by the Board of Governors.

By-Law XI

Local Sections

Sec. 1.—Sections of the Society may be authorized in any state or locality where the Active, Fellow, and Honorary membership exceeds 20. The geographic boundaries of each Section shall be determined by the Board of Governors.

Upon written petition, signed by 20 or more Active members, Fellows, and Honorary members, for the authorization of a Section of the Society, the Board of Governors may grant such authorization.

Section Membership

Sec. 2.—All members of the Society of Motion Picture Engineers in good standing residing in that portion of any country set apart by the Board of Governors tributary to any local Section shall be eligible for membership in that Section, and when so enrolled they shall be entitled to all privileges that such local Section may, under the General Society's Constitution and By-Laws, provide.

Any member of the Society in good standing shall be eligible for nonresident affiliated membership of any Section under conditions and obligations prescribed for the Section. An affiliated member shall receive all notices and publications of the Section but he shall not be entitled to vote at sectional meetings.

Sec. 3.—Should the enrolled Active, Fellow, and Honorary membership of a Section fall below 20, or should the technical quality of the presented papers fall below an acceptable level, or the average attendance at meetings not warrant the expense of maintaining the organization, the Board of Governors may cancel its authorization.

Section Officers

Sec. 4.—The officers of each Section shall be a Chairman and a Secretary-Treasurer. The Section chairmen shall automatically become members of the Board of Governors of the General Society, and continue in such positions for the duration of their terms as chairmen of the local Sections. Each Section officer shall hold office for one year, or until his successor is chosen.

Section Board of Managers

Sec. 5.—The Board of Managers shall consist of the Section Chairman, the Section Past-Chairman, the Section Secretary-Treasurer, and six Active, Fellow, or

Honorary members. Each manager of a Section shall hold office for two years, or until his successor is chosen.

Section Elections

Sec. 6.—The officers and managers of a Section shall be Active, Fellow, or Honorary members of the General Society. All officers and managers shall be elected to their respective offices by a majority of ballots cast by the Active, Fellow, and Honorary members residing in the geographical area covered by the Section.

Not less than three months prior to the annual fall convention of the Society, nominations shall be presented to the Board of Managers of the Section by a Nominating Committee appointed by the Chairman of the Section, consisting of seven members, including a chairman. The Committee shall be composed of the present Chairman, the Past-Chairman, two other members of the Board of Managers not up for election, and three other Active, Fellow, or Honorary members of the Section not currently officers or managers of the Section. Nominations shall be made by a three-quarters affirmative vote of the total Nominating Committee. Such nominations shall be final, unless any nominee is rejected by a three-quarters vote of the Board of Managers, and in the event of such rejection the Board of Managers will make its own nomination.

The Chairman of the Section shall then notify these candidates of their nomination. From the list of acceptances, not more than two names for each vacancy shall be selected by the Board of Managers and placed on a letter ballot. A blank space shall be provided on this letter ballot under each office, in which space the names of any Active, Fellow, or Honorary members other than those suggested by the Board of Managers may be voted for. The balloting shall then take place.

The ballot shall be enclosed in a blank envelope which is enclosed in an outer envelope bearing the local Secretary-Treasurer's address and a space for the member's name and address. One of these shall be mailed to each Active, Fellow, and Honorary member of the Society residing in the geographical area covered by the Section, not less than forty days in advance of the annual fall convention.

The voter shall then indicate on the ballot one choice for each office, seal the ballot in the blank envelope, place this in the envelope addressed to the Secretary-Treasurer, sign his name and address on the latter, and mail it in accordance with the instructions printed on the ballot. No marks of any kind except those above prescribed shall be placed upon the ballots or envelopes. Voting shall close seven days before the opening session of the annual fall convention.

The sealed envelopes shall be delivered by the Secretary-Treasurer to his Board of Managers at a duly called meeting. The Board of Managers shall then examine the return envelopes, open and count the ballots, and announce the results of the election.

The newly elected officers and managers shall take office on January 1st following their election.

Section Business

Sec. 7.—The business of a Section shall be conducted by the Board of Managers.

Section Expenses

Sec. 8.—(*a*) As early as possible in the fiscal year, the Secretary-Treasurer of each Section shall submit to the Board of Governors of the Society a budget of expenses for the year.

(*b*) The Treasurer of the General Society may deposit with each Section Secre-

tary-Treasurer a sum of money, the amount to be fixed by the Board of Governors, for current expenses.

(c) The Secretary-Treasurer of each Section shall send to the Treasurer of the General Society, quarterly or on demand, an itemized account of all expenditures incurred during the preceding interval.

(d) Expenses other than those enumerated in the budget, as approved by the Board of Governors of the General Society, shall not be payable from the general funds of the Society without express permission from the Board of Governors.

(e) A Section Board of Managers shall defray all expenses of the Section not provided for by the Board of Governors, from funds raised locally by donation, or fixed annual dues, or by both.

(f) The Secretary of the General Society shall, unless otherwise arranged, supply to each Section all stationery and printing necessary for the conduct of its business.

Section Meetings

Sec. 9.—The regular meetings of a Section shall be held in such places and at such hours as the Board of Managers may designate.

The Secretary-Treasurer of each Section shall forward to the Secretary of the General Society, not later than five days after a meeting of a Section, a statement of the attendance and of the business transacted.

Section Papers

Sec. 10.—Papers shall be approved by the Section's Papers Committee previously to their being presented before a Section. Manuscripts of papers presented before a Section, together with a report of the discussions and the proceedings of the Section meetings, shall be forwarded promptly by the Section Secretary-Treasurer to the Secretary of the General Society. Such material may, at the discretion of the Board of Editors of the General Society, be printed in the Society's publications.

Constitution and By-Laws

Sec. 11.—Sections shall abide by the Constitution and By-Laws of the Society and conform to the regulations of the Board of Governors. The conduct of Sections shall always be in conformity with the general policy of the Society as fixed by the Board of Governors.

By-Law XII

Amendments

Sec. 1.—These By-Laws may be amended at any regular meeting of the Society by the affirmative vote of two-thirds of the members present at a meeting who are eligible to vote thereon, a quorum being present, either on the recommendation of the Board of Governors or by a recommendation to the Board of Governors signed by any ten members of Active or higher grade, provided that the proposed amendment or amendments shall have been published in the Journal of the Society, in the issue next preceding the date of the stated business meeting of the Society at which the amendment or amendments are to be acted upon.

Sec. 2.—In the event that no quorum of the voting members is present at the time of the meeting referred to in *Section 1*, the amendment or amendments shall

be referred for action to the Board of Governors.   The proposed amendment or amendments then become a part of the By-Laws upon receiving the affirmative vote of three-quarters of the Board of Governors.

JOURNAL AWARD AND PROGRESS MEDAL AWARD

In accordance with the provisions of Administrative Practices of the Society, the regulations of procedure for the Journal Award and the Progress Medal Award, a list of the names of previous recipients, and the reasons therefor, shall be published annually in the JOURNAL as follows:

JOURNAL AWARD

The Journal Award Committee shall consist of five Fellows or Active members of the Society, appointed by the President and confirmed by the Board of Governors.   The Chairman of the Committee shall be designated by the President.

At the fall convention of the Society a Journal Award Certificate shall be presented to the author or to each of the authors of the most outstanding paper originally published in the JOURNAL of the Society during the preceding calendar year.

Other papers published in the JOURNAL of the Society may be cited for Honorable Mention at the option of the Committee, but in any case should not exceed five in number.

The Journal Award shall be made on the basis of the following qualifications:

(1) The paper must deal with some technical phase of motion picture engineering.

(2) No paper given in connection with the receipt of any other Award of the Society shall be eligible.

(3) In judging of the merits of the paper, three qualities shall be considered, with the weights here indicated:

(a) Technical merit and importance of material........   45 per cent.
(b) Originality and breadth of interest...............   35 per cent.
(c) Excellence of presentation of the material.........   20 per cent.

A majority vote of the entire Committee shall be required for the election to the Award.   Absent members may vote in writing.

The report of the Committee shall be presented to the Board of Governors at their July meeting for ratification.

These regulations, a list of the names of those who have previously received the Journal Award, the year of each Award, and the titles of the papers shall be published annually in the April issue of the JOURNAL of the Society.   In addition, the list of papers selected for Honorable Mention shall be published in the JOURNAL of the Society during the year current with the Award.

The Awards in previous years have been as follows:

1934—P. A. Snell, for his paper entitled "An Introduction to the Experimental Study of Visual Fatigue." (Published May, 1933.)

1935—L. A. Jones and J. H. Webb, for their paper entitled "Reciprocity Law Failure in Photographic Exposure." (Published Sept., 1934.)

1936—E. W. Kellogg, for his paper entitled "A Comparison of Variable-Density and Variable-Width Systems." (Published Sept., 1935.)

1937—D. B. Judd, for his paper entitled "Color Blindness and Anomalies of Vision." (Published June, 1936.)

1938—K. S. Gibson, for his paper entitled "The Analysis and Specification of Color." (Published Apr., 1937.)

1939—H. T. Kalmus, for his paper entitled "Technicolor Adventures in Cinemaland." (Published Dec., 1938.)

1940—R. R. McNath, for his paper entitled "The Surface of the Nearest Star." (Published Mar., 1939.)

1941—J. G. Frayne and Vincent Pagliarulo, for their paper entitled "The Effects of Ultraviolet Light on Variable-Density Recording and Printing." (Published June, 1940.)

1942—W. J. Albersheim and Donald MacKenzie, for their paper entitled "Analysis of Sound-Film Drives." (Published July, 1941.)

1943—R. R. Scoville and W. L. Bell, for their paper entitled "Design and Use of Noise-Reduction Bias Systems." (Published Feb., 1942; Award made Apr., 1944.)

1944—J. I. Crabtree, G. T. Eaton, and M. E. Muehler, for their paper entitled "Removal of Hypo and Silver Salts from Photographic Materials as Affected by the Composition of the Processing Solutions." (Published July, 1943.)

1945—C. J. Kunz, H. E. Goldberg, and C. E. Ives, for their paper entitled "Improvement in Illumination Efficiency of Motion Picture Printers." (Published May, 1944.)

The present Chairman of the Journal Award Committee is F. E. Carlson.

PROGRESS MEDAL AWARD

The Progress Medal Award Committee shall consist of five Fellows or Active members of the Society, appointed by the President and confirmed by the Board of Governors. The Chairman of the Committee shall be designated by the President.

The Progress Medal may be awarded each year to an individual in recognition of any invention, research, or development which, in the opinion of the Committee, shall have resulted in a significant advance in the development of motion picture technology.

Any member of the Society may recommend persons deemed worthy of the Award. The recommendation in each case shall be in writing and in detail as to the accomplishments which are thought to justify consideration. The recommendation shall be seconded in writing by any two Fellows or Active members of the Society, who shall set forth their knowledge of the accomplishments of the candidate which, in their opinion, justify consideration.

A majority 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 at their July meeting for ratification.

The recipient of the Progress Medal shall be asked to present a photograph of himself to the Society and, at the discretion of the Committee, may be asked to prepare a paper for publication in the JOURNAL of the Society.

These regulations, a list of the names of those who have previously received the Medal, the year of each Award, and a statement of the reason for the Award shall be published annually in the April issue of the JOURNAL of the Society.

Previous Awards have been as follows:

The 1935 Award was made to E. C. Wente, for his work in the field of sound recording and reproduction. (Citation published Dec., 1935.)

The 1936 Award was made to C. E. K. Mees, for his work in photography. (Citation published Dec., 1936.)

The 1937 Award was made to E. W. Kellogg, for his work in the field of sound reproduction. (Citation published Dec., 1937.)

The 1938 Award was made to H. T. Kalmus, for his work in developing color motion pictures. (Citation published Dec., 1938.)

The 1939 Award was made to L. A. Jones, for his scientific researches in the field of photography. (Citation published Dec., 1939.)

The 1940 Award was made to Walt Disney, for his contributions to motion picture photography and sound recording of feature and short cartoon films. (Citation published Dec., 1940.)

The 1941 Award was made to G. L. Dimmick, for his development activities in motion picture sound recording. (Citation published Dec., 1941.)

No Awards were made in 1942 and 1943.

The 1944 Award was made to J. G. Capstaff, for his research and development of films and apparatus used in amateur cinematography. (Citation published Jan., 1945.)

No Award was made in 1945.

The present Chairman of the Progress Medal Award Committee is E. A. Williford.

REPORT OF THE TREASURER

SOCIETY OF MOTION PICTURE ENGINEERS

JANUARY 1–DECEMBER 31, 1945

Members' Equity, Jan. 1, 1945: $40,855.75

Receipts, Jan.–Dec., 1945:

Membership Dues	$17,813.92	
Sustaining Memberships	8,087.50	
Publications (Subscriptions, Reprints, Journals, Book, Standards, *etc.*)	7,576.43	
*Test Films	79,615.87	
Other (Conferences, Interest, *etc.*)	838.87	

   Total Receipts $113,932.59

Disbursements, Jan.–Dec., 1945:

General Office (Salaries, Rent, Supplies, Tel. and Tel., Equipment, Travel, Postage, *etc.*)	15,798.58
Publications (Journal, Reprints, *etc.*)	9,641.69
*Test Films	51,502.44
Dues and Fees to Other Organizations (ASA, RTPB, NFPA, ISCC)	835.00
Sections (Atlantic and Pacific)	590.36
Other (Committees, Awards, *etc.*)	518.91

   Total Disbursements   78,886.98

Excess Receipts Over Disbursements, 1945   35,045.61

Members' Equity, Dec. 31, 1945 $75,901.36

* Subject to Renegotiation

           Respectfully submitted,
           EARL I. SPONABLE, *Treasurer*

The cash records of the Treasurer were audited for the year ended December 31, 1945, by Sparrow, Waymouth and Company, certified public accountants, New York, and are in conformity with the above report.

           M. R. BOYER,
          Financial Vice-President

SOCIETY ANNOUNCEMENTS

ATLANTIC COAST SECTION MEETING

Foreign language releases of American motion picture films were discussed by W. A. Pozner of MGM International Films Corporation, New York, at the meeting of the Atlantic Coast Section of the Society on February 13. The meeting was held in the auditorium of the Museum of Modern Art, New York.

Mr. Pozner reviewed the history of dubbing methods, discussed the importance of sound perspective, and gave a detailed description of the dubbing technique used by MGM. The talk was followed by 3 motion picture shorts illustrating the special projection magazine and the MGM dubbing process, an example of an original English release print with alternate Spanish and English sound tracks, and an original foreign film with English sound track.

Because of the wide interest in the industry in preparing foreign versions of entertainment films, a large audience turned out for this presentation. MGM International night was one of a series of meetings arranged by the Atlantic Coast Section to promote wider knowledge of industry techniques and practices. The paper will be published in a forthcoming issue of the JOURNAL.

PACIFIC COAST SECTION MEETING

Stuart W. Seeley, director of the Industry Service Laboratory of Radio Corporation of America, New York, described the latest developments in television and their relationship to the motion picture industry before members and guests of the Pacific Coast Section of the Society in Hollywood, February 20.

Mr. Seeley also gave a highly interesting description of the "Shoran" system which made possible accurate blind bombing through ability to locate the plane's position in the air to an accuracy of a few feet at all times. The current application of Shoran to mapping was also explained.

The Walt Disney Studios was host to the gathering of some 250 members, studio executives, and others.

NOMINATIONS FOR ANNUAL ELECTIONS

In accordance with Administrative Practices of the Society, a Committee on Nominations has been appointed by the President to recommend candidates for offices expiring December 31, 1946. General elections are held prior to the October Technical Conference. The offices expiring and incumbents are given on the reverse of the contents page of this issue.

Voting members of the Society (Honorary, Fellow, and Active) are invited to submit recommendations for candidates to the Nominating Committee. Only Honorary, Fellow, and Active members may hold office. Names should be sent to E. M. Honan, Chairman of the Committee, 6601 Romaine St., Hollywood 38, Calif., or to any committee member listed on page 317 of this issue. A report will be submitted to the Board of Governors at the July meeting.

EMPLOYMENT SERVICE

In the December 1944 JOURNAL the Society announced the inauguration of a free Employment Service to assist members in making business connections, and to offer industry organizations an opportunity to place their engineering personnel requirements before a large group of experienced engineers and specialists in the motion picture industry. This mutual service has been carried in the JOURNAL since, showing both *Positions Open* and *Positions Wanted*.

The General Office has received letters from individuals and companies commending the service, and many members have made new business affiliations through this medium. The following excerpt from a letter by a returned war veteran-member is typical:

> "Happy to report my ad in 'Positions Wanted' section of the SMPE Journal of January and February, 1946, has had results and I have gained a satisfactory position. . . . My sincere thanks to the staff for the insertion of this ad. . . ."

The Society believes that this medium may be helpful to other members, especially veterans, and companies in the motion picture industry and it is requested that any interested member or company send particulars to the General Office for insertion in the next JOURNAL. Top experts in the field read the JOURNAL regularly and there are excellent prospects of obtaining the position or engineer desired. The Society, however, reserves the right both to edit or reject any notice submitted for publication.

POSITIONS OPEN

Designer and engineer experienced in optics, lighting, and microphotography, capable of designing microfilm reading equipment and products related to microfilm industry. Reply to Microstat Corporation, 18 West 48th St., New York 19, N.Y.

Position available for Optical Designer, capable of handling the calculation and correction of aberrations in photographic and projection lens systems. Junior designers or engineers will be considered. Write fully giving education, experience, and other qualifications to Director of Personnel, Bell and Howell Company, 7100 McCormick Road, Chicago 45, Ill.

Motion picture studio in Bombay, India, has positions open for professional motion picture camerman with studio and location experience; sound recording engineer experienced in installation, maintenance and operation of recording equipment; motion picture processing laboratory supervisor; and professional make-up artist. Five-year contracts at favorable terms are offered to those qualified. Write or cable direct to Personnel Manager, Dawlat Corporation Ltd., Patel Chambers, French Bridge, Bombay 7, India, giving experience, etc., in detail.

New film production unit to be located at Athens, Georgia, needs film editor-writer and film director. Experience in 16-mm as well as 35-mm production desirable. Southern background or interest in South pre-

ferred but not essential.   Write giving full details of experience, etc., to Nicholas Read, The National Film Board, Ottawa, Canada.

POSITIONS WANTED

Sound recording engineer, 16- or 35-mm equipment, studio or location work, single or double system.   Free to travel.   For details write J. J. K., 354 Ninth Ave., New York 1, N.Y.

Honorably discharged veteran with 15 years' experience in all phases of motion picture production, including film editing, directing, producing.   For details write F. A., 30-71 34th St., Long Island City 3, N.Y.   Telephone AStoria 8-0714.

Projectionist-newsreel editor with 15 years' experience just released from service.   Willing to locate anywhere.   Write P. O. Box 152, Hampden Station, Baltimore 11, Maryland.

Honorably discharged veteran with 10 years' experience in projection and installation of projection and sound equipment, both for booth and back-stage.   Prefer to locate in California, Oregon or Nevada.   For additional details write F.A.N., Box 113, Holley, Oregon.

MEMBERS OF THE SOCIETY LOST IN THE SERVICE OF THEIR COUNTRY

———

FRANKLIN C. GILBERT

ISRAEL H. TILLES

MORGAN L. HOBART

HARRY B. CUTHBERTSON

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

CONTENTS

A LENS CALIBRATING SYSTEM *

C. R. DAILY**

Summary.—This paper describes a method for the calibration of the effective f/stop value of a camera lens in terms of the light transmitted by the lens. Owing to light losses within a lens, the f/value determined in this manner will normally be numerically larger than the values obtained from the geometry of the lens. However, stop values based on transmission are of considerably greater value to a cameraman than values based on apertures.

An interrupted, collimated beam of light falls on the entrance port of an integrating sphere. The lens to be calibrated is centered over the opening and the light output from the sphere measured through a stable a-c amplifier equipment. A calibration curve is then obtained for the equipment wherein metal plates with holes of known diameters are placed over the entrance of the sphere in place of the lens. The effective aperture of the lens is then defined as the size of opening which will pass the same total amount of light as the lens under calibration. This method avoids the use of secondary standards and should be capable of duplication in any laboratory.

The light transmission properties of a photographic objective lens are materially improved if the lens surfaces are coated to reduce reflection losses. Therefore the true photographic speed of a lens is not given directly by the effective aperture ratio and a cameraman must make allowances for variations from the marked f/values on various types of lenses in order to obtain a correct exposure, since the marked f/values do not include transmission losses. The error increases with the number of air-glass surfaces, and the effect of coating a lens should be to reduce the difference between the transmission-effective and the geometric-effective apertures. This variable, coupled with differences in original factory calibration, has led a number of investigators to study the problem and as a result several methods for calibrating lenses in terms of the true photographic speed have been put into use.

The method of lens calibration described in this paper was developed to provide a standard which could be reproduced in any laboratory and which would be photographically correct for the central part of the image.   The use of fixed aperture stops of known diameter satisfied the first requirement for standard reference apertures, while the use of collimated light simulated a point source of light at infinity and therefore should give results equivalent to the image intensity in the center of the field.   *Close correlation to photographic density tests has been obtained which appears to validate the method.*

In earlier work on lens calibration by Technicolor and Twentieth Century-Fox,[1] the lenses to be tested were placed in front of a large illuminated ground glass.   The cone of light collected by and passing through the lens was focused on a standard motion picture aperture plate.   A phototube and suitable meters then measured the total light falling on the phototube behind the aperture, and the ratio of the light transmitted served as the basis for the lens diaphragm calibration.   Such methods, however, are not absolute and it is necessary to refer all lenses to one which is retained as a "standard."   Likewise, a large cone of light is picked up and since the meter gives an average reading for the total light transmitted, it will not be truly proportional to the light in the center of the field.   This "fall-off" effect is more noticeable in the case of short focus lenses.

More recently,[2] the Signal Corps Photographic Center at Long Island City, New York, has been studying this problem and described the preliminary form of their apparatus before the Society in Hollywood in May, 1945.   They undertook this same problem of recalibration because of the wide variation in exposure which was being observed among the various lenses used by them.

Work on this same problem was undertaken several years ago at Paramount,[3] and the first results were reported in August, 1942. Following the interruption of this study because of the war, the problem was again opened for study and a new method developed which should materially increase the accuracy, reproducibility, and speed with which a lens can be calibrated, and at the same time be considered as standard.

Since the f/number of a lens is defined on the basis of parallel rays, the electrical f/, or t/number as it will be called here, obtained by the proposed method should be equal to the f/value assigned to a lens by classical methods of calibration, corrected for the axial transmission losses of the lens.

Proposed Calibration System.—*Optical Schematic.*—Fig. 1 shows a schematic of the optical portion of the calibrating equipment. A 3-in. diameter, $4^1/_2$-in. focal length condenser lens images the biplane filament of a 1000-w projection lamp on a $^1/_2$-in. diameter round aperture in a metal plate. In order to more evenly illuminate this aperture, a diffusing glass which is ground on both sides is placed over the aperture. The filament image at this point is approximately $^3/_4$ in. sq. An $f/3.5$, 30-cm focal length lens, located at a distance equal to its focal length from the $^1/_2$-in. aperture, directs a homogeneous collimated beam of light toward the opening in the integrating sphere. This collimated beam does not vary appreciably in brightness either along the beam or across a 1.8-in. diameter at the center of the 3-in. diameter beam.
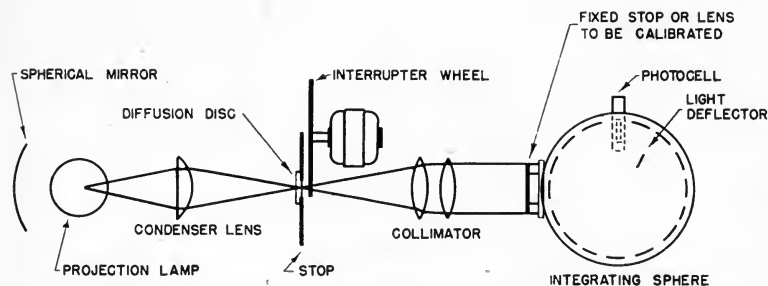
FIG. 1.   Optical schematic of lens calibrating equipment.

A light interrupter wheel is mounted near the $^1/_2$-in. aperture to provide a substantially sinusoidal, 400-cycle per sec interruption of the light beam in order to permit the use of stabilized a-c amplifiers in the measuring system. The light is picked up by means of an integrating sphere which has a 12-in. internal diameter. A General Electric type *GL-441* vacuum phototube is inserted inside the sphere. This cell has an *S-4* surface and provides a maximum sensitivity at 540 mμ when exposed to a tungsten lamp operating at 2848 K.

Fig. 2 shows the spectral characteristic of the combined phototube and tungsten lamp under these conditions. The response curve appears to be adequate for comparative tests on black-and-white film. A refinement of the apparatus is now under way to mount 2 phototubes with selective filters in order to obtain a substantially flat response from 400 to 700 mμ, for a better determination of lens properties when used with color.

Electrical Schematic.—An a-c measuring system was adopted for several reasons:

(*1*)   Higher gain stability can be obtained with respect to power supply voltage variations, *etc.*, compared with d-c amplifier systems.

(*2*)   Ease of providing precise attenuation to measure relative electrical input.
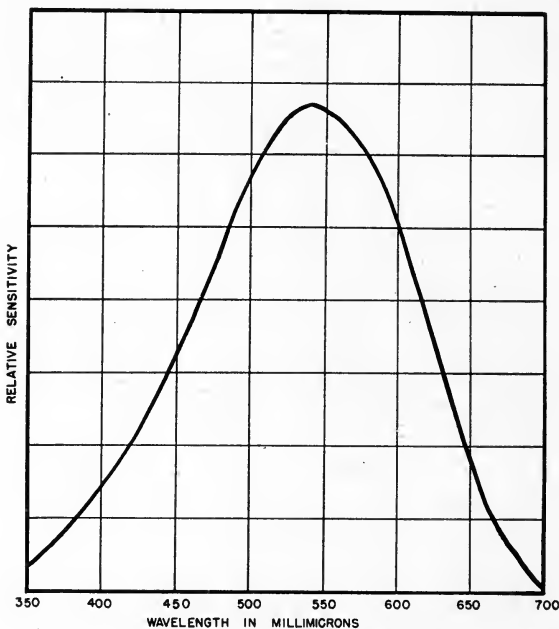
FIG. 2.   Over-all special sensitivity of a *GL-441* phototube and tungsten lamp operating at 2848 K.

(*3*)   High signal-to-noise ratio can be obtained with band-pass filters, when single-frequency amplification only is being used.

The schematic of the electrical system is shown in Fig. 3.   The phototube is resistance-coupled to a 2-stage phototube amplifier which has a 14-db interstage gain switch that is cut in when measuring with the largest diaphragm openings, or the largest lenses, to prevent overload of the second stage.   A vernier gain control is also provided to permit accurate adjustment of the output for reference calibration with a given fixed stop.   This vernier control takes care of variations in phototube sensitivity and aging of the lamp.

The phototube amplifier is followed by two 30-db variable precision bridged T attenuators, a 70-db gain feedback-stabilized line amplifier,

FIG. 3.   Block schematic of electrical equipment used with lens calibrating equipment.

a 400-cycle band-pass filter, terminating resistance, and a copper oxide rectifier-type volume indicator.
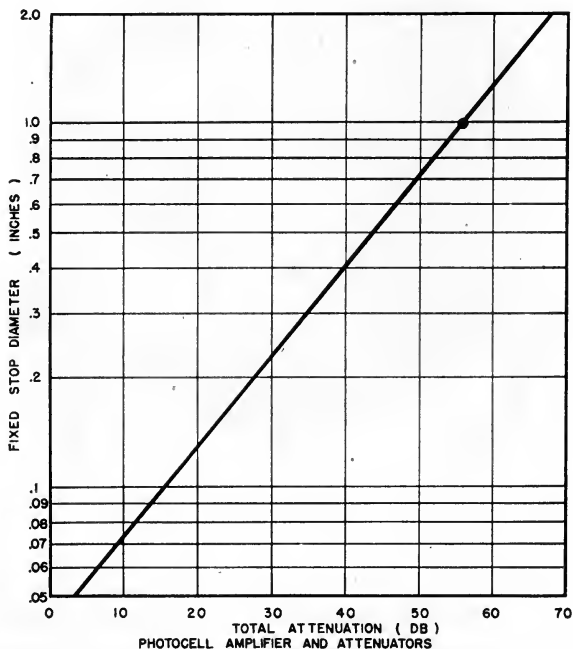
FIG. 4.   Required attenuation versus calibrating stop diameter.

Electrical Calibration of a Lens.—The system is first calibrated by placing a series of metal plates over the entrance to the integrating sphere. These plates have been drilled with circular holes of precisely known diameters so that the total area of the opening is

known. With the projection lamp held at constant voltage, the total attenuation for reference deflection of the volume indicator is read for the whole series of fixed stops which vary from 0.068 in. to 1.813 in. in diameter.

The calibration curve obtained for such a series of fixed stops is shown in Fig. 4 and has a slope in decibels of $40 \log_{10} d_1/d_2$, where d_1 and d_2 are any 2 diameters of fixed stop opening, assuming a uniform beam

Fig. 5. Integrating sphere with a calibrating stop mounted over sphere opening.

of light. It will be noted that this calibration curve is linear over the range covered which indicates linearity of the light beam over the aperture, of the collection of light by the sphere, of the phototube and of the amplifiers. Changes in lamp voltage cause output changes of approximately 0.25 db per volt, corresponding to effective lens diaphragm variations of 0.045 stops per volt.

Fig. 5 shows a photograph of the integrating sphere with one of the fixed calibrating stops mounted in position. In order to determine the uniformity of the light beam over the entrance to the sphere, a plate

with a very small opening was moved over the entrance hole to the sphere. It was found that the volume indicator deflection was essentially constant for any position of the small hole over the 1.813-in. diameter opening.

Fig. 6 shows a photograph of the sphere with a lens to be calibrated installed over the opening. After the system has been calibrated as indicated in the previous paragraphs, the lens is placed over the open-
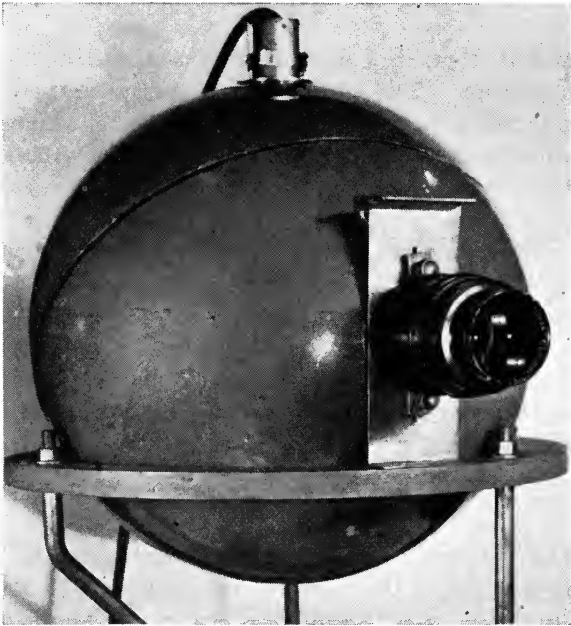
FIG. 6.   Integrating sphere with lens mounted over the sphere opening.

ing and the electrical attenuation adjusted for reference deflection of the volume indicator for the various lens diaphragm positions. For any attenuation obtained from the lens, there is a corresponding fixed stop diameter which would require the same attenuation. *This correlation to precisely known stop diameters is the basis of the absolute calibration provided by this equipment.*

Table 1 shows a typical calibration for lens A, which had a nominal focal length of one inch. The precise focal length as determined by the method described in the following section indicated that $F = 1.01$ in.

TABLE 1

Original $f/$- Value Marked on Lens	Electrical Attenuation (db)	Effective Dia- phragm Opening Diameter (In.)	t—Corrected f/Value	n—Diaphragm Marking Error
1.8	42.0	0.444	2.27	-0.52
2.3	41.0	0.435	2.32	-0.02
3.2	36.2	0.330	3.06	0.13
4.5	29.4	0.234	4.32	0.12
6.3	25.0	0.173	5.88	0.20
9	20.0	0.130	7.77	0.43
12	14.0	0.090	11.20	0.20

The electrical attenuation was adjusted as indicated above for each diaphragm position. The effective diameters were then read from the stop calibration curve shown in Fig. 4. The effective f/value of the lens, which will be tentatively designated by t, was then calculated from the defining equation

$$t = \frac{\text{Focal length}}{\text{Fixed stop diameter which will produce the same electrical output as the lens}} \quad (1)$$

The correlation is fairly close for this lens, although some lenses have been tested where the t/value differed from the originally marked f/value by as much as one stop. The last column of the table shows the error in fractions of a stop. The conversion to error of diaphragm marking can be readily made by means of the formula

$$n = 6.65 \log_{10} \frac{f_2}{f_1}; \text{ or } 6.65 \log_{10} \frac{t_2}{t_1} \quad (2)$$

where n is the fractional stop difference between t_2 and t_1.

In Table 2 is shown the range of attenuations which will be encountered for lenses at 1- to 4-in. focal length, at diaphragm openings of from $f/1.8$ to $f/18$. It will be noted that a range in attenuation of 64 db is required and care must therefore be taken in the design and wiring to prevent overloading of the phototube amplifier and to insure that the indicated attenuation is being obtained.

TABLE 2

Required Attenuation (Db)

f	Focal Length of Lens (In.)			
	1	2	3	4
1.8	45.24	57.28	64.32	69.32
2.3	41.00	53.04	60.08	65.08
4.5	29.34	41.38	48.42	53.42
9	17.32	29.36	36.40	41.40
18	5.24	17.28	24.32	29.32

Determination of Focal Length.—In order to determine the t/value, one may assume the focal length as given. However, if it is desirable to recheck this value, a direct photographic method may be used which is quite precise and direct. The method to be described was selected from several which are in use, since it employed available equipment and could be readily applied.

An outdoor location near the laboratory was selected, a transit set up at a fixed point and the angles separating a number of distant reference points measured to an accuracy of the nearest minute of arc. The reference points were more than 200 ft distant and the angular separations were selected so that it would be possible to use points for the various focal length lenses which would be separated on the image by approximately two-thirds of a standard motion picture frame width. Fig. 7 shows the geometry of this setup.

The lens under test was mounted on a Speed Graphic camera which had been equipped with quick change mounts. The image of the distant reference points was carefully centered and focused on the ground glass.

FIG. 7. Determination of focal length by a photographic method.

A photograph was then taken on a glass plate and processed in fine-grain developer. After fixing, washing, and drying the plate, the distance between the reference points on the photograph was measured on a precision toolmaker's microscope. The focal length was then computed from the formula

$$F = \frac{h/2}{\tan \theta/2} \tag{3}$$

where θ is the angle subtended by the distant reference points and h is

the distance between the reference points on the image plate.   In the determination of focal length by this method, the accuracy is much better than one per cent and is satisfactory in lieu of an optical bench which might not always be available.   Table 3 shows the angle and distance relationships obtained on a number of lenses.

Photographic Confirmation.—In order to check the accuracy of the proposed method of t/stop calibration, photographic tests were
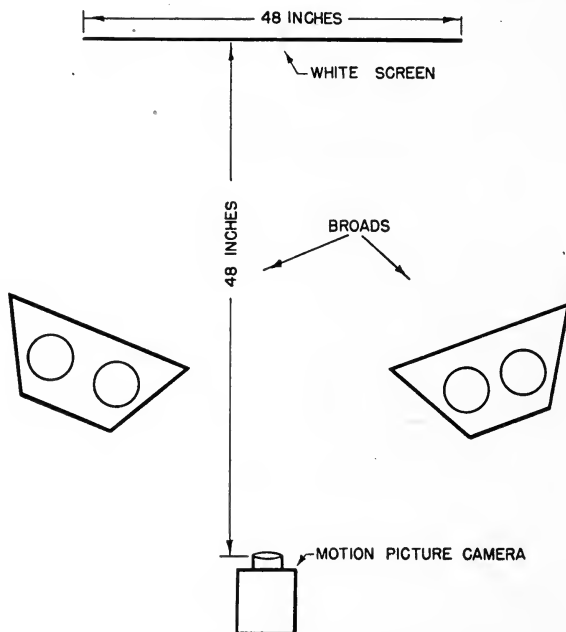
FIG. 8.   Method of illuminating a test screen for photographic confirmation test with a camera.

made using various lenses which had been calibrated by the above method.   A white test card approximately 4 ft sq was set up and uniformly illuminated by diffuse light from four 1000-w lamps, as shown in Fig. 8.   A standard motion picture camera, driven at constant speed by an interlock motor was set up 4 ft from and facing the illuminated test card.

The camera was loaded with a roll of standard 35-mm picture negative film and exposure tests were then made on the various lenses at several apertures each.   The film was given standard machine processing to insure uniformity of development.

In the photography of a light source at a distance greater than $100 \times$ focal length, the intensity in the center of the field of the image on the photographic plate should be substantially independent of the focal length of the lens, for a given f/value. Therefore, if a photo-
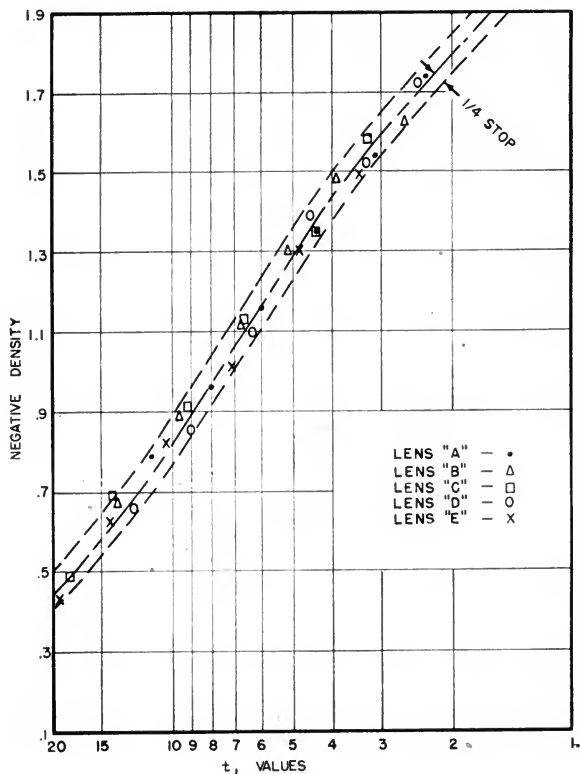
FIG. 9.   Photographic confirmation data.   The visual diffuse density of the film as measured in the *center* of the film area is plotted against the effective stop value of the lens, t_d, corrected to a distance of 4 ft.

graphic test were made of a large source at a considerable distance from the lens, a plot of negative-density versus f/value should give only one curve regardless of the lens used, which would be the dynamic sensitometric gamma characteristic of the film used.   It was more convenient, however, to photograph a smaller object at a distance of only a few feet from the camera, which introduces a small

TABLE 3

Focal Length Data on a Number of Lenses, Distant Object Photographic Method

Lens	Nominal (Mm)	Focal Length Measured (Mm)	(In.)	Tan $\theta/2$	$h/2$ In.
A	25	25.6	1.01	0.356	0.359
B	35	35.5	1.40	0.259	0.378
C	50	48.9	1.92	0.364	0.364
D	75	74.8	2.95	0.138	0.410
E	100	102.0	4.01	0.0945	0.379

correction factor because of the variation in magnification. This correction can be expressed as

$$t_d = t_\infty \cdot \frac{n-1}{n} \tag{4}$$

where t_∞ is the t/value of the lens at infinity focus, in the electrically calibrated value, t_d is the t/value at a distance d, d is the distance from lens to screen, F is the focal length of the lens, and n is the distance from lens to screen, expressed in focal lengths, *i.e.*, d/F. For the 4-ft screen distance used, this correction factor is listed in Table 4.

TABLE 4

F (In.)	n	t_4
1	48	1.02
2	24	1.04
3	16	1.06
4	12	1.09

Fig. 9 shows a plot of the electrically obtained t/values of several lenses, corrected to 4 ft, versus the density of the film as measured in the *center* of the film area. The agreement of calibrated t/numbers and photographic densities is seen to be quite close. These tests have also been repeated at 10-ft distances to the screen with a similar close agreement. Fig. 10 shows a plot for two of the lenses used in Fig. 9, where the density of the film is plotted in 2 ways: (a) the f/ numbers as originally marked on the lenses, corrected, of course, by Eq. (3); and (b) plotted against t_d in the same manner as in Fig. 9. This plot illustrates that lens C as marked would give quite erroneous exposure values.

Proposed Improvements.—A number of improvements are currently planned for this measuring apparatus to provide improved convenience of operation and to provide new information. The re-

calibration of lenses will be expedited by the use of a special attenuator whose loss per step will be the electrical equivalent of $^1/_4$ stop.

With such an attenuator, the operators can start with a reference deflection on the volume indicator corresponding to a predetermined
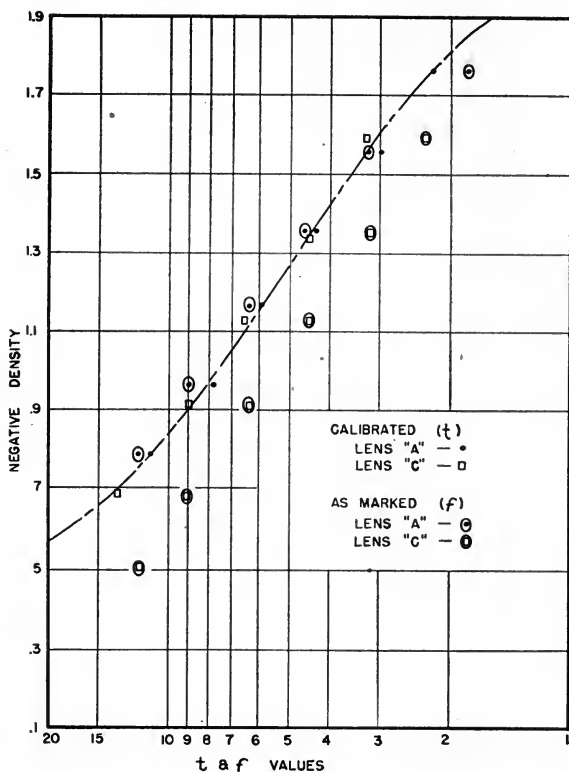
FIG. 10.   Comparison of photographic data for 2 lenses, where the originally marked and electrically calibrated stop values are plotted against the density in the *center* of the field.

maximum diaphragm opening on the lens and then start changing the attenuator by quarter- or half-stop intervals, setting the diaphragm to re-establish reference deflection again and scribe the lens for the desired marking.

The fall-off of image brightness for off-axis rays will be checked on this apparatus when provision is completed for pivoting the inte-

grating sphere around the center of the front face of the lens under test.

The equipment is also being modified to mount 2 phototubes on the sphere with filter attachments for each cell. This change will permit adjustment of sensitivity and color balance of the system to make it substantially flat over the useful color range. Selective filters can then be inserted in the light path ahead of the lens to permit the precise calibration of the transmission of a lens with respect to color, including the infrared region. Spectrophotometric measurement has shown that coated lenses may vary appreciably in their transmission characteristics over the useful spectrum. The sensitivity of the equipment may be high enough so that the transmission of a lens can be calibrated directly from a monochromatic light source. The narrow band-pass filter used in the electrical system rejects practically all noise except in the narrow band being measured, permitting a substantial increase in gain of the amplifier system used.

Summary.—A description has been given of a new form of lens transmission calibrating equipment which should give reproducible results in any laboratory. The effective f/values are obtained in terms of a known stop diameter. It may be desirable to continue to use the small letter f for the diaphragm marking of a lens based on the geometry of that lens and introduce a new symbol such as t to represent the equivalent calibration in terms of the transmission of light.

The writer wishes to express his appreciation to Lars Moen for the many suggestions and help in carrying out the preliminary part of this investigation.

REFERENCES

[1] Clark, D. B., and Laube, G.: "Twentieth Century Camera and Accessories," *J. Soc. Mot. Pict. Eng.*, **XXXIV,** 1 (Jan., 1941), p. 50.

[2] Berlant, E.: "A System of Lens Stop Calibration by Transmission," *J. Soc. Mot. Pict. Eng.*, **46,** 1 (Jan., 1946), p. 17.

[3] Silvertooth, E. W.: "Stop Calibration of Photographic Objectives," *J. Soc. Mot. Pict. Eng.*, **XXXIX,** 2 (Aug., 1942), p. 119.

ANSCO COLOR FOR PROFESSIONAL MOTION PICTURES*

H. H. DUERR AND H. C. HARSH**

Summary.—The 3 new Ansco Color Films which are designed for producing full color motion picture release prints are described. These films are (1) Ansco Color Type 735 (Camera Film), (2) Ansco Color Type 132 (Duplicating Film), and (3) Ansco Color Type 732 (Release Film). Methods for making second generation dupes, special effects, lap dissolves, etc., are discussed, and the procedure for printing sound tracks is outlined.

The basic principles of the Ansco Color process have been described previously. We will, therefore, limit the discussion of these principles to a brief review of the fundamentals of the process so far as they are necessary for the proper understanding of the application of Ansco Color to motion picture production.

The Ansco Color process is an integral subtractive color process using the method of dye coupling for the production of dye images in a multilayer material. Colorless color-forming components are incorporated in the emulsion layers. It is the unique and very important property of the color-formers in the Ansco Color process that they are of a molecular structure which renders them nondiffusing. The color-formers are immobilized in their respective emulsion layers and do not bleed into adjoining layers.

The layer arrangement of Ansco Color Reversible Film is shown in Fig. 1a and 1b. The film base, which can be either cellulose nitrate or acetate, carries an antihalation layer, followed by the red-sensitive emulsion layer. This emulsion layer also contains a colorless dye-forming component which, upon development in a suitable color developer, develops an image in color, complementary to the color sensitivity of the layer. In the case of the red-sensitive emulsion layer, the color is blue-green or cyan. For reasons of simplicity, this layer is usually referred to as the "cyan" layer.

357

The green-sensitive middle layer contains a color-former which, upon development, produces a magenta image, therefore called "magenta" layer.   A yellow filter layer, coated on top of the magenta layer, absorbs all blue light, which would normally affect also the cyan and magenta layer, and therefore has to be filtered out in order to obtain the desired separation of color in these layers.   The top emulsion layer is blue-sensitive only and the nondiffusing color-former in this layer develops to a yellow image.   This layer will be referred to as the "yellow" layer.

The dye formers or color-formers in all 3 layers have been carefully selected so that they develop to a cyan, magenta, and yellow color, re-
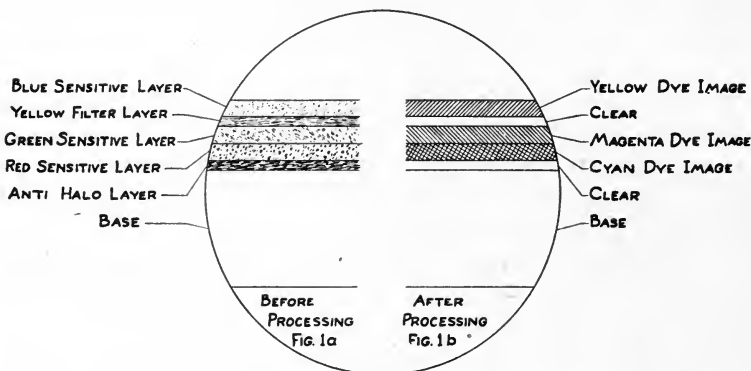
FIG. 1.   Layer arrangement of Ansco Color Film.

spectively, in one color developing step.   This greatly simplifies the processing of Ansco Color Film and makes it possible to have the complete processing done by the consumer with developing equipment which is very similar to that regularly used for black-and-white reversible development.

The fundamental principles of the Ansco Color process are applicable to a great variety of color products.   Ansco Color Reversible Film for daylight and tungsten light has been in use for some time in the form of 16-mm and sheet film.   These materials are being manufactured for use primarily for direct projection and, therefore, have gradation characteristics which make them particularly well suited for this purpose.   These film types, however, are not very satisfactory for the motion picture industry, where the requirements are essentially different.   The most important requirement for a color transparency

suitable for 35-mm motion pictures is that it lends itself to the printing of first and second generation duplicates with a minimum loss in color brilliance and fidelity.

These considerations call for a camera film which is quite different in gradation, color balance and other characteristics from the regular Ansco Color Film. Ansco Color Type *735* is the new film material designed and developed to meet these specific requirements of the motion picture industry.

Fundamentally, Ansco Color Type *735* is quite similar to the regular Ansco Color Film and the layer arrangement is the same as shown
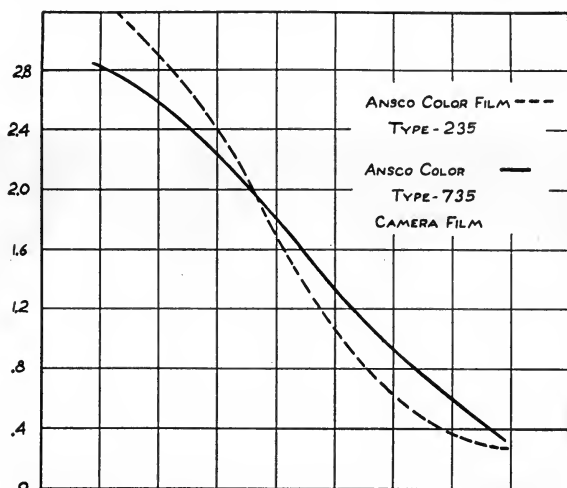
FIG. 2.   Characteristic curves of Ansco Color Camera Films.

in Fig. 1a. It differs from this film primarily in that the gradation is considerably softer, the grain is finer, and the color balance is purposely slightly off-neutral. Fig. 2 shows a comparison of the H and D curves of Ansco Color Type *735* and the regular Ansco Color Daylight Film Type *235*. This new material is designed to provide a film for exposure in the camera which is ideally suited for making release prints on Ansco Color Release Film Type *732*. Ansco Color Type *735* is not intended for projection and its use in motion picture practice should parallel the use of the original negative in black-and-white motion pictures. Because it is a positive color transparency, it is, however, possible to judge immediately after development the color rendition and other pictorial effects of the scene.

Ansco Color Camera Film is available on both nitrate and acetate base, and designated *735* and *835*, respectively.

Ansco Color Camera Film is balanced for exposure by daylight and the best color rendition on exterior exposures will be obtained in bright sunlight. For studio exposures, excellent results are obtained with key-light provided by high-intensity carbon arcs which are modified by *Y-1* gelatin filters and fill-light by tungsten lamps for color photography filtered with Macbeth Whiterlite filters. The spectrogram shown in Fig. 3 gives the relative response of the film to the visible region of a daylight spectrum.

Suggested meter settings for the exposure of Ansco Color Type *735* are Weston 8, or G. E. 12.

For optimum print results, it is desirable that the Ansco Color original be slightly underexposed or somewhat heavier in density than
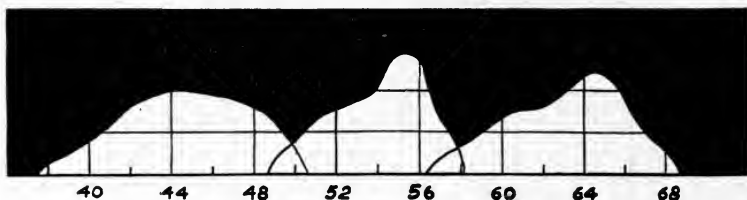
Fig. 3.   Wedge spectrogram of Ansco Color Camera Film, Type *735*.

is the usual practice when exposing a transparency for screen projection. The reason for preferring a heavy original is to maintain as much of the exposure as possible on the straight-line portion of the H and D curve and avoid inaccurate color reproduction which can result from exposures which fall predominantly in the toe region.

The processing of Ansco Color Type *735* is almost identical to that which has previously been described by Forrest.[1] The only variation is a somewhat shorter developing time in both the first and the color developer. In this connection we believe it is indicative of the simplicity of the Ansco Color process that several laboratories have converted existing black-and-white machines for the processing of Ansco Color Film and in all instances very little difficulty has been encountered. At least in one case, the very first roll of Ansco Color Film which was developed on a converted black-and-white machine was of excellent quality.

(1) **Direct Prints from Original Color Transparency.**—As previously mentioned, the release printing stock for an Ansco Color

Type *735* original is Ansco Color Release Film Type *732*. This film is also of the reversible type and while fundamentally similar to the other Ansco Color reversible films, it is characterized by a relatively low speed, very fine grain and special sensitization for printing. This printing stock can be developed to a high maximum density to obtain optimum color brilliance. Fig. 4 shows a typical H and D curve for this film. Fig. 5 shows a wedge spectrogram of the Ansco Color Release Film. There are relatively sharp sensitivity peaks in the green and red regions and a partial gap between these peaks. Good separa-

ANSCO COLOR
RELEASE FILM
TYPE - 732
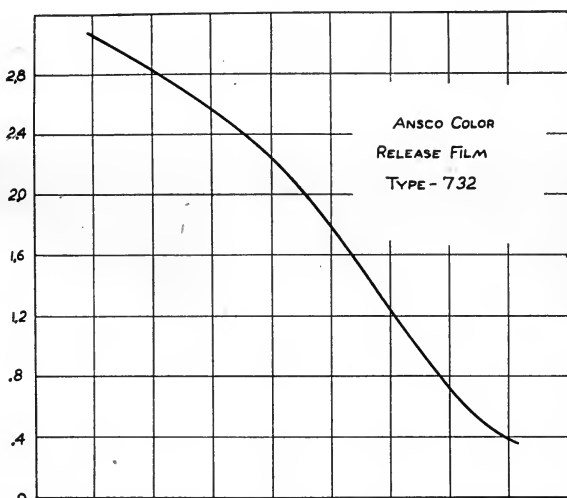
FIG. 4.   Characteristic curve of Ansco Color Release Film.

tion of the peaks of sensitivity is very essential in a printing film in order to obtain faithful color reproduction.

Ansco Color Release Film will be available on both nitrate and acetate base and designated *732* and *832*, respectively.

Most motion picture printers which are suitable for printing present-day black-and-white positive stocks can be readily adapted to print Ansco Color Release stock. If not already available, the following features should be provided on a printer to make it suitable:

(*1*) A light source which operates at a color temperature of approximately 3000 K.

(*2*) A means for inserting printing filters into the light path quickly and conveniently.

(3) A condenser lens system for the light source in order to concentrate the light at the aperture.   Ansco Color Release Film, with the printing filters in place, will require 2 to 4 times the light needed for printing black-and-white positive fine-grain stock.

(4) It is good practice to provide an air blast or fan as a means of dissipating the heat from the lamp house in order to avoid damage to the filters and film.

Using a regular black-and-white printer with the modifications just described, the printing of the Ansco Color original onto Ansco Color Release Film requires the insertion of filters to balance the color quality of the light source.   A standard series of Ansco color compensating filters, in varying densities of yellow, magenta, and cyan, are available for this purpose.   Considerable control of the color balance of the release print is possible by the selection of these printing filters.
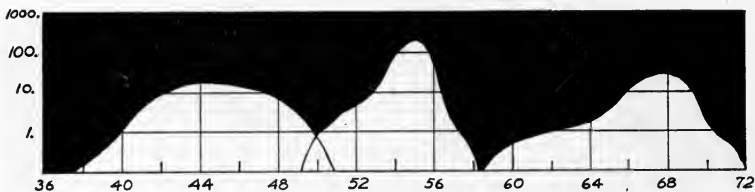
FIG. 5.   Wedge spectrogram of Ansco Color, Type 732 Release Film.

The processing of Ansco Color Release Film is carried out on the same developing machine and in the same solutions as used for the Ansco Color original.   Adjustments of the developing times to suit the particular machine conditions are necessary.

So far we have discussed the camera film and the release printing film for the Ansco Color process without referring to methods for including optical lap dissolves, wipes, and special effects where second generation duplicates of the original Ansco Color will be involved.

(2) **Prints from Duplicates.**—It is generally recognized that in color reproduction each printing step results in a noticeable degradation in color.   For this reason it is desirable to reduce the number of printing operations in color photography to a minimum. However, in motion picture practice it is not feasible in many instances to print from the original color transparency.   This is particularly true in those cases where special effects, such as lap dissolves and wipes, have to be incorporated in the sequence of the picture, also for foreign releases where it is essential that a master dupe is available

for release printing.   Two methods for making master dupes have
been worked out for this purpose.

The first method consists of straightforward optical printing of the
Ansco Color original onto Ansco Color Type *132* Duplicating Film.

The duplicating stock Type *132* requires about the same exposures
as the release stock *732*, that is, approximately 2 to 4 times the light
needed for regular positive fine-grain stock.   The film is processed in
the same solutions as the Type *735* original.   The developing time in
the first and second developer is shorter.   A duplicate is obtained
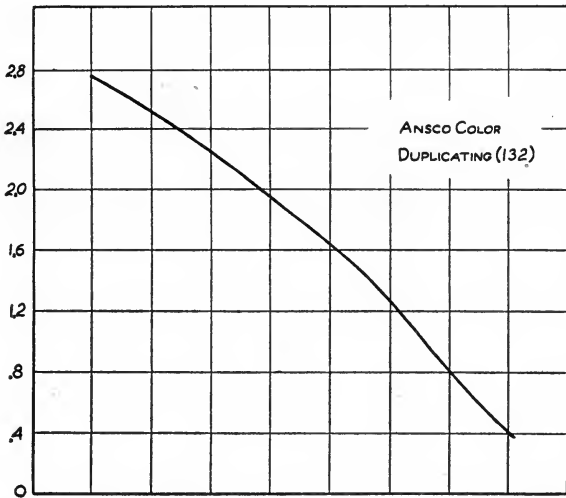
FIG. 6.   Characteristic curve of Ansco Color Duplicating Film.

which is substantially equal in contrast to the camera original.
This first generation duplicate can then be interspliced with the
original and used for release printing on Ansco Color Type *732*
Release Film.   The H and D curve of the Type *132* Duplicating
Film is shown in Fig. 6.

The fact that the original as well as the dupe and the release print
stock can all be developed in the same machine and in the same solu-
tions represents a very essential simplification of the Ansco Color
process.   As pointed out before, there are differences in the develop-
ing times for these 3 color films, and in order to allow a more exact
comparison, the approximate developing times are listed:

	First Developer	Color Developer
Ansco Color Type *735* or *835* (Camera Film)	9 min	11 min
Ansco Color Type *132* or *232* (Duplicating Film)	8 min	9 min
Ansco Color Type *732* or *832* (Release Film)	10 min	18 min

The developing times shown are only approximate, since the exact time depends very largely upon the machine speed and the solution agitation in the machine.

There will be an inevitable loss in color brilliance in the second generation duplicate prepared by this method. However, the loss is
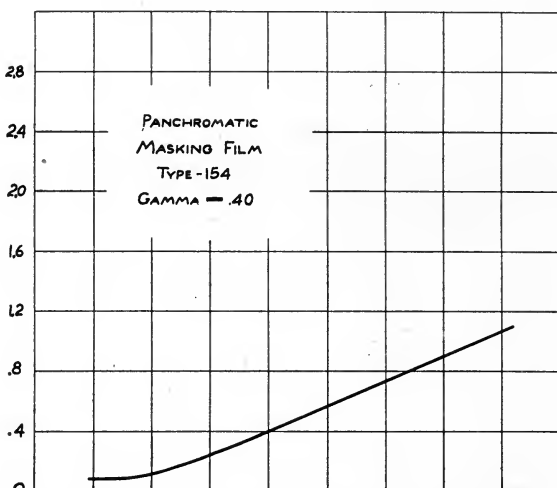
FIG. 7.   Characteristic curve of Ansco Masking Film, Type *154*.

probably not serious enough to preclude its use for certain lap dissolves, wipes, and other special effects, especially if the subject of these special effects is of such a nature that a very critical judgment of color rendition is not possible. Because of the loss of color brilliance by this method, it is not recommended for making full-length master dupes. For this purpose and where good color reproduction is desired on special effects, the following second method is preferred.

(*3*) **Prints from Masked Duplicates.**—In order to counteract the color degradation, the second method of making a master dupe employs a black-and-white silver mask. It is not the purpose of this paper to go into the details of the theoretical requirements of masking,

but rather restrict this discussion to the recommendation of a simple procedure for masking Ansco Color Type *735*.

A special low-shrink, panchromatic, black-and-white film has been developed for masking in connection with the Ansco Color process. The characteristics of this material are such that the required masking densities are obtained with the least amount of critical control. For this reason, the gamma infinity of the material is adjusted to the
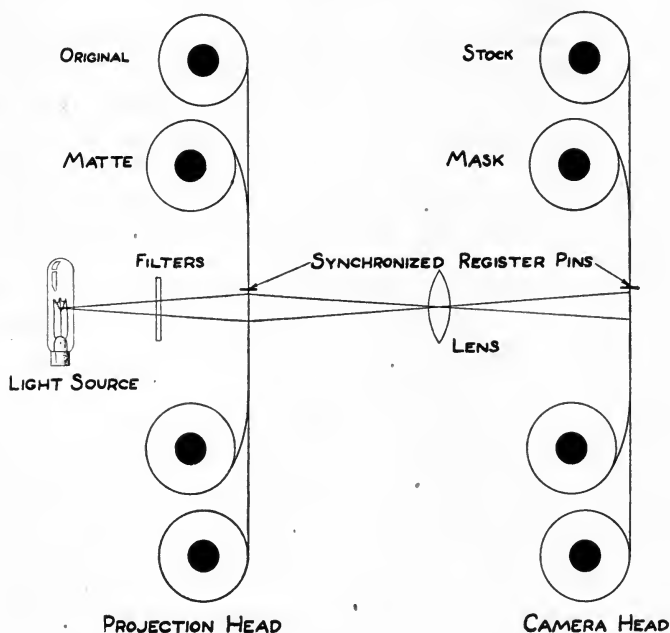
FIG. 8.   Schematic view of optical printer.

masking requirements.   In Fig. 7, the characteristic H and D curve of this special masking film is shown.   In order to insure good registration, the same printing equipment should be used for the printing of this color correction mask which later on is used for the printing of the masked master dupe.   In Fig. 8, a schematic outline of the type of optical printing equipment which can be used for this purpose is shown.   The essential features of a suitable printer are 2 synchronized intermittent movements with register pins which are combined with the necessary optical equipment.

In making the black-and-white mask, the original and the mask are run in contact in the camera head while using the projection head empty as a light source only. A yellow filter is placed into the light path while printing the masking film. After the mask has been developed in a regular negative developer, the master dupe is printed. In this operation, the original is run in the projection head and optically registered with the black-and-white silver mask which is now run in the camera head in contact with the Ansco Color Type *132* Duplicating Film.

The printer must be equipped with a viewer or other suitable means so that the registration of the original and the mask can be checked before printing the master dupe. The conformed master dupe can be made in one printing operation, even though special effects may be necessary. In the case where special effects that require mattes are to be inserted, these should be run in the projection head with the original. This method will yield a conformed master dupe that will show little or no loss in color brilliance.

This masked master dupe is then used for printing of the release prints, using Ansco Color Type *732* Release Film in a regular continuous printer with provisions for the insertion of filters and a stronger light source, as described earlier.

So far, only the pictorial part of the process has been discussed, but it is realized that methods of obtaining good sound are of equal importance. Since the release printing stock is a reversible film, a positive black-and-white track is required for printing. The ideal way to obtain the black-and-white positive would be a direct-positive recording. However, equipment to record to a direct positive is not generally available, and the following method has been found almost equally satisfactory and is the one recommended. The recording head of the sound equipment is moved so that the negative recording is obtained on the opposite side of the film. This negative is then printed onto black-and-white positive stock, which will then have the sound track in the proper position for printing directly onto the Ansco Color Type *732* Release Film in the conventional manner.

Dye tracks, especially those obtained by the dye coupling method, have a relatively low absorption in the infrared region. Therefore, the conventional infrared-sensitive photocell, for example type *868*, is not too well suited for these dye tracks and a loss in volume amounting to approximately 6 db is encountered. This loss in volume, while serious, still comes within the range where adjustment can be made

by fader setting on most 35-mm projection equipment. Fortunately, within the last few years the development of blue-sensitive photocells has progressed and cells are available today which are ideally suited for dye tracks and will play normal silver tracks with approximately the same volume so that interchange of tubes is not required. This photocell, which is at present available from the Radio Corporation of America, is designated as the *1P-37*.

Summarizing, the Ansco Color process is capable of producing full color motion picture release prints, including commonly used effects, with only minor changes in equipment which is now used extensively for black-and-white motion pictures. We believe that the Ansco Color process offers a relatively simple method for making motion pictures in color which can be readily mastered by those skilled in black-and-white motion picture techniques.

REFERENCE

[1] FORREST, J. L.: "The Machine Processing of 16-Mm Ansco Color Film," *J. Soc. Mot. Pict. Eng.*, **45,** 5 (Nov., 1945), p. 313.

SENSITOMETRIC EVALUATION OF REVERSIBLE COLOR FILM*

RONALD H. BINGHAM**

Summary.—*Two considerations are involved in the sensitometric evaluation of reversible color film; we are interested in determining the gray-scale characteristics of the material, as well as its faithfulness of color rendition. Equations have been derived relating the equivalent densities of the 3 layers to the color densitometer readings. The 3 curves showing equivalent densities as functions of log exposure indicate speeds, contrasts, maximum densities, and color balance of the film. Color rendition problems are investigated using the principles of colorimetry.*

The equivalent densities of a reproduction depend upon the spectral sensitivities of the material as well as the spectral characteristics of the light source and color sample; the color of the reproduction, however, depends not only upon the equivalent densities but also upon the spectral characteristics of the dyes and of the projection source. A typical problem is that of the effect of change of contrast upon the color renditions. Unit contrast, although giving lighter reproductions, involves saturation errors which are prohibitive. A contrast of 1.5 is found to more nearly balance the errors of lightness, hue and saturation.

Introduction.—In the sensitometric evaluation of color film we seek the answer to 2 questions: first, how well does the material reproduce a scale of grays, and second, how well does it render the whole gamut of photographically important colors? The first of these questions concerns certain sensitometric characteristics of the individual layers, their speeds, contrasts, and toe and shoulder characteristics, while the second is related, in addition, to the spectral aspects including the spectral sensitivities of the layers and the spectral densities of the primary dyes.

Gray-Scale Sensitometry.—With color film, just as with black-and-white film, gray-scale sensitometry centers about the characteristic curve which expresses the relationship between the density of a given layer and the logarithm of the exposure. In the case of subtractive color film we have 3 such curves (Fig. 1a and 1b) which are related to the yellow, magenta, and cyan layers, respec-

---

tively. They are plotted from measurements made on a sensitometric strip which has been exposed and developed under standardized conditions.

In exposing the sensitometric strip, we require an intensity scale sensitometer which has a light source of the correct spectral energy distribution and which yields an exposure of the order of $1/25$ sec. For tungsten-type film, the incandescent light source need only have the required color temperature of 3200 K, while daylight-type film
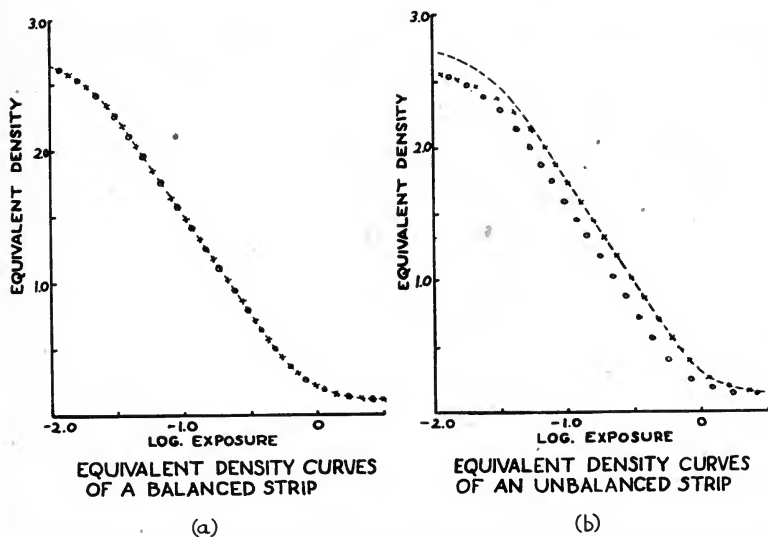
FIG. 1.   Equivalent density curves of balanced and unbalanced sensitometric strips—yellow - - - ; magenta x x x; cyan o o o.

requires a lamp-filter combination having, as nearly as possible, the same energy distribution as daylight.

As a means of expressing quantitatively the absorption owing to the dye in each of the 3 layers, Heymer and Sundhoff[1] and Evans[2] developed the concept of equivalent density, defining it essentially as follows: "In a subtractive color process, the equivalent density of the primary dye in a layer is equal to the gray density which would be obtained if it were superimposed upon the required amounts of the other two primaries to form a visually gray combination."   The usefulness of this concept becomes increasingly clear when we note that, by definition, a perfectly balanced strip—one having all steps

gray—would have 3 curves which would coincide as in Fig. 1a. On the other hand, with an unbalanced strip (Fig. 1b), any step which departs from gray results in inequality of the 3 equivalent densities, a reddish step, for instance, having a deficiency of cyan, *etc.*

In determining the 3 characteristic curves we are unable to separate the layers and hence are forced to make our measurements on all 3 superimposed layers of the sensitometric strip. Evans[2] has described
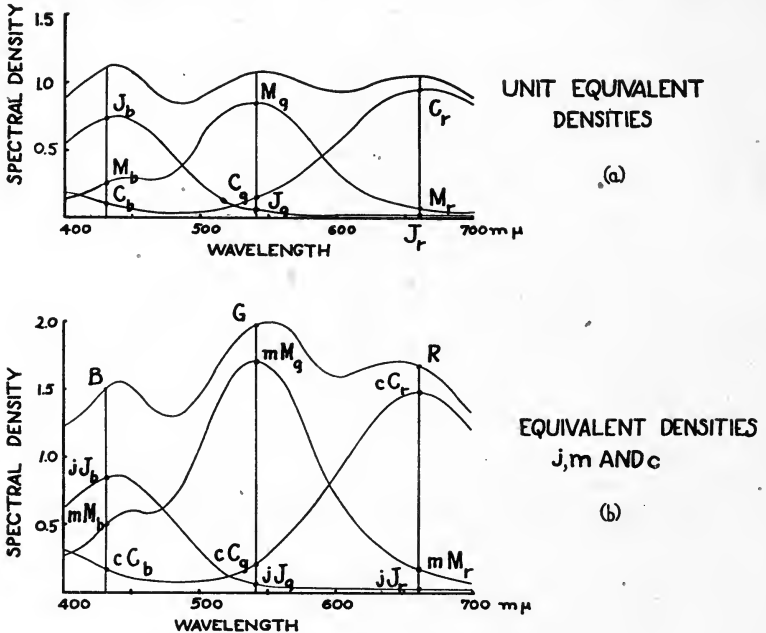
FIG. 2.   Spectral density curves of 3 primary dyes.

a visual type of color densitometer patterned after the Capstaff-Purdy instrument which uses wedges made of the primary dyes of the process.   Another approach which has proved of considerable value involves the measurement of the integral spectral densities* at 3 wavelengths.   For this purpose, accurate work such as determination of calibration constants, is carried out on a spectrophotometer. In our development and control work, however, we have preferred to use a photoelectric instrument such as the one which was de-

---

* The word "integral" as used here implies that the spectral density measurement is made on the superimposed yellow, magenta, and cyan layers.

scribed by Sweet.[3] This instrument employs a photomultiplier tube circuit in combination with an incandescent source and 3 narrow band-pass optical filters. With it, 3 spectral density readings are made using nearly monochromatic light, with each of the wavelengths being located near the peak of one of the 3 primary dyes.[*]

Typical primary dye curves as shown in Fig. 2a evidence a considerable amount of overlap so that, for example, a reading made at 430 mμ is influenced not only by the amount of dye in the yellow layer but also, to a considerable extent, by the amounts in the other 2 layers as well. The curves of Fig. 2a have been drawn for dyes each of which have an equivalent density of 1.0. Thus, by definition, the corresponding sample must be gray and have a visual density of 1.0. In preparation for the derivation to follow, let us consider the spectral densities of each of the 3 layers at the peak wavelengths. For the yellow layer these are designated[**] J_b, J_g, and J_r; for the magenta, M_b, M_g, and M_r, while the corresponding cyan densities are C_b, C_g, and C_r.

Now let us consider another sample, whose curves are shown in Fig. 2b, having unknown equivalent densities, j, m, and c, which are to be determined. It has been shown experimentally that Beer's law holds sufficiently close for the typical primary dyes under consideration, hence the spectral densities of the primary dye curves of Fig. 2b are proportional to those of Fig. 2a. Furthermore, experimental work has shown that the 3 proportionality constants are just the equivalent densities of the layers in question, so that, for example, the spectral densities of the yellow layer at the peak wavelengths are jJ_b, jJ_g, and jJ_r, while the corresponding densities of the other 2 layers are mM_b, mM_g, mM_r, cC_b, etc.   As a means of evaluating the equivalent densities of such a 3-layer sample we read its integral spectral densities B, G, and R at the peak wavelengths. Each of these values equals the sum of the corresponding spectral densities of the individual layers. Using the notation developed above, we have

$$\begin{aligned} B &= jJ_b + mM_b + cC_b, \\ G &= jJ_g + mM_g + cC_g, \\ R &= jJ_r + mM_r + cC_r. \end{aligned} \qquad (1)$$

[*] These 3 wavelengths will be referred to as the "peak" wavelengths; with the instrument referred to above they are 430, 540 and 660 mμ.

[**] The letters J and j are used instead of Y and y to represent densities in the yellow layer in order to avoid conflict with the notation of additive colorimetry.

These equations involve the 3 unknown equivalent densities j, m, and c in terms of the measurable spectral densities, B, G, and R as well as the constants J_b, J_g, etc., which are determined by the curves of Fig. 2a. In order to determine the equivalent densities we simply solve for j, m, and c, obtaining

$$
\begin{aligned}
j &= k_1B - k_2G - k_3R, \\
m &= -k_4B + k_5G - k_6R, \\
c &= -k_7B - k_8G + k_9R.
\end{aligned}
\tag{2}
$$

Eqs (2) have been written with the proper signs so that the constants, k_1, k_2–k_9 will be positive.

The constants of Eqs (2) are determined from measurements on representative samples of the color film. The spectral density curve of each of the dyes is determined by measuring samples in which 2 layers have been strongly exposed to leave only one dye. From these data, the curves corresponding to unit equivalent densities are calculated using the standard equations of colorimetry.[4, 5] Having determined the constants, we are ready to use Eqs (2) as a basis for routine sensitometry. The sensitometric strip is read at each step to obtain the densitometer densities B, G, and R. These data are substituted into Eqs (2) yielding the corresponding equivalent densities of each step. In routine application of the equations, charts are used which permit rapid calculation of the equivalent densities from the values of B, G, and R.

The equivalent density curves of Fig. 1b may now be interpreted in the light of the above discussion. Considering first the curves representative of a perfectly balanced material, we note that we are able to carry over directly the concepts of black-and-white sensitometry such as speed, contrast, maximum density, toe and shoulder characteristics, *etc.* We thus see that equivalent density is merely a generalization of the usual definition of density.

Turning our attention to the curves of the unbalanced material, we note certain parts of the log exposure range where one curve is higher than another. Thus, in the shoulder region we have the yellow falling above the other two. This may be interpreted to indicate that the shoulder will be yellowish. Similarly, we find a deficiency of cyan in the intermediate densities with the result that the reproductions of middle tones would be slightly brownish. Since in this case the contrasts of all 3 layers are about equal, the reproductions would have been considerably improved had the cyan layer been a

little slower or better still, of course, if the other two had been faster.

Determination of Color Rendition.—Having considered the gray-scale aspects of the problem, let us turn our attention to the problem of color rendition. It is well known that the proper rendition of a gray-scale is by no means the only requirement which must be fulfilled by a color reproduction material, since in the worse cases, for example, sensitizing dyes could be used which would yield completely false colored pictures. It should be pointed out that theoretical as well as experimental work has shown that the best we can do is to choose the film characteristics in such a way as to give a minimum of distortion, since it can be shown that perfect color reproduction by a reversible material is impossible without negative sensitivities over certain parts of the visible range of wavelengths.

Experimentally the process of evaluating a film as to its faithfulness of color reproduction is straightforward. We make up a color chart from a series of reflecting color samples whose colors have previously been calculated from their spectral reflectance curves. This color chart is illuminated by a light source of carefully selected and controlled spectral energy distribution, and photographed, yielding a series of reproductions which are measured with a spectrophotometer. The reproduction colors are calculated from the resulting spectral transmittance curves by standard colorimetric methods.[4, 5] Detailed comparisons between samples and reproductions may be made and the over-all color rendition may be determined by the methods outlined later in this paper.

A color rendition problem of considerable importance is that of determining the difference in color reproduction to be expected if we should either change the photographic material in the course of manufacture or change the processing procedure. In many cases, it becomes desirable to determine the reproduction errors by theoretical methods. In order to illustrate the general approach let us consider the problem of relative color distortion at 2 different contrasts, $\gamma = 1.0$ and $\gamma = 1.5$. In other words, the question which we raise is, "Which of these 2 contrasts will give the better color reproduction?" This example has been selected for theoretical discussion because the conclusions have been checked experimentally.

Without going into the mathematical details it may simply be said that we start with the spectral sensitivity curves which have been experimentally determined. In addition, we must know the energy distribution curve of the illuminant as well as the spectral

densities of the primary dyes. We adopt a series of reflection color samples whose reproductions are to be calculated, determining first the exposures to be expected in the 3 layers and from them the equivalent densities. For the straight-line portion of the characteristic curve, the density is proportional to γ, thus,

$$
\begin{aligned}
j &= - \gamma \log E_b, \\
m &= - \gamma \log E_g, \\
c &= - \gamma \log E_r,
\end{aligned}
\tag{3}
$$

from which we see that over this exposure range the effect of the change of contrast is just to multiply all equivalent densities by 1.5.

In these equations the exposures in the blue, green, and red sensitive layers, E_b, E_g, and E_r, are expressed in such units that for white, $E_b = E_g = E_r = 1.0$. Thus in Eqs (3), $\log E_b = \log E_g = \log E_r = 0$.

The equivalent densities which were calculated for the reproductions of 5 saturated Munsell colors are shown in Table 1.

TABLE 1

Equivalent Densities of the Reproductions of 5 Munsell Samples at $\gamma = 1.0$ and $\gamma = 1.5$

Sample		Equivalent Density					
	Munsell	$\gamma = 1.0$			$\gamma = 1.5$		
Color	Notation	j	m	c	j	m	c
White	$N\ 10$	0	0	0	0	0	0
Red	$5R\ 4/14$	1.31	1.37	0.27	1.97	2.05	0.41
Yellow	$5Y\ 8/12$	1.30	0.20	0.18	1.95	0.29	0.27
Green	$5G\ 5/8$	1.05	0.64	1.12	1.58	0.97	1.68
Blue	$5B\ 4/8$	0.67	0.95	1.28	1.00	1.42	1.93
Purple	$5P\ 4/12$	0.47	1.10	0.55	0.70	1.65	0.82

Having obtained the reproductions in terms of the amounts of the yellow, magenta, and cyan primary dyes, we are next interested in determining the actual color specifications and finally the color differences. In order to carry out the necessary colorimetric integrations we need an expression for the spectral transmittance of a sample of equivalent densities, j, m, and c. From the definition of equivalent density, we have for the spectral density curve of the 3-layer sample

$$
D = jJ_1 + mM_1 + cC_1,
\tag{4}
$$

where J_1, M_1, and C_1 are the spectral density curves for unit equivalent densities. It then follows from the definition of density that the spectral transmittance is given by

$$
T = 10^{-D} = 10^{-(jJ_1 + mM_1 + cC_1)}.
\tag{5}
$$

Using the primary dyes of Fig. 2a, the tristimulus specifications were calculated by the usual integration formulas[4, 5] yielding the data of Table 2 in which are given the luminous reflectance Y and the trichromatic coefficients x and y for each of the 5 samples as well as the corresponding specifications of their reproductions.

TABLE 2

Tristimulus Specifications of 5 Munsell Samples and Their Reproductions at $\gamma = 1.0$ and $\gamma = 1.5$[*]

		Y	x	y
White	Sample	1.000	0.322	0.338
N 10	$\gamma = 1.0$	1.000	0.322	0.338
	$\gamma = 1.5$	1.000	0.322	0.338
Red	Sample	0.131	0.572	0.314
5R 4/14	$\gamma = 1.0$	0.117	0.499	0.337
	$\gamma = 1.5$	0.048	0.578	0.329
Yellow	Sample	0.570	0.466	0.488
5Y 8/12	$\gamma = 1.0$	0.536	0.426	0.451
	$\gamma = 1.5$	0.397	0.458	0.471
Green	Sample	0.190	0.258	0.431
5G 5/8	$\gamma = 1.0$	0.153	0.298	0.356
	$\gamma = 1.5$	0.061	0.304	0.410
Blue	Sample	0.113	0.205	0.252
5B 4/8	$\gamma = 1.0$	0.098	0.257	0.282
	$\gamma = 1.5$	0.032	0.235	0.254
Purple	Sample	0.121	0.299	0.191
5P 4/12	$\gamma = 1.0$	0.140	0.331	0.263
	$\gamma = 1.5$	0.054	0.331	0.237

* In these calculations the illuminant was taken to be daylight, 6000 K, as determined from data of Parry Moon.[3]

In Fig. 3 the trichromatic coefficients are presented graphically. On this color diagram, points which represent different colors are grouped about the center (white) point, according to hue, with those representing colors of greater saturation being located farther from the center. Thus, for example, the 2 reproductions of the red sample are seen to be of about the same hue but of considerable difference in saturation.

Analyzing the data, we conclude that the principal effects of increasing the contrast is to darken the samples and make them more saturated. In order to express quantitatively the difference between

each of the samples and its 2 reproductions, we have calculated the errors in lightness, hue and saturation as they would appear under projection conditions. The formulas which were employed are of the type developed by Judd[6] and Hunter[7] at the National Bureau of
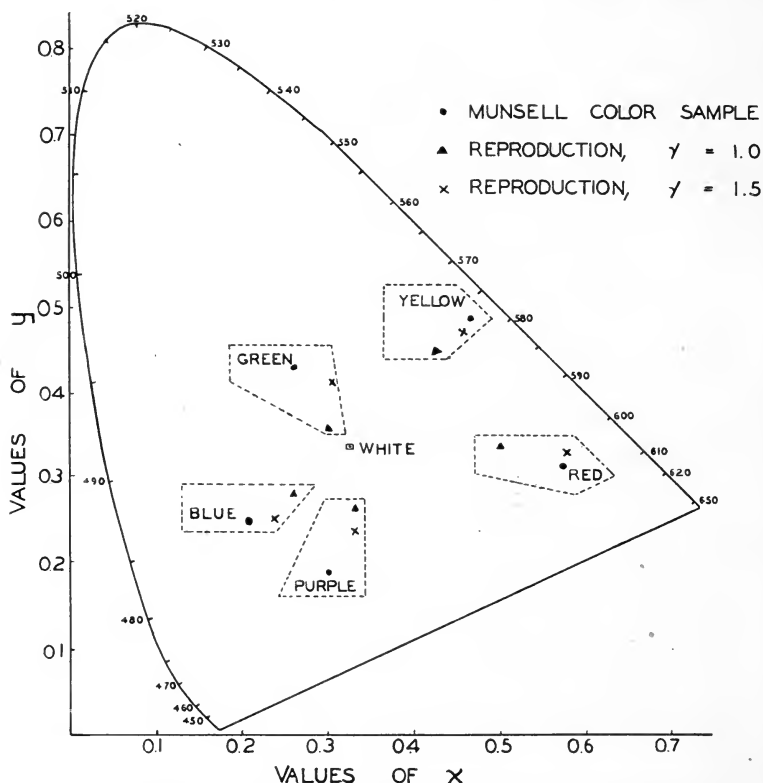
Fig. 3.   Chromaticities of reproductions calculated at 2 different contrasts. (Note: Dotted lines indicate sample and reproduction points associated with each color.)

Standards. The results are given in Table 3. Each error in lightness, hue or saturation has been computed in terms of the number of color steps which would be distinguishable between the sample and its reproduction, while the total color error is taken in the usual way as the square root of the sum of the squares of the 3 separate errors. The average color error is computed as a criterion of the over-all reproduction.

In Table 3 a positive lightness error indicates a reproduction lighter than the sample, a positive hue error indicates a hue shift in the counter-clockwise direction as seen in Fig. 3, while a positive saturation error indicates reproduction more saturated than the sample.

TABLE 3

Color Errors for 5 Munsell Samples Reproduced at $\gamma = 1.0$ and $\gamma = 1.5$

Sample	Contrast	Errors			
		Lightness	Hue	Saturation	Color
White	$\gamma = 1.0$	0	0	0	0
N 10	$\gamma = 1.5$	0	0	0	0
Red	$\gamma = 1.0$	−0.7	4.2	−24.0	24.4
5R 4/14	$\gamma = 1.5$	−4.8	3.6	0.8	6.1
Yellow	$\gamma = 1.0$	−0.8	−1.0	−18.7	18.8
5Y 8/12	$\gamma = 1.5$	−4.2	−2.3	− 5.4	7.5
Green	$\gamma = 1.0$	−1.5	1.6	−14.5	14.7
5G 5/8	$\gamma = 1.5$	−6.3	−5.3	− 6.2	10.3
Blue	$\gamma = 1.0$	−0.8	0.8	−10.5	10.6
5B 4/8	$\gamma = 1.5$	−5.2	2.8	− 4.0	7.2
Purple	$\gamma = 1.0$	0.9	4.6	−17.3	17.9
5P 4/12	$\gamma = 1.5$	−3.8	5.7	−11.0	13.0
	$\gamma = 1.0$			Average Color Error =	17.5
	$\gamma = 1.5$			Average Color Error =	8.8

Examination of the data discloses the fact that the reproductions at $\gamma = 1.0$ are lighter but considerably desaturated as compared with those at $\gamma = 1.5$. The loss of saturation at the lower contrast is so serious as to more than offset the gain in lightness with the result that the over-all reproduction at $\gamma = 1.0$ is considerably less satisfactory than that at $\gamma = 1.5$.

The author wishes to acknowledge valuable advice and encouragement on the part of Dr. H. Hoerlin, under whose direction the work was carried out.

REFERENCES

[1] HEYMER, G., AND SUNDHOFF, D.: "Uber de Messung der Gradation von Farbenfilman," *Agfa Zentral-Labor, Veroff.*, **5** (1937), p. 62.

[2] EVANS, R. M.: "A Color Densitometer for Subtractive Processes," *J. Soc. Mot. Pict. Eng.*, **XXXI**, 2 (Aug., 1938), p. 194.

[3] SWEET, M. H.: "Densitometry of Modern Reversible Color Film," *J. Soc. Mot. Pict. Eng.*, **44**, 6 (June, 1945), p. 419.

[4] MacAdam, D. L.: "The Fundamentals of Color Measurement," *J. Soc. Mot. Pict. Eng.*, **XXXI**, 4 (Oct., 1938), p. 343.

[5] O.S.A. Colorimetry Committee: "Quantitative Data and Methods for Colorimetry," *J. Opt. Soc. Am.*, **34** (1944), p. 633.

[6] Judd, D. B.: "Specification of Color Tolerances at the National Bureau of Standards," *Am. J. Psychol.*, **52** (1939), p. 418.

[7] Hunter, R. S.: "Photoelectric Tristimulus Colorimetry with Three Filters," *J. Opt. Soc. Am.*, **32** (1942), p. 509.

[8] Moon, P.: "Proposed Standard Solar-Radiation Curves for Engineering Use," *J. Frank. Inst.*, **230** (1940), p. 583.

A PHOTOTUBE FOR DYE IMAGE SOUND TRACK*

ALAN M. GLOVER AND ARNOLD R. MOORE**

Summary.—*In view of the use of dye image sound track on new-type color film, a phototube has been developed with characteristics suitable for sound reproduction from these films as well as from ordinary silver tracks. It is a gas-filled, high-sensitivity phototube for use in standard reproducing equipment. The maximum spectral response occurs in the blue blue-green region of the spectrum. Details of construction, sensitivity, characteristic curves, spectral response, frequency response, and life are presented.*

Color is a subject of considerable interest to the Society of Motion Picture Engineers. Color complicates the problem of the sound track engineer. As an introduction to the discussion of a new photosensitive surface which will be of considerable value for use with dye image sound tracks, a brief review of the characteristics of the phototubes now in general use is in order.

The advent of sound with motion pictures in the late 1920's was in large measure made possible by the introduction of the caesium-silver-oxygen photosurface. Considerable effort had been expended in the previous decade in an attempt to raise the hitherto limiting sensitivity of the photosurfaces then available and, as is so frequently the case in technical progress, it is difficult to assay the part which the photosurface itself played in the new sound industry. Concomitant with the new photosurface were improved amplifying tubes and steady progress in the quality of the film, but the industry would have progressed slowly without the new photosurface.

The most advantageous characteristic of the caesium-silver-oxygen photosurface was its high sensitivity in the near infrared, a region of the spectrum in which the major portion of the energy of the incandescent light source is concentrated. About three-quarters of the total sensitivity of this photosurface to light from an incandescent source lies in the infrared. This sensitivity to infrared was of great advantage as long as the sound track consisted of a developed silver image which

may be exposed to densities as high as three in this region.   With the advent of dye image tracks a possibility, it immediately became apparent that the marked transparency of such tracks in the near infrared to which the *S-1* surface is so sensitive would seriously limit the modulation obtainable.   This is true whether the sound track is of the variable-area or variable-density type.   Other authors have already touched on this subject in a previous issue of the JOURNAL.[1]
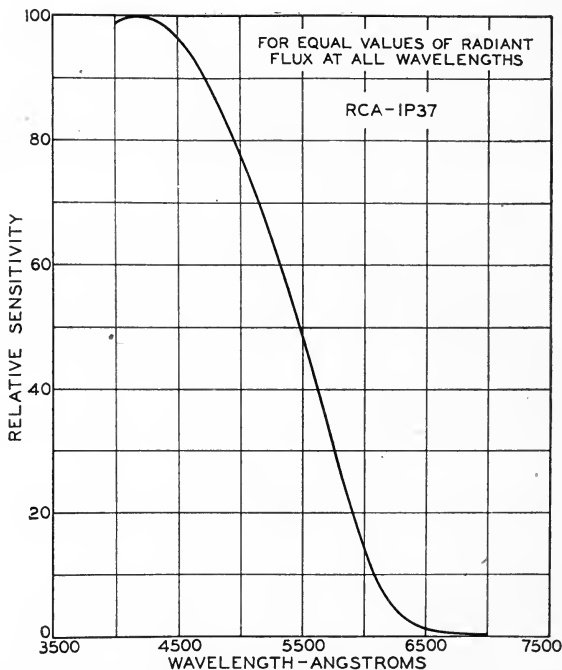
FIG. 1.   Spectral sensitivity of phototube having *S-4* response.

In 1940 there appeared information on a new photosurface, the sensitivity of which is largely concentrated at the short wavelength portion of the visible spectrum.[2]   Most of the phototubes which have employed this surface are of the high-vacuum type and this is probably the reason for the slow acceptance of such tubes by the motion picture industry.   The gas-filled phototube has been popular in the industry for 3 reasons: high sensitivity with resultant high signal-to-noise ratio, adaptability of the voltage sensitivity of the gas tube as a

volume control, and the lower impedance level of the gas tube.   Although the cause is not yet completely known, some difficulty has been encountered in introducing inert gas into phototubes containing the *S-4* surface.   Such tubes have suffered from short life.   However, this paper will outline the characteristics of a new tube, the RCA *1P37*, a gas-filled phototube of good life whose properties are such as to indicate the broad possibilities for its use with dye image sound tracks.
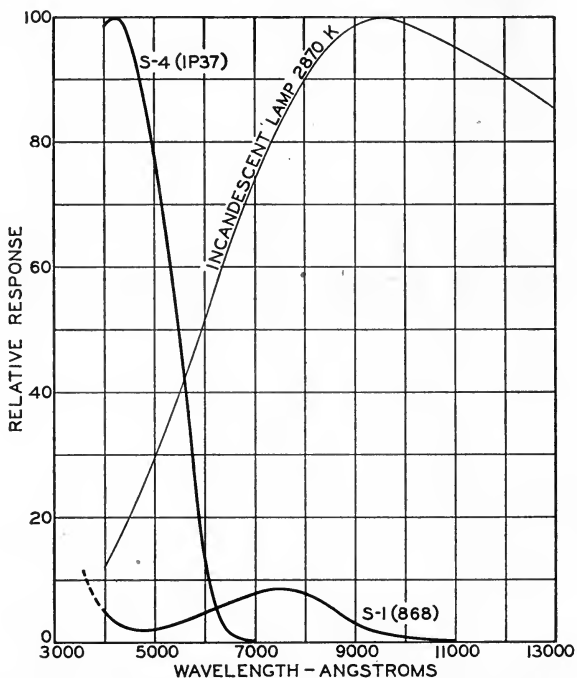
FIG. 2.   Spectral response of *S-1* and *S-4* phototubes.

The important characteristic of the new photosurface, its spectral sensitivity, is shown in Fig. 1.   By contrast the same characteristic for the caesium-silver-oxygen *S-1* surface is also shown in Fig. 2.   It should be borne in mind that these characteristics are typical of an average tube and that considerable variation from tube to tube may be expected.   It is believed that the variations in the *S-4* spectral response are proportionately much less than those encountered in the *S-1* surface.   In addition to our own data, the data taken by a number of investigators have recently been analyzed by us, and the curve

shown is suggested as one which might be adopted as a typical standard. Variations in the position of the spectral maximum from 4000 to 4500 A are commonly found with occasionally a peak at as short a wavelength as 3700 A being encountered. Based on data in greater quantity than previously available a curve giving the position of the maximum at 4200 A is believed typical. Little variation in the longer
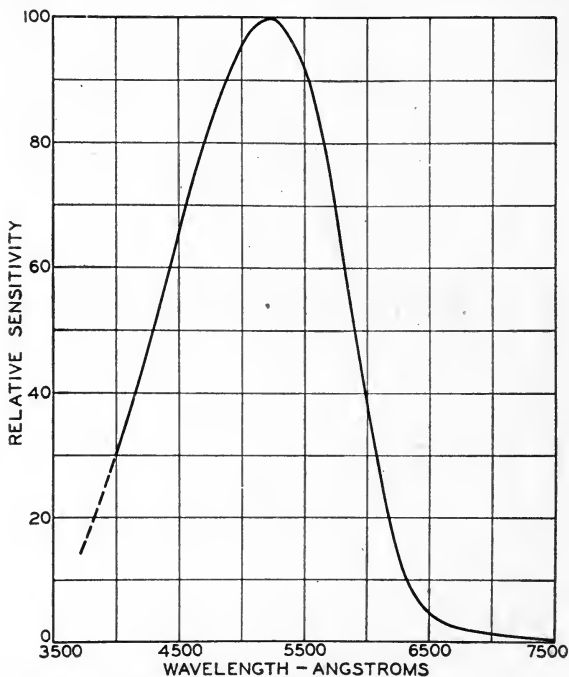
FIG. 3. Spectral response of *S-4* surface with tungsten light at 2870 K.

wavelength portion of the curve is encountered. Since the phototube will be commonly used in conjunction with an incandescent light source, the product of the spectral response curve of the tube and of a light source operating at 2870 K is shown in Fig. 3. This represents the effective spectral sensitivity of the tube as used in motion picture equipment.

The sensitivity of a gas-filled phototube containing the *S-4* photo-surface to a tungsten light source operating at a standard color temperature, 2870 K, may be made to vary considerably. For the pur-

pose of introducing a replaceable phototube for the *868* into the motion picture industry a relatively high sensitivity is not required. The amount of argon gas added can be varied to make the resultant over-all sensitivity comparable to that of the *868* even though the energy output of the light source is not well adapted to the *S-4* surface. The frequency response of the phototube is also a function of the gas pressure employed as is the breakdown voltage of the tube. With these factors in mind, an average gas amplification factor of three has been chosen. The gas amplification is less than that of the
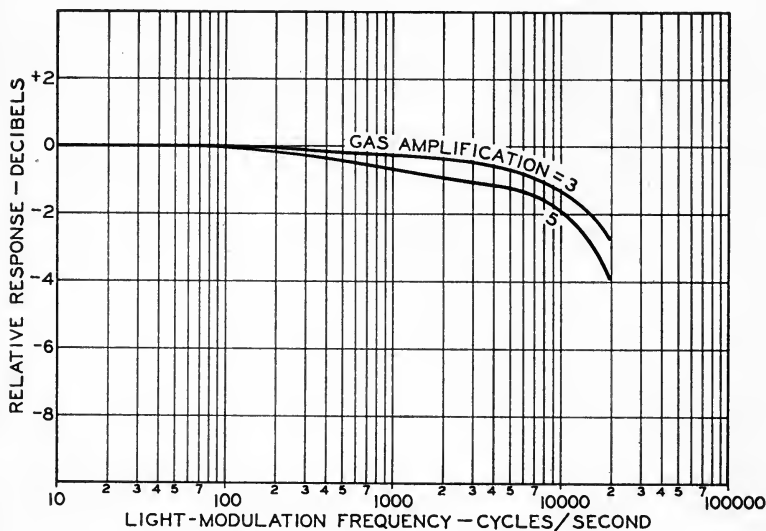
FIG. 4.   Frequency response of *1P37*.

868 and therefore the frequency response of the *1P37* is slightly better. The frequency response for 2 different gas amplification factors is shown in Fig. 4. These curves were obtained using a glow lamp modulated light source,[3] the data being corroborated by measurements with standard frequency sound track.

It may be readily seen from the spectral characteristics that the blue-sensitive photosurface is more sensitive to variations in the temperature of the light source. This characteristic is believed to be its only point of inferiority when compared with the *S-1* surface. Data are shown in Fig. 5. Regulation of the light source voltage should be designed accordingly. It should be emphasized that the sensitivity

figures quoted for any photosurface when expressed in microamperes per lumen vary with color temperature of the light source. Care should be taken to state on what basis data are quoted.

Data giving the anode or output characteristic curves of the RCA *1P37* phototube are shown in Fig. 6. These curves are comparable to those for the *868*, thus permitting replacement of the latter tube by the *1P37* without modification of the circuit.
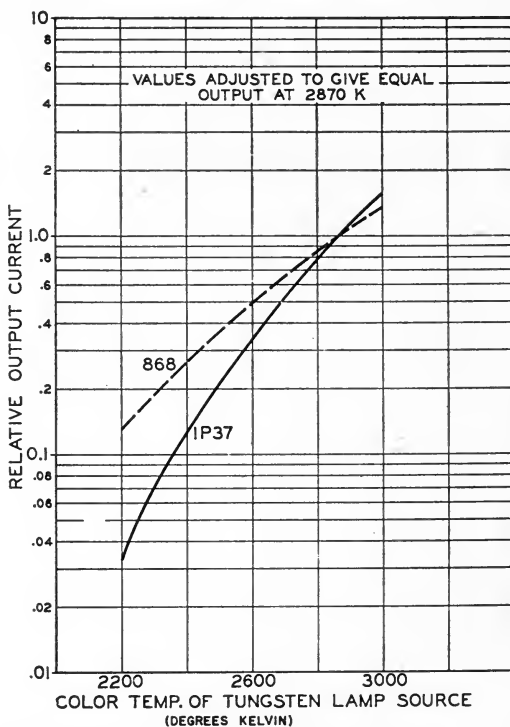
FIG. 5.   Relative output of *868* and *1P37* as function of light source color temperature.

Prior to the war, one of the authors began work on the problem of making gas-filled tubes using the *S-4* surface. Considerable loss in sensitivity on use was encountered, and this conclusion was later stated in foreign articles on the subject.[4] Renewed efforts to eliminate or reduce this loss in sensitivity have met with considerable success. Life data for 2500 hr of continuous service are shown in Fig. 7. It is expected that life equal to that obtained with the *868* phototube will be obtained with the new tube. However, the life characteristic
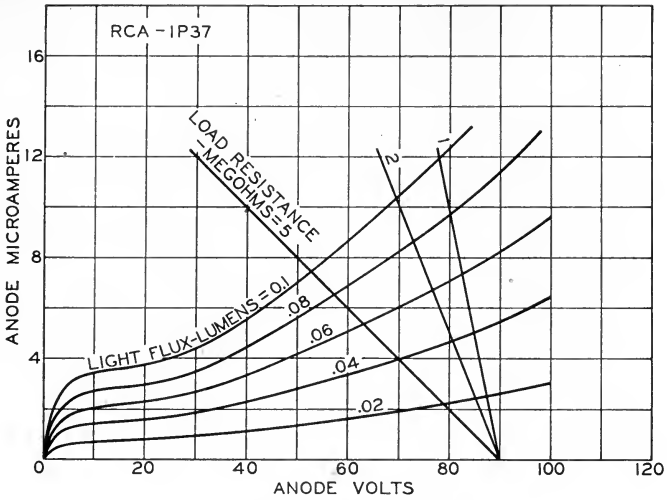
FIG. 6.   Anode characteristics of *1P37*.
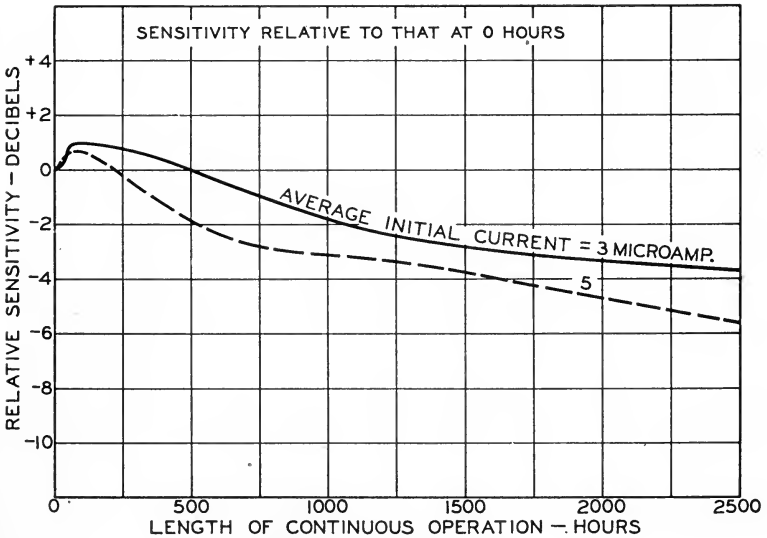
FIG. 7.   Life data on *1P37*.

is somewhat different from that of the *S-1* in that the extremes of variation encountered each time the tube is operated are not so

marked. As in other phototubes the life varies with the level of current drawn and the rated maximum average . current is set with this in mind. The currents shown are about those drawn with tubes of average sensitivity in a 35-mm optical system with the film in place. Greater currents may be drawn for brief intervals such as the time required for changing reels but limiting series resistance should always be included with a gas-filled phototube to prevent damage from extreme current in the case of voltage breakdown of the gas.

Data taken with the *1P37* phototube, a photograph of which is shown as Fig. 8, with dye image tracks, are the subject for other papers presented before the Society.[5,6] The structure of the *1P37* has been dictated by the replacement problem of the *868*. The use of the photomultiplier type RCA *931A* in which the *S-4* surface is included may also be of interest for developmental study.

REFERENCES

[1] GÖRISCH, R., AND GÖRLICH, P.: "Reproduction of Color Film Sound Records," *J. Soc. Mot. Pict. Eng.*, **43,** 3 (Sept., 1944), p. 206.

[2] GLOVER, A. M., AND JANES, R. B., "A New High-Sensitivity Photosurface," *Electronics*, **13,** (Aug., 1940), p. 26.

[3] KRUITHOF, A. A.: "Time Lag Phenomena in Gas-Filled Photoelectric Cells," *Philips Tech. Rev.*, **4,** (Feb., 1939), p. 48.

[4] SOMMER, A.: "The Influence of Illumination on the Fatigue of Photoelectric Cells," *Elec. Eng.*, **17,** (May, 1945), p. 504.

[5] DREW, R. O., AND JOHNSON, S. W.: "Preliminary Sound Recording Tests with Variable-Area Dye Tracks," *J. Soc. Mot. Pict. Eng.*, **46,** 5 (May, 1946), p. 387.

[6] PHYFE, J. D.: "Behavior of a New Blue-Sensitive Phototube in Theater Sound Equipment," *J. Soc. Mot. Pict. Eng.*, **46,** 5 (May, 1946), p. 405.

PRELIMINARY SOUND RECORDING TESTS WITH VARIABLE-AREA DYE TRACKS*

R. O. DREW AND S. W. JOHNSON**

Summary.—*The introduction of new color emulsions to the industry makes it necessary for the sound engineer to investigate problems in connection with the recording and reproducing of quality tracks on this new medium.*

This paper is a discussion of the results of some preliminary tests made with variable-area tracks on Ansco reversible monopack color film. The tracks were processed in exactly the same manner as for picture and therefore are of dye composition.

Three specific methods of printing are discussed. Quantitative measurements of tracks containing modulated and constant-amplitude tones reproduced with the new gas-filled blue-sensitive and the ordinary red-sensitive phototubes are given.

The problems of producing a satisfactory sound track on a conventional black-and-white film have been discussed in many papers in the JOURNAL of the Society during the past 18 years. Projection of pictures in color began with very limited use of systems in which alternate frames were projected through filters of complementary colors. Kodacolor, with its lenticulated film, opened the way to colored pictures from 16-mm film; while Technicolor, with its dye transfer process, gave us 3-color pictures in the theater. Sound could no doubt have been recorded on Kodacolor films, but the flutings of the base were a handicap and sound had not been widely applied to 16-mm films when Kodacolor was superseded by the more practical and satisfactory Kodachrome. So far the problem of reproducing sound tracks recorded in other mediums than silver emulsion had not become serious, since the Technicolor process had provided for recording the sound in a silver emulsion, and then after clearing the remainder of the film, producing the colored picture by transferring dye colors to the clear gelatin.

The Cinecolor process produces its blue color by iron toning, and the color thus formed works satisfactorily in sound systems designed for reproduction of silver tracks.

Reproduction of dye tracks assumed greater importance with the advent of multilayer films. Kodachrome, Ansco, and the new Kodacolor film described by Mees[1] are examples. It is obviously desirable that the processing of the sound track be the same as for the picture. This means that the light absorption in the sound track must be provided by the same dyes that produce the picture. The Report of the
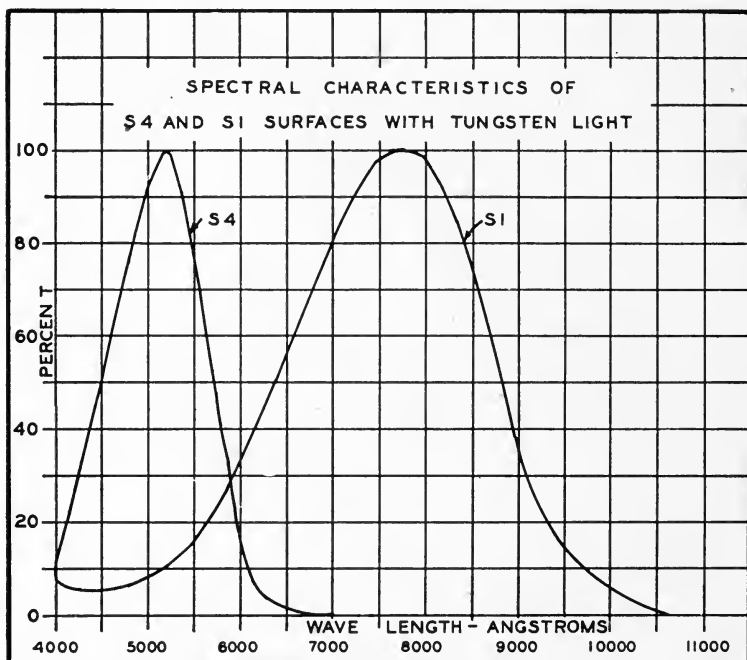
Fig. 1. Phototube characteristics of *S1* surface used in RCA Type *868* and *S4* surface used in RCA Type *929* and *IP37*.

Color Committee[2] in July, 1937, suggests that use of a phototube whose response is confined to the visible spectrum would be desirable in giving color technicians greater freedom in the choice of their coloring materials, but there is nothing in the report to indicate that a serious difficulty had already been encountered in efforts to reproduce from dye tracks with present optical systems. This difficulty seems first to have been called to the attention of our readers by Görisch and Görlich.[3] These authors point out that the dyes so far found suitable for the picture are quite transparent to infrared light while the

phototubes in general use are very sensitive to infrared light, their peak sensitivity with tungsten light being at about 8000 A, whereas 7000 A represents the extreme of the visible.   This relationship means that the phototube current is weakly modulated by the dye or dyes, but scratches and dirt modulate it almost as much as they would through clear film.   The authors of that paper propose the substitution of a blue-sensitive phototube which does not respond at all
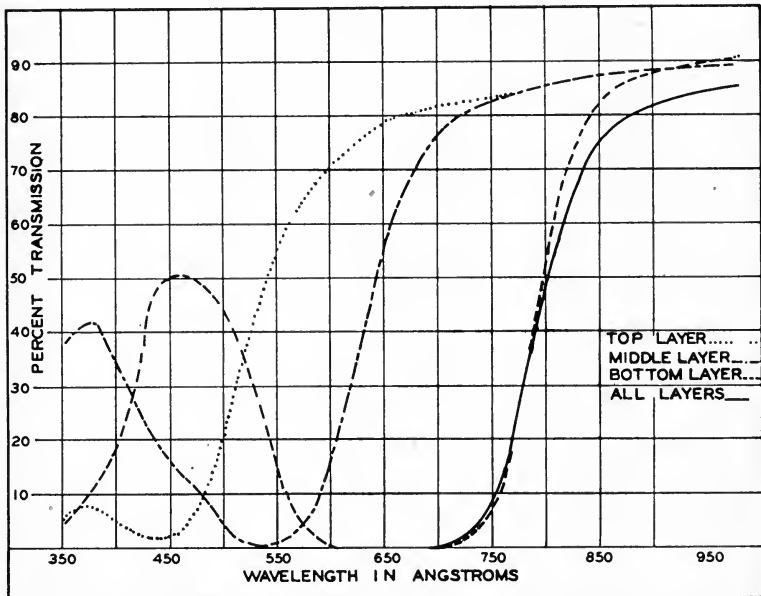
FIG. 2.   Dye characteristics of Ansco duplicating color film used in tests reported here.

to infrared, and they describe a phototube with which they have worked with maximum response at about 5000 A.

In 1944, Dr. A. M. Glover of RCA was approached by J. A. Ball of du Pont, who is Chairman of the SMPE Color Committee, to learn whether a phototube could be provided having the same spectral characteristics as the *RCA 929*, but with higher sensitivity, so that it could be substituted for the *868* caesium phototubes in existing reproducing systems, without the necessity of providing additional amplifier gain.   The *929* phototube has its maximum sensitivity in the visible spectrum and has no response to infrared light.   Inde-

pendently and at almost the same time, the problem was presented
to Dr. Glover by M. H. Sweet of Ansco.
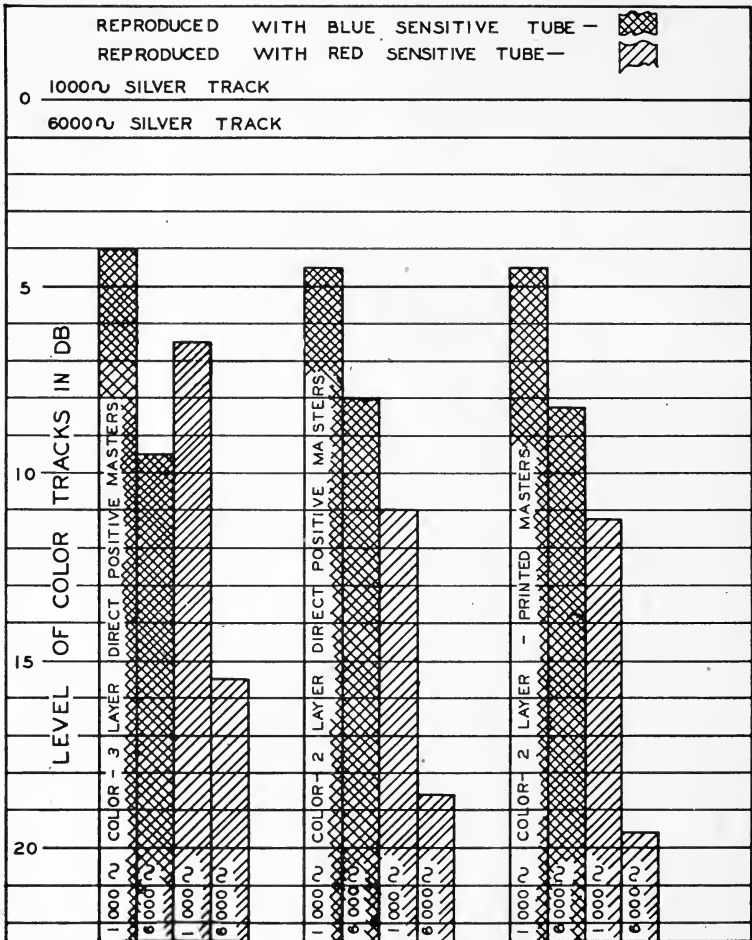
FIG. 3.   Relative output levels of color tracks.

Fig. 1 shows the spectral characteristics of the *868* and *929* tubes.
A new tube with similar cathode surface to the *929* tube and with
identical spectral characteristic but with gas multiplication of the
electron current has been developed, which has the desired sensitivity.
It is designated as tube *1P37*.   The development of this tube is de-

scribed in a paper by Glover and Moore.[4] The reader will find further discussion of this subject in the current Report of the Color Committee.[5] The transparency of dyed gelatin to infrared light is general and not confined to certain dyes as is further indicated by a statement in the Eastman Wratten Filter catalogue which says that all of the gelatin filters are transparent to infrared. Fig. 2 shows the transmission characteristic of several dyes and of a complete track.

To show that a phototube having the spectral characteristics of the *1P37* tube would be more satisfactory than the infrared sensitive *868* tube for reproducing sound recorded in dye tracks, did not call for extensive tests. To learn how to get the best results from the dye track recordings and the blue-green sensitive *1P37* tube is the next step, therefore, and this paper is a report of a series of tests made with that object in view.

In the figures we frequently refer to the *868* as the red-sensitive tube and the *1P37* as blue-sensitive, since it seemed to us that these descriptive terms would make the relationships easier for the reader to follow. It

DIFFUSION OF LIGHT IN PRINT

FIG. 4. Gradation of exposure through emulsion layers indicated by equal exposure contours.

should be understood, however, that the *868* is one of a number of phototubes using what is designated as an S_1 cathode surface, which is especially sensitive to infrared as well as to red light, and that the *1P37* and *929* phototubes use the S_4 surface which is highly sensitive to blue and to green light.

All of our tests to date have been made on Ansco duplicating positive color film. The general features of this film are described by Forrest and Wing[6] and by Duerr and Harsh.[7] The film, like other tripack systems, is arranged with a top layer emulsion sensitive only to blue, the next layer is a yellow filter followed by an emulsion sensitive to green, and finally, next to the base a layer sensitized to red. The emulsion layers, in the order named, upon being developed produce yellow, magenta, and cyan or blue-green dyes. An arrangement for processing short pieces of film was set up in our laboratory and

checks made which showed that our processing gave results substan-
tially the same as those with films which we exposed and sent to Bing-
hamton for processing.

Although the final test for quality is actual listening to recordings
of various classes of sound, there are 4 laboratory tests that have
proved satisfactory for processing control in the case of variable-area
silver tracks. These are volume level, high-frequency response, cross-
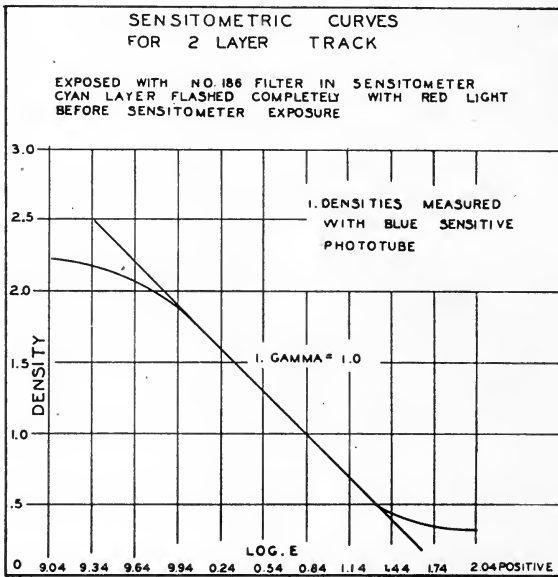
FIG. 5. Sensitometric curves for type 11b sensito-
metric exposure of 2 layers of Ansco reversible duplicat-
ing color film. Densities were measured on micro-
densitometer with tungsten light for the blue-sensitive
phototube.

modulation, and noise measurements. The usual volume level test
is to measure the output of a 1000-cycle tone with full track modula-
tion. Fig. 3 shows the outputs from dye tracks made in several ways.
The 1000-cycle output from a silver track is taken as the reference
or zero-db level. High-frequency response is judged from the level
of a 6000-cycle tone as compared with the 1000-cycle tone. The
cross-modulation test is that described by Baker and Robinson.[8]

Noise determinations consist in measuring the rms random noise
output from an unmodulated biased track, and comparing the read-
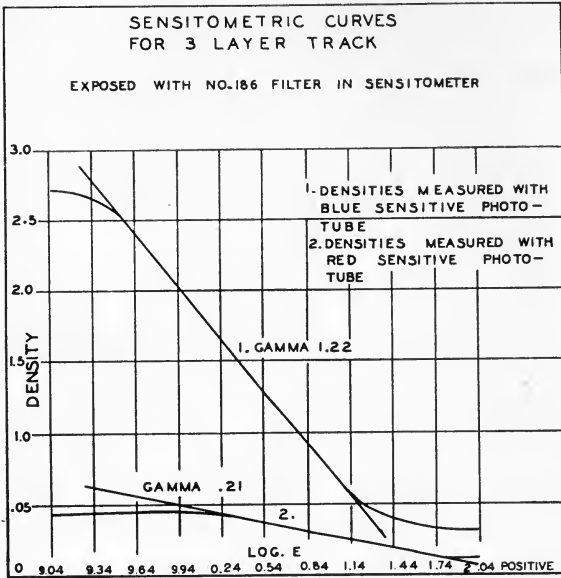
FIG. 6. Sensitometric curves for type 11b sensitometric exposure of Ansco reversible duplicating color film. Densities were measured on microdensitometer with tungsten light for the blue-sensitive phototube and for the red-sensitive phototube.
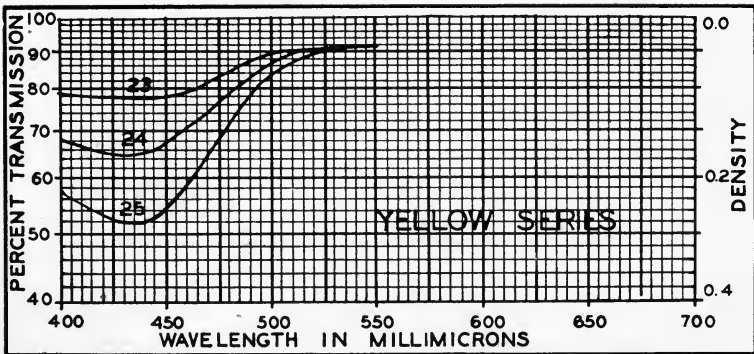
FIG. 7. Spectrophotometric transmission curves for Ansco yellow series filters Nos. *23*, *24*, and *25*.
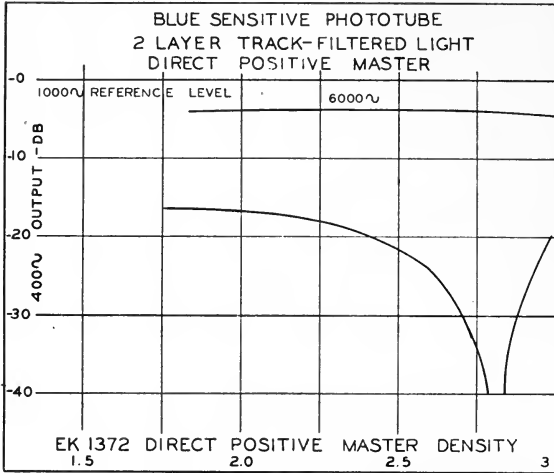
Fig. 8. Curves showing optimum direct-positive
master density and frequency response at 6000 cycles
for 2-layer tracks printed with tungsten light through
one No. *25* Ansco filter after preliminary flashing with
red light.   The tracks were reproduced with the blue-
sensitive phototube.
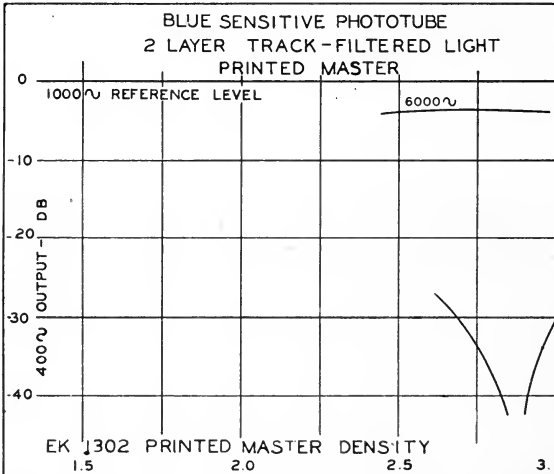
Fig. 9. Curves showing optimum printed master
density and frequency response at 6000 cycles for 2-
layer tracks printed with tungsten light through one
No. *25* Ansco filter after preliminary flashing with red
light.   The EK *1302* printed master was printed from
an original recorded EK *1372* negative of 2.65 density.
The color tracks were reproduced with a blue-sensitive
phototube.

ing with the 1000-cycle full modulation output.   The unmodulated biased track consists of 2 clear strips 0.003-in. wide with the remainder of the scanned area opaque. Film noise is caused by any photographic irregularities or graininess which may be present, and by scratches and specks of dirt. Such dirt specks as appear over the narrow clear areas produce fairly loud noises. Dirt in other areas causes noise in proportion to the light transmitted, so that low densities mean noisy films. The ratio of signal to noise, or relative noise level, is not greatly
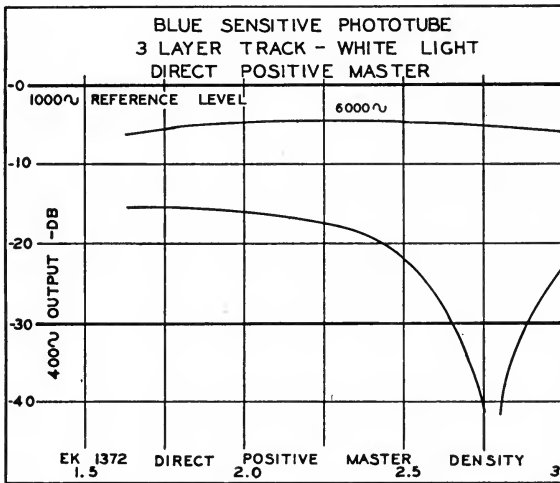
FIG. 10. Curves showing optimum direct-positive master density and response at 6000 cycles for 3-layer track printed with unfiltered tungsten light. The tracks were reproduced with the blue-sensitive phototube.

affected by some light absorption in the clear areas, since this reduces intensities of both signal and noise. Low densities in the dark areas, on the other hand, raise the absolute magnitude of the noise and at the same time reduce that of the signal, and are therefore doubly injurious. Graininess is not likely to be a serious source of noise in dye tracks developed by reversal.

Both the high-frequency loss and the cross-modulation are the result of diffusion of light within the emulsion, which causes the exposure to spread outside the boundaries of the area where exposure is desired. This takes place especially in the lower layers of the emulsion. Fig. 4 illustrates the effect of light diffusion in the emulsion
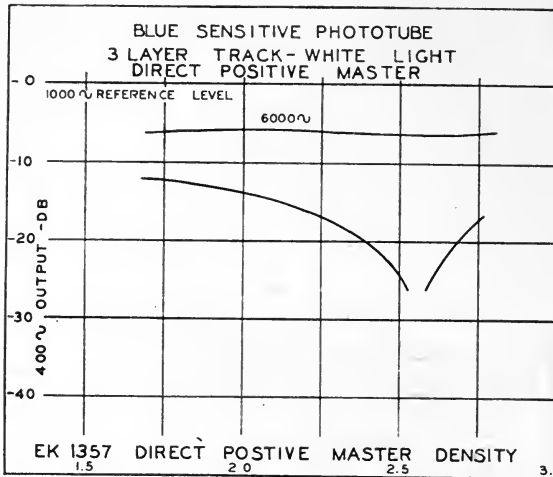
Fig. 11. Curves showing direct-positive master density and frequency response at 6000 cycles for 3-layer tracks printed with unfiltered tungsten light from EK *1357* master. The color tracks were reproduced with the blue-sensitive phototube.
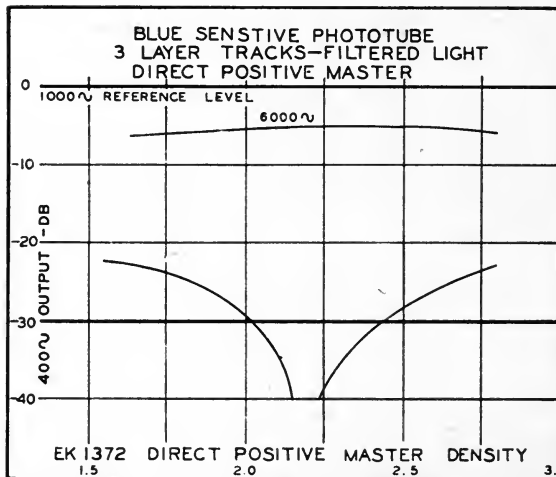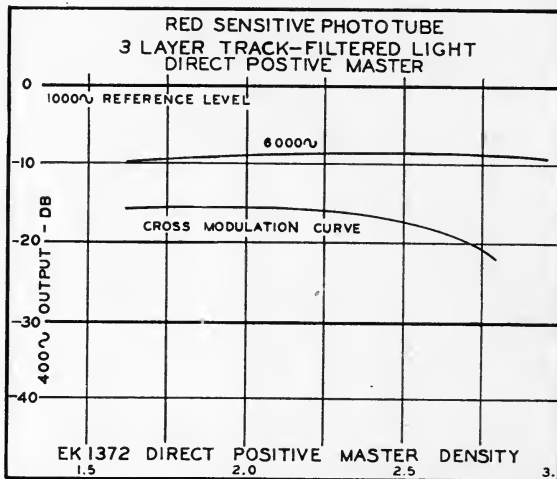

Fig. 12. Curves showing optimum direct-positive master density and frequency response at 6000 cycles for 3-layer tracks printed with tungsten light through 3 thicknesses of No. *25* Ansco filters from EK *1372* masters. The color tracks were reproduced with the blue-sensitive phototube.

layer of a film being printed from a relatively sharp negative of high density. In recording and printing silver sound tracks, a major improvement is made by confining the image close to the surface by exposing with ultraviolet light. In high-contrast negatives and non-reversal prints exposed to produce high densities, the spread of exposure results in outward shifting of the boundary of black areas, or what we call "image spread." It is evident that image spread in a negative offsets image spread in a print. This is because the image
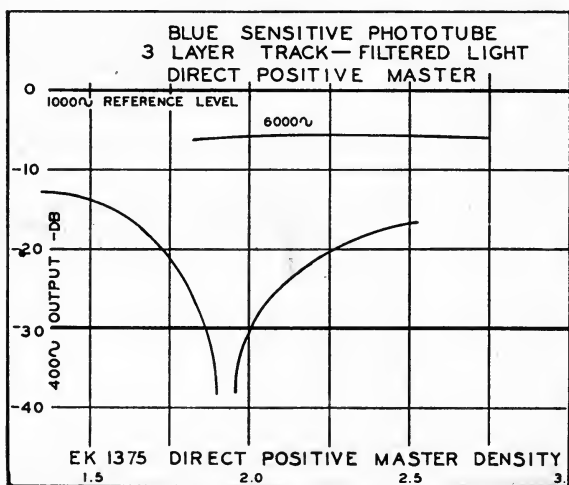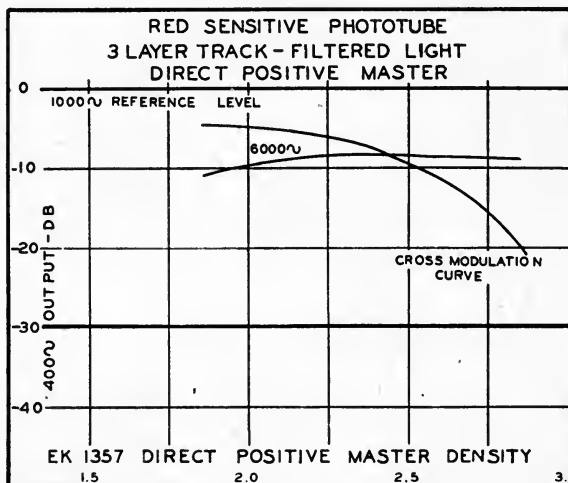

FIG. 13. Curves showing optimum direct-positive master density and frequency response at 6000 cycles for 3-layer tracks printed with tungsten light through 3 thicknesses of Ansco No. *25* filter from EK *1357* master. The color tracks were reproduced with the blue-sensitive phototube.

spread in the negative tends to make undersized the black areas in a nonreversal print. The cross-modulation method of processing control consists in choosing a combination of negative and print densities at which the image spread in the negative just balances out that in the print. For this balance the cross-modulation recording is a delicate test, and conditions that give minimum cross-modulation mean minimum distortion and the best sounding prints. Commercially, prints are considered satisfactory if cross-modulation is 30 db below signal. Such balancing of image spread does not eliminate high-frequency

losses, which are substantially the same over a range of densities on both sides of that which gives best balance.

Since the Ansco Color film with which we worked is processed by reversal, the effect of diffusion of light in the emulsion is to eat into the area which should be opaque, and cause image contraction instead of image spread. To neutralize this image contraction, the black area of the master (we cannot in this case call it a negative) has to be oversize, thus protecting a slightly larger area than that which is to be
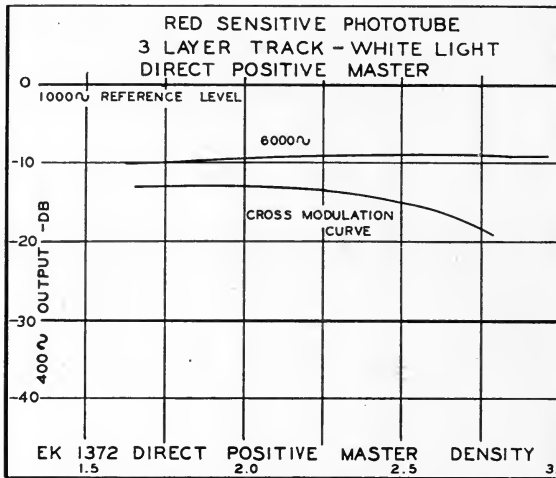
FIG. 14. Curves showing optimum direct-positive master density and frequency response at 6000 cycles for 3-layer tracks printed with unfiltered tungsten light. The tracks were reproduced with the red-sensitive phototube.

cleared of dye. With reversal prints, the plotted cross-modulation measurements show the same kind of V curves as are shown in the case of negative-to-positive prints, but the distortions on opposite sides of the minimum point are of opposite sign. Thus, if the abscissae are master (or negative) density, the branch of the curve to the right of minimum means undersize opaque image in the case of ordinary prints, but indicates oversized image in the case of reversal prints.

There are also more exacting requirements in the case of the reversal print. In all variable-area sound prints, it is important to keep the transparent areas clear, and this calls for complete exposure of

the emulsions. On the other hand, since all of the density obtainable is wanted in the dark areas, this part of the track must be almost completely protected from exposure.

The ideal printing master is a direct recorded positive. Most of our tests were with direct positives, but we have also tried printed masters.   In either case, high densities and some image spread are wanted.

Since in silver prints best high-frequency response and density tolerances for good cross-modulation cancellation had been obtained
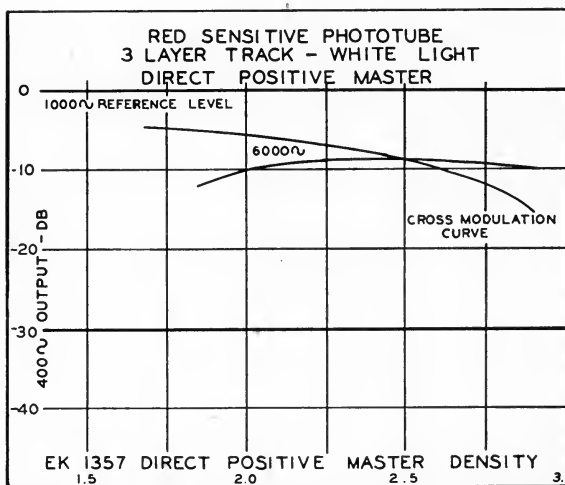
FIG. 15. Curves showing optimum direct-positive master density and frequency response at 6000 cycles for 3-layer tracks printed with unfiltered tungsten light.   The tracks were reproduced with the red-sensitive phototube.

by confining the exposure as near the surface as possible, it was anticipated that similar benefits would result from using only the surface layers of the tripack. This can be readily accomplished by clearing the bottom layer by an auxiliary exposure to red light, leaving only the dyes in the 2 top layers to produce the modulation.   Tracks so printed are here designated as "2-layer tracks," in distinction to "3-layer tracks" wherein no flashing exposure is employed, and all 3 dyes are produced in the dark areas.

A slight advantage of the kind expected was found for the 2-layer track, but it is not surprising that the margin of advantage is small. The diffusion of printing light under edges of the black area extends

farthest in the bottom layer thus shading off the edges of the image, but since this takes place principally in the cyan-dyed layer, and the cyan dye is transparent to the blue and green light to which the *1P37* tube is most sensitive, the presence or absence of some of the cyan dye makes comparatively little difference in the phototube current. Such difference as it does make results from the fact that the cyan dye is not 100 per cent transparent in this range. Figs. 5 and 6 show the relation of density to exposure in 2- and 3-layer tracks, the densities being calculated from phototube currents.

FIG. 16. Curves showing optimum direct-positive master density and frequency response at 6000 cycles for 3-layer tracks printed with tungsten light through 3 thicknesses of Ansco No. *25* filters. The tracks were reproduced with the red-sensitive phototube.

Some trials were made of single-layer tracks, using only the yellow dye in the top layer to do the modulating. If the *1P37* tube were sensitive only in the blue, the single-layer track would be logical, but it is sensitive far into the green, and hence to absorb all of the light to which the tube is sensitive the yellow dye must be supplemented by the magenta (minus green) dye.

Since the color film prints made with white light showed a blue tint in the dense areas, trial was made of yellow filters in the printing light. Fig. 7 shows the transmission of the Ansco No. *25* filter of which 3 thicknesses were used in printing the 3-layer tracks, and one thick-

ness in printing the 2-layer tracks. The use of the yellow filter permits relatively more of the yellow dye of the top layer to be formed, and there is less image contraction because undercutting is least in the top layer. As shown in Figs. 10 to 13, best cancellation occurs at a lower master density than in the case of color prints made with white light.

Figs. 8 and 9 indicate satisfactory cross-modulation cancellation for 2-layer tracks printed from either a direct positive or a printed

FIG. 17. Curves showing optimum direct-positive master density and frequency response at 6000 cycles for 3-layer track printed with tungsten light through 3 thicknesses of No. *25* Ansco filter. The tracks were reproduced with the red-sensitive phototube.

master. The 6000-cycle output is only 3.5 db below the 1000-cycle output.

Figs. 10 to 13 show that filtered printing light gives cancellation at lower master densities than does white light, and slightly increased density tolerance for 30-db cancellation. Also, direct-positive masters recorded on the fine-grain, low-spread E.K. *1372* give slightly more 6000-cycle output, and greater density tolerance for 30-db cancellation than is given by masters recorded on the somewhat coarser grained E.K. *1357*. The 3-layer tracks of Figs. 10 to 13 give about 1.5 db less 6000-cycle response than the 2-layer tracks.

Both give about the same 1000-cycle response, which is 4 db below that of a silver track.

Apart from determining optimum recording conditions for a dye track used with a blue-green sensitive tube, and demonstrating that the combination works well, the purpose of our investigation was, using *1P37* tube, to compare the dye track with a silver track, and also, using the dye track, to compare the results using the blue-sensitive *1P37* with those obtained with the red-sensitive *868* tube.
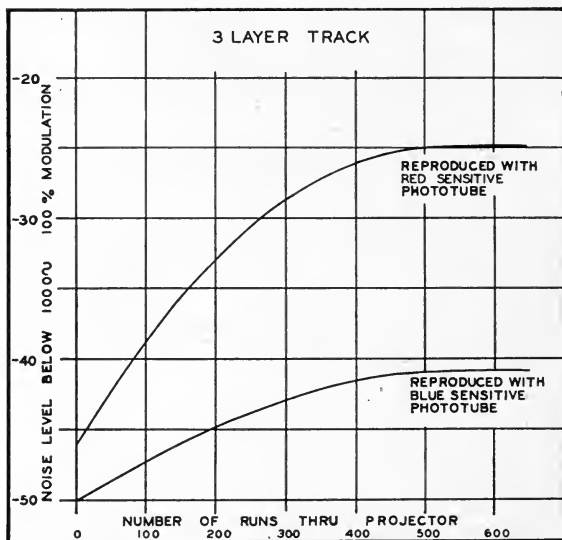
FIG. 18.   Curves showing relation between signal to noise for 3-layer biased unmodulated track and number of runs through a theater-type projector.

Fig. 2 shows the comparison of levels.   It is obviously not fair to the *868* tube to make the comparison with any but the 3-layer track.   In the 2-layer track as we made it, the cyan-dye layer was cleared, thus removing the only dye that effectively modulates red light.   Using the 3-layer track, the *868* tube is still at a disadvantage, not only in the transparency of the dyes to the infrared light which produces most of the phototube current of the *868* tube, but also in the arrangement of the layers which puts the cyan-dye layer at the bottom, or farthest from the surface where the printing light is applied, and therefore where it gets the poorest printing conditions.

The low maximum density reached when the *868* phototube is used is indicated in Fig. 6. Figs. 3 and 14 to 17 show the results of the tests of output and cross-modulation with the *868* tube. It appears that no practically obtainable master density gives enough image spread to offset the image shrinkage in the color film, although an approach toward balance appears in Fig. 17.

In both the 2-layer and 3-layer tracks reproduced with the *1P37* phototube, the 1000-cycle outputs were about 4 db below that of a silver track. Ground noise with fresh film was likewise about 4 db below that of the silver track, each of these tracks showing a noise level 41 db below its own 1000-cycle output. The 2-layer track was then run 200 times through a projector, and it was found that both the silver and the dye tracks increased in absolute noise output power by substantially equal amounts. In another test the increase of noise from a 3-layer dye track owing to wear was determined. Fig. 18 shows the noise increase as measured with an *868* and a *1P37* phototube. The rapid increase in noise in the case of the *868* tube is what would be expected in view of the low density of the dark portions of the track.

Summarizing the results of our tests, good high-frequency response and low distortion are obtainable with dye tracks and *1P37* phototubes, with levels slightly below those from silver tracks, and with signal-to-noise ratios practically the same as with silver tracks.

Two-layer tracks have slightly superior performance as compared with 3-layer tracks. Good tracks can be made from either direct positives or printed masters, provided a good negative is available for making the master. Masters should have higher densities and more image spread for printing color tracks than for making standard silver tracks, and the control for minimum distortion follows the usual cross-modulation test procedure.

REFERENCES

[1] Mees, C. E. K.: "Direct Processes for Making Photographic Prints in Color," *J. Soc. Mot. Pict. Eng.*, **42**, 4 (Apr., 1944), p. 230.

[2] Report of the Color Committee: *J. Soc. Mot. Pict. Eng.*, **XXIX**, 1 (July, 1937), p. 54.

[3] Görisch, R., and Görlich, P.: "Reproduction of Color Film Sound Records," *J. Soc. Mot. Pict. Eng.*, **43**, 3 (Sept., 1944), p. 206.

[4] Glover, A. M., and Moore, A. R.: "A Phototube for Dye Image Sound Track," *J. Soc. Mot. Pict. Eng.*, **46**, 5 (May, 1946), p. 379.

[5] Report of the Color Committee: *J. Soc. Mot. Pit. Eng.*, **45**, 6 (Dec., 1945), p. 397.

[6] Forrest, J. L., and Wing, F. M.: "The New Agfacolor Process," *J. Soc. Mot. Pict. Eng.*, **XXIX,** 3 (Sept., 1937), p. 248.

[7] Duerr, H. H., and Harsh, H. C.: "Ansco Color for Professional Motion Pictures," *J. Soc. Mot. Pict. Eng.*, **46,** 5 (May, 1946), p. 357.

[8] Baker, J. O., and Robinson, D. H.: "Modulated High-Frequency Recording as a Means of Determining Conditions for Optimal Processing," *J. Soc. Mot. Pict. Eng.*, **XXX,** 1 (Jan., 1938), p. 3.

BEHAVIOR OF A NEW BLUE-SENSITIVE PHOTOTUBE IN THEATER SOUND EQUIPMENT*

J. D. PHYFE**

Summary.—*A new phototube designed to provide optimum performance when used in reproducers with films having standard black-and-white silver sound tracks, or with color films having either dye or edge-treated sound tracks, has been developed in the RCA laboratories.*

Some results of laboratory tests and field observations when the new phototube is substituted for the standard red-sensitive 868-type phototube are discussed.

Need has recently arisen for a phototube that could be interchanged with the type commonly used in theater sound heads. The necessity is the result of an apparent trend toward an increasing use of color in motion picture film productions. Also, there is the possibility that a larger percentage of these color films will have dye sound tracks instead of the usual silver tracks. The desired tube should be interchangeable with the red-sensitive type, therefore, and must perform as well when used with films that have the regular silver sound tracks.

Such a phototube has been developed in anticipation of these needs, and is known commercially as the type *1P37*. To date the observed performance of this tube indicates that it accommodates this change-over very well. Mechanically and electrically the *1P37* is interchangeable with the type *868* phototube which has been used in RCA theater sound equipment for more than a decade.

In order to evaluate the merit of this new blue-sensitive phototube for theater use, comparisons of performance have been made in the laboratory with the type *868* red-sensitive tube. In addition a number of the blue-sensitive phototubes have recently been distributed to various theaters throughout the country with instructions to use them in place of the *868* tube, and report their relative behavior.

Too short a time has elapsed since these phototubes were placed in the field for observation, so reports on performance are not complete at present.

Laboratory tests have been made, however, to determine how well they would function in theater sound heads with standard release

prints, and if there were any adverse operating characteristics which might preclude their being substituted for the *868* tube.   Some of the characteristics investigated were:

(*1*)   Relative gain as compared to the *868* tube when used with films having the usual silver sound tracks.

(*2*)   Relative hiss level and microphonics.

(*3*)   Ionization or glow point.

(*4*)   Relative distortion.

(*5*)   Relative hum level when used with raw (unfiltered) a-c on the exciter lamp.

(*6*)   Gain variation with changes in exciter lamp brilliancy owing to line voltage fluctuations.

(*7*)   Ease of balancing output between sound heads by varying the anode voltage.

(*8*)   Frequency response relative to the *868* tube.

(*9*)   Refocusing of the optical system because of different spectral sensitivities of blue-sensitive and red-sensitive phototubes when interchanged.

Results of Laboratory Tests.—The results of these tests are reported in the order in which they were enumerated above:

(*1*)   *Gain Check.*—This was made by running a 1000-cycle loop of standard silver sound track through a regular theater sound head and amplifier channel, and noting the levels.   Both types of phototubes were used.   A sufficient number of both types were checked to represent an average cross section of sensitivity variation.   Exciter lamp and phototube anode voltages were held constant at $8^1/_2$ and 75 v, respectively.

Results of this check showed that the sensitivity of the 2 types of phototubes is practically the same with a slight superiority of the *1P37* tube.   It was noted that the *1P37* tube showed somewhat less variation in output from one tube to another than tube *868*.

(*2*)   *Hiss Level and Microphonics.*—This test was made by checking the relative outputs of a group of red-sensitive and blue-sensitive phototubes using a 1000-cycle film loop as a signal source.   The film was then removed, the amplifier gain was raised to approximately 130 db and the hiss level was measured.   The hiss level was checked both on an output meter and a sound-level meter used in conjunction with a standard 2-way theater loudspeaker system.

Microphonics was then checked by starting the projector motor and noting the output level, as was done in measuring hiss.

The results of these tests revealed no apparent difference in hiss or microphonics when the blue-sensitive phototube was used.

(*3*)   *Ionization or Glow Point.*—No changes in voltage supply are

necessary when changing from the type *868* phototube to the *1P37* type. The same maximum supply voltage limitations exist for both types.

(4) *Distortion.*—A constant-frequency film having 80 per cent modulation was run through a standard theater sound head and theater amplifier channel using both types of phototubes, and the rms harmonic distortion measured by means of a distortion factor meter. The measured distortion was found identical for the *1P37* tube and the *868*.

EXCITER LAMP VOLTS A.C.	OUTPUT WITH 1000 CYCLE FILM		HUM OUTPUT		HUM OUTPUT BELOW 1000 CYCLE FILM OUTPUT	
	IP37	868	IP37	868	IP37	868
7.5	17.7	19.1	-0.4	-3.4	18.1	22.5
8.0	20.0	20.4	+2.0	-1.6	18.0	22.0
8.5	21.8	21.8	+3.8	-0.2	18.0	22.0
9.0	23.3	22.7	+5.7	+1.1	17.6	21.6
9.5	24.8	23.8	+7.4	+2.6	17.4	21.2
10.	26.5	24.9	+10.0	+4.0	16.5	20.9

FIG. 1.   Relative film and hum output variations in db—*IP37* versus *868*. Film removed for hum output measurements.

(5) *Relative Hum Level.*—Using a-c on the filament of a standard 10-v, 7.5-amp exciter lamp, the *1P37* tube showed 4 db more hum when the exciter lamp voltage was adjusted to a normal operating value of 8.5 v. This was based on equal signal outputs for both types of phototubes using a 1000-cycle film loop. Figs. 1 and 2 show relative signal output and hum levels between the *1P37* tube and the *868* when the exciter lamp voltage was varied between 7.5 and 10 v. Hum level was measured by removing the film after output measurements were taken.

(6) *Gain Variation with Changes in Exciter Lamp Voltage.*—Referring to Figs. 1 and 2, a gain change of 5.8 db is observed for the *868* phototube and 8.8 db for the *1P37* tube, using a 1000-cycle film. This shows a 3-db increase in gain variation for the *1P37*

FIG. 2.   Relative signal-to-hum response.

tube when the exciter lamp voltage is varied between 7.5 and 10 v.

(7)   *Balancing Sound Head Outputs by Adjusting Anode Potential of Phototube.*—The adjustments used for balance of the sound head outputs are the same for both the *1P37* tube and the *868*. These are made by control of anode supply voltage.

(8)   *Optical System Focus When Using Both Types of Phototube.*— A standard $1^1/_4$-mil slit image optical system was focused for maximum output using a 7000-cycle loop of film and an *868* red-sensitive phototube. Output readings were then taken for both types of phototubes. No observable increase in output was obtainable with the *1P37* tube by refocusing the optical system. This test was then repeated using a 9000-cycle loop of film. The results were identical.

This observation seems to substantiate the assumption that there is no need to refocus a standard $1^1/_4$-mil slit image optical system when the *1P37* tube is used in place of the *868*.

(9)   *Relative Frequency Response.*—For this check a standard theater reproducing channel having an optical system with a $1^1/_4$-mil slit image was adjusted for maximum focus using a 9000-cycle loop. No low-pass filter was used since this might have had the effect of making relative output at the higher frequencies. Frequency runs were then made using a calibrated test film which included 31 different frequencies between 30 and 9000 cycles. Response measurements revealed no difference in relative frequency response when the *1P37* tube was substituted for the *868*.

Conclusion.—Reports from the field are awaited in order to better judge the seriousness of the increased hum, and greater variation in signal level with changes in exciter lamp voltage obtained with the *1P37* tube. No attempt will be made at this time to evaluate the seriousness of these 2 points.

It is felt, however, that the increased hum might be satisfactorily compensated by modification of the 120-cycle hum filter in those installations which operate with raw a-c on the exciter lamp.

For those installations which operate with d-c exciter lamps and which have some form of regulation of the exciter lamp voltage, it does not appear that the latter point would become a problem.

In the meantime, however, the tubes that have been substituted are working very well, indicating that no differences in operating characteristics have been observed, or else are not of sufficient magnitude to justify an immediate report.

ELECTRONIC SHUTTER TESTERS*

R. F. REDEMSKE**

Summary.—The following paper, reprinted from Electronics, describes a photo-electric system which feeds a bank of stylii producing on Teledeltos paper a recording of camera shutter-opening area plotted against time, for testing both iris and focal-plane shutters. Direct-indicating accessory shows per cent deviation from rated shutter speed.

The editors of the Journal feel that the methods and equipment outlined here will be of timely interest to members in the motion picture industry and allied fields.

Military demands for large numbers of precision aerial cameras during World War II dictated an accelerated mass production program. With this program arose the need for a shutter tester of high accuracy, applicable to production-line use. Previous shutter-testing methods, employing both photographic and electronic techniques, were well suited to laboratory use but hardly applicable to production requirements.

One requirement of the new tester was that it be capable of yielding a permanent record of shutter characteristics for both iris-type (between-the-lens) shutters and focal-plane shutters. In the case of the iris type, the record should indicate both speed and efficiency, while for the focal-plane type the record should show the shutter speed at 3 points: near the beginning, center, and end of the curtain travel. This instrument must also have an auxiliary time-measuring circuit for testing the *K-19* night photo camera. Another requirement was a visual indicating shutter tester for both iris and focal-plane shutters. This article describes shutter testers that evolved from this development program and outlines the factors influencing the design.

In considering the requirement that data from the recording shutter tester be in the form of a permanent record, it was deemed impractical to use any method involving a photographic process. This

conclusion was reached because the time consumed in the develop-
ment, fixing, washing, and drying sequence would be prohibitive, and
because a setup involving a darkroom is inconvenient.   This elimi-
nates photographic methods of shutter testing, as well as electronic
methods that employ a recording string-oscillograph.

Other possible recording means were studied, and as a result of this
investigation it was decided to use Teledeltos recording paper, which
has the property of carbonizing and forming a dark line when a stylus
energized with sufficient voltage is drawn against it.

Recording Shutter Tester.—The best recorded data to provide
speed and efficiency figures for an iris shutter is the curve of shutter
opening area versus time.   A typical curve is shown in Fig. 1A.   The
advantage of this type of presentation is that it provides sufficient
data to rate shutter speed on any of the several bases.   To reproduce
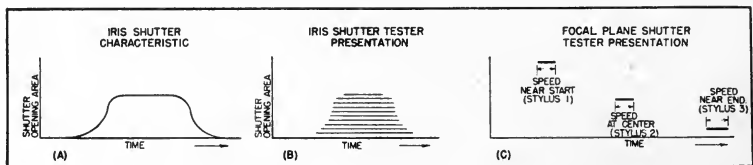
FIG. 1.   Examples of records obtained with electronic shutter tester for iris
and focal-plane shutters.

this curve on Teledeltos paper, it was decided to move the paper
under 10 stylii equally spaced in a straight line and controlled in-
dividually, to give the result shown in Fig. 1B.

With this setup the focal-plane shutter tester could use three of
the stylii to show the speed at 3 curtain positions, giving a record like
that in Fig. 1C.   The recorded lines would not necessarily appear in
sequence, as it is possible for the recording drum to make more than
one revolution between traces.

The paper was moved beneath the stylii by mounting it on a cylin-
drical drum of 15-in. circumference, driven by a synchronous motor.
The stylii cannot be allowed to rest too long on the paper with the
drum rotating as they wear marks which can be confused with the
signal traces.   To avoid this trouble, the stylii arms are held off the
paper by a spring system.   Just before the shutter is tripped, a
switch is thrown to energize a solenoid which overcomes the spring
and contacts the stylii with the paper.   Two drum speeds are pro-
vided.   This is necessary to prevent the traces for low shutter speeds

from taking up more than one revolution and overlapping, and still be able to provide a long enough trace for accurate measurement at high shutter speeds. Knowing the drum speed and circumference, the lengths of trace for various shutter speeds can be calculated. Typical values are given in Table 1.

TABLE 1

Relation of Shutter Speeds to Trace Lengths

Shutter Speed (Sec)	Drum Speed	
	1200 rpm (In.)	2400 rpm (In.)
$1/25$	12	. . . .
$1/50$	6	. . . .
$1/100$	3	. . . .
$1/200$	. . . .	3
$1/500$	. . . .	1.2

The shutter speed tolerance of ± 10 per cent can readily be detected on this basis. The system necessary to accomplish this presentation of data on Teledeltos is outlined in block diagram form in Fig. 2.

Iris Shutter Optic and Phototube Unit.—In the case of the iris shutter, the first step necessary to achieve the end result shown in Fig. 1B is to convert the shutter opening area into a corresponding electrical voltage. This was accomplished by the photoelectric arrangement of Fig. 3. A light source consisting of a tungsten-filament bulb in a reflector is placed a considerable distance above the shutter. This applies uniform illumination with approximately parallel light rays to one side of the shutter.

It was found necessary to operate the lamp from a d-c source to avoid ripple pickup by the phototube. A lens system on the other side is adjusted to focus an image of the light source on a piece of diffusing material which in turn reflects light to the phototube. The shutter then acts as a variable iris controlling the amount of light received by the phototube. This proved to be the best way to maintain a linear relationship between shutter opening area and phototube output current. The voltage output from the phototube load resistor when the shutter is operated is therefore varying as in Fig. 1A. The system that translates this voltage pulse into lines on the Teledeltos paper must have a frequency response range such that no distortion is introduced.

To consider the frequency response requirements, refer to Fig 4. To transmit without distortion an isolated trapezoidal pulse in time a general rule is that the circuit must be flat in response up to a frequency f determined by $1/T$, where T is the time duration of the slope. The pulse obtained from the phototube approaches the shape of Fig. 4. Assuming that the highest shutter speed to be encountered would be $1/_{1000}$ sec and assuming that the slope duration might be 10'
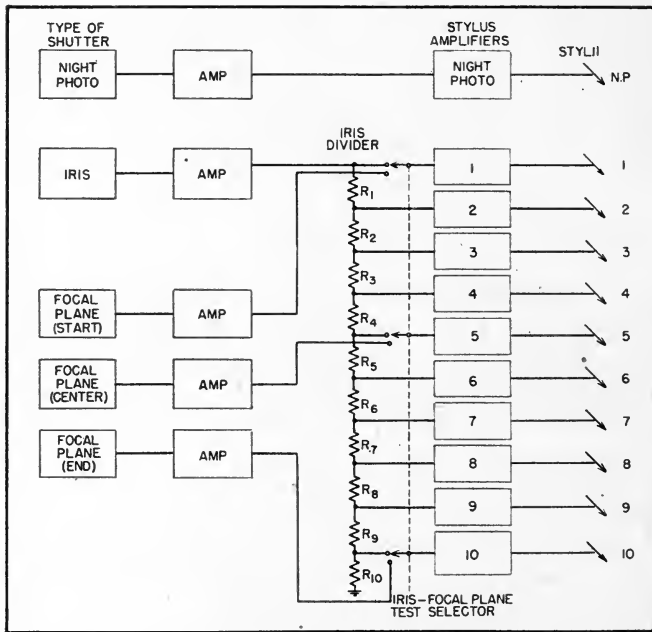
FIG. 2. Block diagram of recording shutter tester.

per cent of this, the upper frequency limit f is 10,000 cps. Circuit constants to meet this frequency requirement are

$$f = {}^1/_2 \pi RC \qquad (1)$$

where f is the frequency where response is 3 db down, R is load resistance, and C is shunt capacitance.

In designing the photoelectric circuit, it is desirable to use the maximum permissible value of load resistance to achieve the maximum signal voltage, and thus reduce the amplifier gain requirements. However, as the phototube is built into the shutter test jig, it must be

separated from the main amplifier-recorder rack by some 5 ft of cable. This introduces a high value of shunt capacitance that severely limits the value of phototube load resistance when Eq (1) is considered. It was accordingly decided to use a cathode follower as an impedance changer at the phototube to reduce the shunt capacitance across the load resistor to a minimum. The circuit is shown in Fig. 5. By locating the 6SN7 very close to the 929, it was possible to use 1.3 megohms for R_L.

Focal-Plane Optic and Phototube Unit.—To measure the speed of a focal-plane shutter, it is necessary to measure the time required for the shutter slit to pass a point. The arrangement in Fig. 6 was designed to do this. This setup

FIG. 3. Optical system of shutter tester.

provides a source of illumination to the top of the shutter while the shutter opening is passed over a narrow slot parallel with it and very closely under it. The light source is restricted with a slot to make the light applied to the shutter more nearly parallel. During the coincidence of the openings, light will fall on the cathode of the phototube. The output of the phototube will then also be in the form of a trapezoidal pulse. The duration T of the slope is the time taken for the edge of the shutter opening to pass over the slot and is therefore a function of slot width.

FIG. 4. Voltage output of phototube during operation of iris shutter.

As the width of this trapezoid near its top is the time recorded to indicate speed, it is desirable to keep the slope duration small enough to limit the error to 2 per cent. It is therefore necessary that the beginning slope and ending slope each be one per cent of the base time. This means that the slot width should be one per cent of the curtain opening width.

The minimum curtain opening to be considered is $1/8$ in., so the

slot was fixed at 0.00125 in.   For a shutter speed of $1/1000$ sec and a one per cent slot, a uniform frequency response up to 100,000 cps is required

$$f = 1/T = 1/0.001 = 100,000 \quad (2)$$

Three phototubes are built into the shutter holder jig and, as in the iris unit, require long cabling to the amplifier, necessitating cathode followers.   The 3 phototube circuits are similar to that shown in Fig. 5, except that a *6J5* is used with R_L equal to 150,000 ohms.
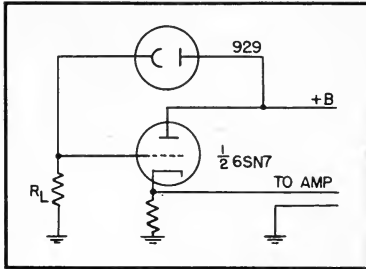
Fig. 5.   Phototube and impedance-changer circuit.

Stylus Control Amplifier.— For controlling the stylii, the circuit of Fig. 7 was used.   It is basically a 2-stage direct-coupled amplifier using Teledeltos as the output plate load resistor.   The *6SF5* plate load resistor satisfies Eq (2) for 100,000 cps.   The *6SF5* is normally at zero bias and the voltage drop across its plate load resistance is sufficient to bias the *6L6* to plate current cutoff.
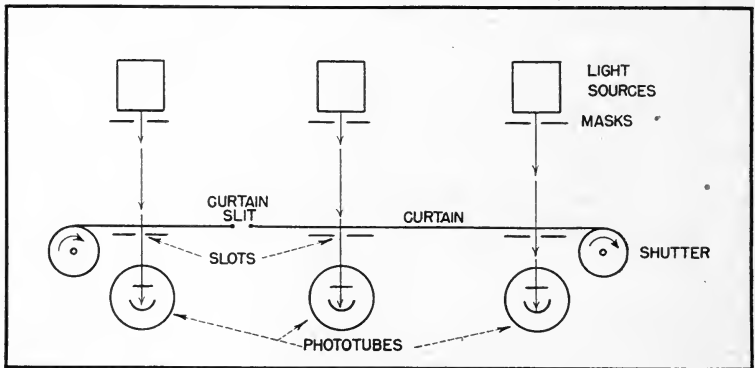
Fig. 6.   Optical system of focal-plane shutter tester.

When a negative signal is applied to the *6SF5* grid, its plate current decreases and the negative bias is removed from the *6L6*, allowing current to flow through the Teledeltos (assuming the solenoid is energized so it holds the stylii down on the recording drum).   An input signal to the *6SF5* grid of one volt is sufficient to produce a trace.

It was initially planned to ground the recording drum, thus grounding the positive 250-v plate supply of the *6L6*. However, this led to hum difficulties in the *6SF5* grid circuit owing to the floating power supply circuit. The drum was therefore insulated and
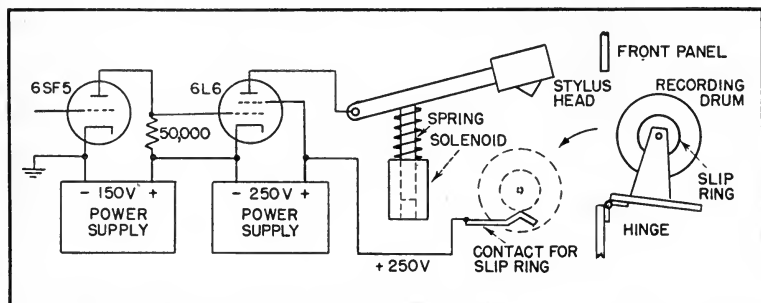
FIG. 7. Basic circuit used in each stylus-control amplifier. Plate circuit of *6L6* is completed when stylus is pulled down to recording drum by the solenoid, because the drum is 250 v positive.

the ground applied at the negative terminal of the *6SF5* power supply. The operator is protected by the mechanical arrangement of the drum. For changing recording paper, the drum is hinged outward, as shown in Fig. 15, disengaging it from the drive motor and disconnecting it from the high voltage.

Eleven of these stylus amplifiers are provided, ten for iris shutter recording (three of which are used for focal-plane recording) and one for night photocamera timing, as was shown in Fig. 2. All run from a common power supply.

Iris Divider System.—The first consideration in designing the iris divider system is the voltage increments on which the chain of stylus amplifiers are to operate. The first amplifier in

FIG. 8. Base-line recording errors for 1-v (*A*) and 10-v (*B*) operating increments of iris voltage-divider.

the chain goes directly to the signal source and will always operate on one volt. If the divider is designed so the succeeding channels

work on one-volt increments, the situation shown in Fig. 8A will exist. This is an undesirable condition as the base line of the recording is not the true base line. To avoid this difficulty, the divider was designed to give 10-v operating increments. This yields a recording with negligible error in the base line, as in Fig. 8B.

The divider resistance was made 100,000 ohms and was built up of precision wire-wound resistors having one per cent tolerance, for which individual values are given in Table 2.

TABLE 2

Voltage Divider Design

	Per Cent of Total	Value in Ohms	Gives 1v When Input Is
R^1	90.90	90,900	11v
R^2	4.33	4,330	21v
R^3	1.54	1,540	31v
R^4	0.79	790	41v
R^5	0.48	480	51v
R^6	0.32	320	61v
R^7	0.23	230	71v
R^8	0.17	170	81v
R^9	0.14	140	91v
R^{10}	1.10	1,100	. . .

Amplifier for Iris Shutters.—From the preceding discussion, it is seen that the amplifier unit for iris shutters must be capable of amplifying the phototube output sufficiently to supply the divider
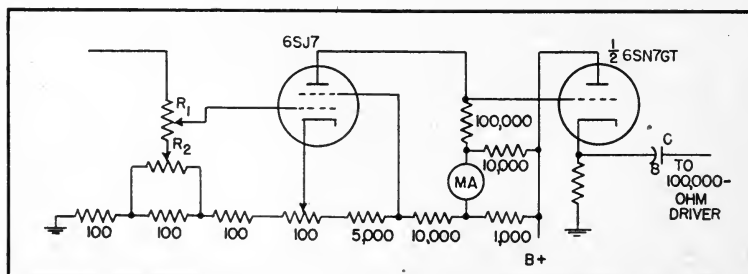
Fig. 9.   Amplifier circuit used between phototube and iris voltage-divider when testing iris shutters.

with a 91-v pulse without appreciable distortion. The components were selected by using Eq (1) on the basis of passing up to 10,000 cps. The resultant circuit is shown in Fig. 9. Gain control R_1 is

necessary to compensate for the difference between maximum open-ing areas of the various shutter types. A position is selected for each shutter type so that the amplifier output to the divider at full shutter opening is the 91 v required so that the last stylus amplifier just operates to form a trace.

The smallest shutter gives a 2-v signal at full opening, so the gain is based on this figure, and all larger shutters are scaled down to this value by R_1.

Potentiometer R_2 is provided to oppose the steady direct voltage present across the cathode follower resistance, so that no d-c potential exists across the gain control. In addition, a 100-ohm potentiom-eter adjusts the bias on the 6SJ7.

With the phototube totally dark and the system warmed up, R_2 is adjusted until moving R_1 slowly from one end to another does not cause the plate current meter to vary. The bias is then ad-justed to the correct value as in-dicated by zero indication of the plate milliammeter. Controls R_1 and R_2 are screwdriver adjust-ments and only have to be re-aligned occasionally as a routine check.
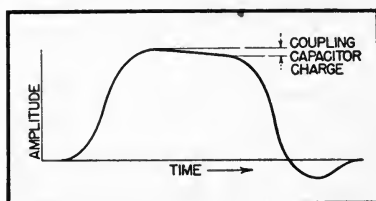
FIG. 10. Overshoot distortion caused by use of isolating capacitor C in Fig. 9.

When the system is to be set up for a new-type shutter, the shutter is opened to its wide-open position and is illuminated. This gives the maximum value of light that the phototube will receive when the shutter is operated nor-mally. Control R_1 is adjusted to give a reading of 1.2 ma on the meter, thus insuring that the top of the phototube output pulse will just be the top of the recorded pulse. The cathode follower is used as before to act as an impedance changer and minimize shunt capaci-tance effects.

It is theoretically desirable to keep the system a d-c amplifier throughout, to handle the d-c component that exists in trapezoidal pulse. However, the practical difficulties encountered in the system dictated the use of an isolating capacitor C. Because the capacitor will not pass direct current, there is some distortion of the pulse as in Fig. 10, but by suitable choice of RC ratio the effect can be reduced to the point where it is not serious.

Amplifier for Focal-Plane Shutters.—The function of the amplifier

for focal-plane shutters is to raise the level of the optical system output to the voltage necessary to excite the stylus control to form a trace.   The maximum output of the phototube is one millivolt and the voltage required to draw a trace is one volt, so the requirement is an amplifier with a gain of 1000 or more and a frequency
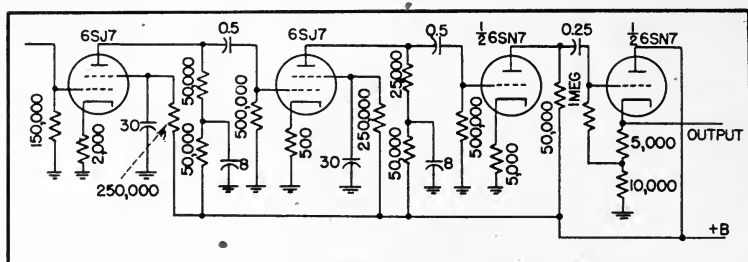
FIG. 11. Amplifier circuit used between phototube and stylus-control amplifier when testing focal-plane shutters.

response to 100,000 cps.   The circuit of Fig. 11 is the result of designing to these figures.   As the lowest shutter speed is $1/125$ sec and as no steady-state light calibration is needed, the amplifier is capacitance-coupled throughout.   The cathode-follower output is used to provide a low-impedance line to the stylus amplifier.   Three of these amplifiers are provided, one for each phototube output.   It was

originally planned to use type 931 photomultipliers for the focal-plane tester because of the low light level encountered, but these tubes were critical at the time of this development and could not be obtained. Their use would have eliminated the need for the high-gain amplifier.

FIG. 12. Optical system of night photo shutter tester.

Night Photo Timing.—The K-19 night photo unit required an auxiliary circuit for adequately testing it.   This camera has a magnetically actuated iris-type shutter which is controlled by a phototube-amplifier arrangement. In use, the light from a flash bomb dropped from the camera airplane reaches the phototube, actuating the shutter through an amplifier.   The requirement is that the shutter shall be fully open in

10 milliseconds from the start of the flash, at which time the flash has reached peak intensity. The system must work on a light intensity change of 0.2 ft-c.

In the testing of this camera, the shutter is tripped by a pulse of light which simultaneously actuates a phototube in the tester. The light pulse is produced by operating a shutter located in front of the light source, as shown in Fig. 12. The shutter speed is $1/500$ sec, which gives a light pulse wave front similar to the actual flash bomb. This is important because the *K-19* camera operates on rate of change of light rather than steady-state values. This light pulse passes through the shutter and strikes an optical dividing system consisting of a piece of glass set at 45 deg to the light path.
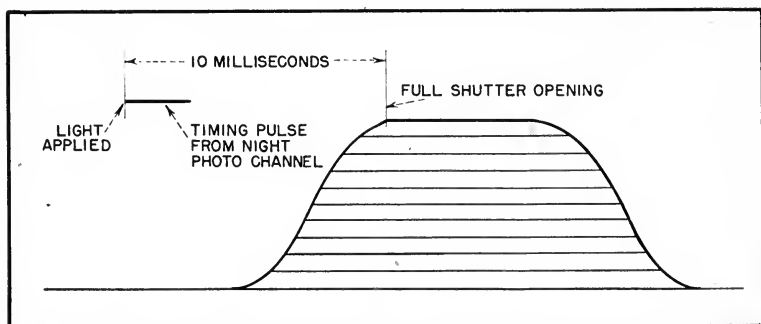
FIG. 13.   Timing record obtained when checking night photo shutters.

Most of the light passes straight through and strikes the cathode of the timing phototube, while a small portion is reflected by the glass to actuate the phototube of the *K-19* camera and trip its shutter.   This reflected light is further attenuated by a neutral filter so the maximum light reaching the *K-19* phototube is 0.2 ft-c. The light reaching the timing-channel phototube is amplified and fed to the stylus control to form a line. The beginning of this line is the exact instant that the *K-19* phototube was energized, so the distance to full open shutter can be measured to see if it is within the 10 milliseconds allowed. A typical record is shown in Fig. 13.

Direct-Indicating Shutter Tester.—The direct-indicating tester was developed as a general utility instrument to be used separately or in conjunction with the recording tester. To obtain a high degree of accuracy from the indicator, the output reading is presented as per cent deviation from rated shutter speed. In this in-

strument, iris shutter speed is defined as the total open time, which is the time duration of the base of the characteristic trapezoid.

The final design of this unit consists of a time-measuring circuit, a comparing circuit, and an indicating circuit, as in Fig. 14.

Time-Measuring Circuit.—The time-measuring circuit makes use of the constant-current characteristic of a pentode to charge a capacitor to a voltage proportional to time. The input is received from the amplifier output of the iris or focal-plane recording testers previously described, or from a similar circuit when used separately.
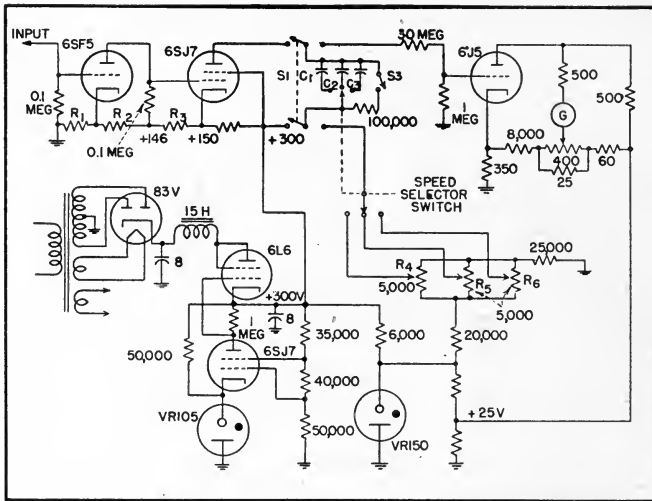
FIG. 14.   Circuit of direct-indicating shutter tester.

The *6SF5* tube acts as a combination amplifier and limiter. It is run normally at some bias such that the drop through its plate load resistor keeps the *6SJ7* biased beyond plate current cutoff. A small negative signal then will drive the *6SF5* to cutoff and the *6SJ7* will become conductive and start charging the capacitor in its plate circuit at constant current. This charging current flowing in the cathode circuit and in the divider causes some regeneration owing to R_1 and R_2, which effectively increases the gain of the circuit but is not sufficient to cause instability. The effect is somewhat counter-

acted by the degeneration in R_3, which is provided to keep the 6SJ7 grid in a region of greater current linearity.

For iris shutters the arrangement is such that the 6SF5 is driven to cutoff by a shutter opening area equal to one per cent of total opening, remaining in that condition until the shutter is within one per cent of being closed. Thus the capacitor is being charged at constant current for the full open time of the shutter. With focal-plane shutters, the trapezoidal pulse described previously is of sufficient amplitude to drive the 6SF5 to cutoff and charge the capacitor for its duration.

One capacitor (C_1, C_2, or C_3) is used for each shutter speed to be covered, and a switch is provided to select the proper one. The capacitor values are so chosen that each one when charged for its indicated shutter speed will develop the same voltage.

Comparator Circuit.—Switch S_1 is a telephone-type switch that connects the 6SJ7 plate circuit to the capacitor selected by the speed selector switch. When the shutter is operated and the capacitor charged, S_1 is thrown to its other position. This disconnects the capacitor from the plate circuit and places it in series opposition with a standard source of voltage.

If the shutter speed is exact, the 2 voltages will be equal and

FIG. 15. Recording drum of recording shutter tester, shown hinged outward for changing of paper. Recordings of 4 shutters can be obtained on a single sheet of Teledeltos paper before reloading.

their resultant will be zero. If the shutter is in error, the voltages will differ and the resultant will indicate the direction and amount of error.

Switch S_3 is provided to completely discharge the capacitor before repeating the charging process.

It was found impossible to conveniently select capacitor values close enough to give an exact voltage for a given charging time, so voltage trimmers R_4, R_5, and R_6 were added. One of these is selected

with each capacitor value and is adjusted to give the proper comparison voltage. This circuit is calibrated by applying electrical pulses of known time duration from a commutator arrangement to the amplifier input.

Indicator Circuit.—The resultant of the capacitor and comparison voltages is fed into an indicator circuit through a 30-megohm resistor. This value is made high so the capacitor will discharge slowly enough to provide a reliable reading for conditions of shutter error.

The $6J5$ circuit is essentially a vacuum-tube voltmeter with a zero-center indicator. Shutter speeds higher than rated result in an up-

Fig. 16.   Direct-indicating shutter tester, with fixture for phototube, light source, and shutter holder at the right.

ward deflection, low speeds in a downward deflection. As the voltages being compared for any shutter speed are the same, the indicator can be calibrated in percentage deviation from rated speed. The slight variations owing to R_4, R_5, and R_6 do not introduce appreciable error. The full meter scale covers ± 15 per cent error.

The circuit constants are such that large inputs cannot damage the 50–0–50 μa meter, as the $6J5$ reaches saturation slightly off scale on the upper end and reaches cutoff beyond the lower end.

Several of these testers were built, for various numbers of shutter speeds. The unit shown in the circuit was arranged for shutter speeds of $^1/_{125}$, $^1/_{250}$, and $^1/_{500}$ sec.

The indicating tester proved an accurate and convenient means of

measuring shutter speed. On some production runs it was used exclusively for speed tests, the recording instrument being resorted to only for occasional spot checks. It was also useful in production adjustment of shutters.

The author is indebted to Irving Doyle, Fairchild engineer, and Robert Nelson of the inspection department for substantial cooperation and many helpful ideas in connection with the development of the recording shutter tester.

BOOK REVIEWS

Television: The Eyes of Tomorrow. By William C. Eddy. Prentice-Hall, Inc. (New York), 1945, 330 pp.; illust. and diagrams; 6 × 9 in., $3.75.

This book is written by a man who has had much experience in the television field. It is strongest and most valuable where it makes available to others the personal experiences of the author. His selection of secondary material, that is, the experiences of others, also adds to the value of the book as a record of practical experience.

The chapter "The Use of Film in Television" outlines experience with a variety of types of film presentation and ends with the conclusion:

"Whether or not film in television will increase in importance in future commercial programming remains an economic rather than an engineering problem. Based on the present development in this field, coupled with the possibilities that are known to exist in future improvements of the system, the popularity of film programs in the home is solely dependent on the entertainment value of the product. It is hoped that a satisfactory solution to the present economic impasse between broadcasters and film distributors will someday be effected and that eventually television will have a satisfactory film product available for programming."

The book is weakest in the chapters dealing with the technical aspects of television, as technical accuracy has been sacrificed at times in the attempt to secure a popular style of presentation. This is probably relatively unimportant in view of the main audience to which the book is addressed. The author was well aware of the hazards involved in writing a book of this type and disarms one by his remarks in the preface:

"Any person who deliberately takes it upon himself to write a book on television asks for criticism of both qualified critics and lay readers. . . .

"Experts in each field will necessarily point out wide discrepancies between my coverage of their specialty and the practical application of their trade on the studio floor."

D. R. WHITE
Mar. 20, 1946

Television Show Business. By Judy Dupuy. General Electric Company (Schenectady, New York), 1945, 246 pp.; illust. and diagrams; 8½ × 11 in., $2.50.

This handbook of television programming and production, based on 5 years of operation of General Electric's Television Station, WRGB, Schenectady, New York, is the most complete and detailed account which has yet appeared in print of experience with television programs. As such it will be an invaluable guide to others in the television field. The treatment of the technical aspects of television is reduced to a brief popular account of little interest to an engineer but adequate for the intended reader.

424

The chapter "Films in Television" is probably the one of greatest interest to the Society members. This outlines various functions performed by films of different types, including their use as a supplement to live talent shows in order to circumvent certain of their limitations.

In common with other books on television this one involves a certain amount of prophecy. Concerning the role of motion pictures in television it says:

"Films will play a major role in television. It is safe to predict that future television programming will consist of about one-third studio shows, one-third remote pickups (mobile unit or distant permanent setups), and one-third motion pictures. These motion pictures may or may not be made exclusively for television. At first many of them will be motion pictures produced for movie theater showing.

"The future holds many unknown factors which will determine the relationship of motion pictures and television."

The General Electric Company has made a very worth-while contribution to the television industry in thus making available its experience at WRGB.

D. R. White
Mar. 20, 1946

Report of Conference on Unification of Engineering Standards, Ottawa Canada, September–October, 1945. Combined Production and Resources Board. 90 pp.; 6 × 9 in. Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.; 20 cents.

This report summarizes the proceedings of the third conference of representatives of the Canadian, British, and American standards associations on the question of unification of standards for screw threads, limits and fits, drawing practice, and metrology in countries using the "inch" system of measurement. Final agreement was reached on unified standards for acme and acme stub screw threads, buttress screw threads, fastening screws of the smaller sizes, and fine motion screws.

The possibility of developing a common standard for screws for camera and lens attachments, and the like, and for tools for screw thread production was referred to committees of the 3 standards associations for further consideration. A proposed specification for a basic screw thread form was prepared for submission to the industries concerned for comments.

No agreement was reached on unified standards for high duty studs in light alloys or for pipe threads. Two alterations in American War Standard B1.6 (June, 1945) on truncated Whitworth threads were recommended and referred to the American Standards Association for study.

Included in the report is a bibliography of standards to which reference was made during the conference, and tables listing the proposed screw thread series and screw thread symbols.

M. Wright
Mar. 7, 1946

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals Photostatic or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y., at prevailing rates.

Acoustical Society of America, Journal
17, 4 (Apr., 1946)
Stereophon Sound Recording System (p. 356)   H. B. LEE, III

American Cinematographer
27, 2 (Feb., 1946)
The Subjective Camera (p. 46)   H. A. LIGHTMAN
Report of the SMPE Committee on Color (p. 48)
Bell & Howell Introducing New 16-Mm Auto Load
  Camera (p. 52)
Bell & Howell Equipment to Be Manufactured in
  England (p. 54)
Eastman Kodak Explains Research Status of Pro-
  fessional Safety Film (p. 54)
New Western Electric Sound Recorder for 16-Mm
  and 35-Mm (p. 60)
27, 3 (Mar., 1946)
Cinematography in the War—Filming Projectile Tests
  for the Navy (p. 80)   A. L. GILKS
The Fluid Camera (p. 82)   H. A. LIGHTMAN
A Positive Vari-Focal View Finder for Motion Picture
  Cameras (p. 84)   F. G. BACK

Biological Photographic Association, Journal
14, 3 (Mar., 1946)
High-Speed Motion Picture Photography (p. 107)   H. M. LESTER

British Kinematograph Society, Journal
8, 4 (Oct.–Dec., 1945)
Motion Picture Laboratory Trends and Practices
  (p. 73)   W. M. HARCOURT

Electronics
19, 4 (Apr., 1946)
Color Television on Ultra High Frequencies (p. 109)

Electronic Industries
5, 3 (Mar., 1946)
CBS Shows Its Color—High-Frequency Transmission with Sound on Same Carrier Demonstrates Their Solution of Color Reception Problems (p. 75)
RCA Color TV Status—Princeton Laboratories Demonstration Reveals Progress in Both Color and Black-and-White—Tube and Transmitter Production (p. 102)

International Photographer
18, 1 (Feb., 1946)
Device Makes Dissolves and Fades with Camera (p. 7)   J. YOLO
Practical Utilization of Monopack Film (p. 11)   C. G. CLARKE
18, 2 (Mar., 1946)
Processing 16-Mm Ansco Color Film (p. 5)   J. L. FORREST
Color Television—When? (p. 20)   W. S. STEWART
Some Considerations in Using Kodachrome, Pt. 2 (p. 22)

International Projectionist
21, 2 (Feb., 1946)
Some Physical Properties of Film Relating to Image Stability (p. 7)   R. H. TALBOT
The New Ampro 16-Mm Projector, Pt. 2—Step-by-Step Analysis of Sound Circuit (p. 12)   L. CHADBOURNE
Acetate *vs.* Nitrate Issue Revived (p. 15)
Basic Design Determines Projector Performance (p. 16)   A. E. MEYER
Projection Lens Aberrations (p. 20)   A. MONTANI
Basic Radio and Television Course, Pt. 20—Transmitters (p. 22)   M. BERINSKY
21, 3 (Mar., 1946)
Elements of Projection Optics (p. 7)   A. MONTANI
An Improved Loudspeaker System (p. 10)   J. B. LANSING AND J. K. HILLIARD
Basic Radio and Television Course, Pt. 21—Transmitters (Oscillators) (p. 18)   M. BERINSKY

Proceedings of the I.R.E.
34, 2 (Feb., 1946)
Transmission of Television Sound on the Picture Carrier (p. 49)   G. L. FREDENDALL, K. SCHLESINGER AND A. C. SCHROEDER

Technique Cinematographique, La
17, 15 (Feb. 5, 1946)
A New Micro-Densitometer (p. 275)   L. RAITIERE

SOCIETY ANNOUNCEMENTS

ATLANTIC COAST SECTION MEETING

One of the largest meetings of the Atlantic Coast Section of the Society was held on March 13 at the new DuMont John Wanamaker Studios when Dr. Allen B. DuMont, president of A. B. DuMont Laboratories, Inc., delivered a paper on "The Relationship of Television to Motion Pictures." The linking of television and motion pictures in a partnership of mutual advantages, with the possibility of motion picture producers soon making films expressly for television, was seen by Dr. DuMont.

Among the advantages cited were that films provide a permanent record for use any time and place, film programs can be handled with a minimum of technical personnel in the studio, and it provides an effective means of syndicating production among any number of stations.

"Movies and television are natural partners," Dr. DuMont said. "One supplements the other. Movies are the permanent record. Television is the more advanced way of getting the picture. Television owes much to movies up to this time. But from here on, movies will be receiving benefits from the rapidly refining television technique."

The meeting concluded with a demonstration of a sight and sound television motion picture film.

The last meeting in the Spring series arranged by the SMPE Section to promote wider knowledge of industry techniques and practices was devoted to the production of newsreels, under the title "The Newsreel—Its Production and Significance." Held at Movietonews Studios, on April 17, the symposium consisted of Dan Doherty, assignment editor, Harry Lawrenson, foreign editor, Warren McGrath, sound engineer, Jack Gordon, unit director, Vyvyan Donner, women's editor, Walter McInnis, cameraman, and Bert Holst, librarian.

Mr. Doherty described the status of the newsreel as a screen journal. He explained why the reel does not attempt coverage like newspapers. "The newsreel editor cannot, for many reasons, attempt to cover all the news. In the first place the cost of keeping a camera staff capable of the noble effort would be prohibitive. In the second place, newsreel presentation time in theaters is limited.

"By this confining fact alone, the editor's task is not one of attaining total coverage but of selection, and selection based on an intimate knowledge and understanding of the medium."

The Movietone editor defended the practice of presenting the same annual events—football games, horse races, *etc.*—on the grounds that audiences wanted them. Mr. Doherty added that other trivia, such as cheesecake and fashion shows, were the result of policy which required an entertaining newsreel.

Mr. Doherty introduced each of the other newsreel experts who discussed their special work in newsreel and fashion short production.

428

These papers, as well as the paper by Dr. DuMont, will be published in a forth-coming issue of the JOURNAL.

PACIFIC COAST SECTION MEETING

The March 20 meeting of the Pacific Coast Section of the Society was addressed by Randal Terraneau of the Humphries Laboratory, London, who is currently making his first visit to Hollywood in several years. Mr. Terraneau's witty descriptions of laboratory operations under blitz conditions in London were highly interesting.

Other speakers at the meeting were W. C. Kunzman, L. L. Ryder, E. A. Williford, and Carrol Dunning, who introduced Mr. Terraneau. Approximately 150 members and guests were present at the discussion, held at the Hollywood Athletic Club.

On March 26 the Section was privileged to hear talks by Dr. H. F. Olson and Dr. V. K. Zworykin of the RCA Laboratories, Princeton, New Jersey. Dr. Olson described the Acoustic Laboratory at Princeton, a reverberation simulator, a duo-cone loudspeaker, and a miniature unidirectional microphone.

Dr. Zworykin discussed the status of television including the Image Orthicon and the Aluminized Kinescope. He also reviewed the advancements in the electron microscope, and described a small electron viewing tube suitable for use under invisible infrared light conditions.

A record-breaking attendance of approximately 600 members and guests completely filled the Walt Disney Studio theater at Burbank, Calif.

EMPLOYMENT SERVICE

Position available for Optical Designer, capable of handling the calculation and correction of aberrations in photographic and projection lens systems. Junior designers or engineers will be considered. Write fully giving education, experience, and other qualifications to Director of Personnel, Bell and Howell Company, 7100 McCormick Road, Chicago 45, Ill.

Motion picture studio in Bombay, India, has positions open for professional motion picture camerman with studio and location experience; sound recording engineer experienced in installation, maintenance and operation of recording equipment; motion picture processing laboratory supervisor; and professional make-up artist. Five-year contracts at favorable terms are offered to those qualified. Write or cable direct to Personnel Manager, Dawlat Corporation Ltd., Patel Chambers, French Bridge, Bombay 7, India, giving experience, etc., in detail.

New film production unit to be located at Athens, Georgia, needs film editor-writer and film director. Experience in 16-mm as well as 35-mm production desirable. Southern background or interest in South preferred but not essential. Write giving full details of experience, etc., to Nicholas Read, The National Film Board, Ottawa, Canada.

POSITIONS WANTED

Projectionist-newsreel editor with 15 years' experience just released from service. Willing to locate anywhere. Write P. O. Box 152, Hampden Station, Baltimore 11, Maryland.

———

Honorably discharged veteran with 10 years' experience in projection and installation of projection and sound equipment, both for booth and back-stage. Prefer to locate in California, Oregon or Nevada. For additional details write F.A.N., Box 113, Holley, Oregon.

———

Cameraman, honorably discharged Army veteran, desires re-enter industrial, educational production with independent producer or studio. Experienced in 35- and 16-mm color and black-and-white. References and complete record of experience available. Write, wire or telephone T. J. Maloney, 406 Oak St., Ishpeming, Mich. Telephone 930.

We are grieved to announce the death of Robert M. Johnston, Associate member of the Society, on September 19, 1945, in Rock Falls, Illinois.

JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS

CONTENTS

AN APPRAISAL OF ILLUMINANTS FOR TELEVISION STUDIO LIGHTING*

R. E. FARNHAM**

Summary.—*The paper first outlines the requirements of an illuminant for television studio lighting, including data as to the illumination levels as well as the quality of the light necessary. Then follows a discussion of each of several possible sources, such as mercury vapor lamps, tungsten filament types, and fluorescent tubes. An appendix is included, giving tabular data as to the energy available in the ultraviolet, visible, and infrared regions.*

Thus, the paper makes possible an accurate judgment of the advantages and disadvantages of several illuminants adapted to this application.

In making an analysis of the various light sources applicable for television studio illumination, it is necessary to make certain general assumptions regarding the characteristics of the several elements in the light path. These are as follows:

(1) **Spectral Sensitivity of the Iconoscope.**—The light pickup surface of the iconoscope generally employs a caesium or modified caesium coating whose sensitivity to energy radiation is best illustrated in Fig. 1. It is interesting to note that the iconoscope sensitivity is practically the reverse of that of the eye, which has its peak in the yellow-green region (5500 A), thus color values will be badly distorted unless corrective means are taken. Deep reds and violets, ordinarily considered as the darker colors, tend to appear bright, while yellow and green go dark.

(2) **Requisite Illumination Levels.**—Based on tungsten illumination, approximately 1000 to 1200 ft-c, vertical surface illumination, are generally required. This presumes the television camera lens to be operating at its maximum satisfactory aperture (f 4.5).

---

(3)   **Reflection Characteristics of Televised Areas.**—Inasmuch as the quality of the television image is judged largely by the appearance of the faces, skin reflection characteristics constitute an important element in the effectiveness of a light source.

It is evident from Fig. 2 that in spite of a high iconoscope sensitivity in the violet and near-ultraviolet regions, an illuminant rich in violet and ultraviolet energy is going to be greatly reduced in its effectiveness when reflected from the faces of the actors. Dark clothes and properties may oftentimes be good reflectors of violet and ultraviolet energy with the result that faces may appear darker by comparison.
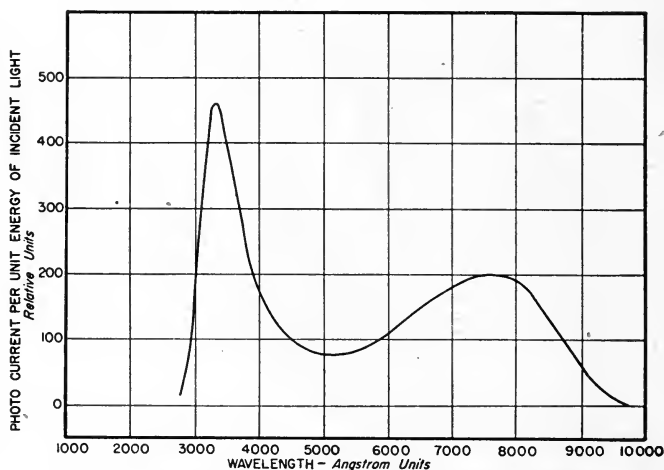
FIG. 1.   Spectral distribution of photoelectric surface.

On the other hand, the combination of the iconoscope's 7500 A sensitivity peak, the high reflectivity of skin, and the strong energy radiation from tungsten at 7500 A tends to accentuate the faces in the television image to the point of loss of detail. In other words, faces become chalky white when the attempt is made to show detail in the darker parts of the setting.

Other general factors affecting the choice of television illuminants are as follows:

Heat on the Set.—Experience gained in connection with motion picture studio lighting indicates that at 100–200 ft-c illumination from unfiltered tungsten sources, a noticeable though not uncomfortable warmth is felt. At 400–500 ft-c, the infrared radiation

produces a definite discomfort, particularly in prolonged scenes. At the 1000–1200-ft-c level necessary for television, the discomfort is immediate and means must be taken to reduce the volume of infrared radiation such as filtering or the set cooled by positive ventilation.

Electrical Interference.—The light output of electric discharge sources, such as mercury and some fluorescent lamps, follows the cyclic variation of the a-c supply quite closely. This 120-cycle light ripple has not in general been difficult to neutralize. The neutralization problem can be somewhat simplified by operation of these sources in groups of three, from a 3-phase supply, greatly re-
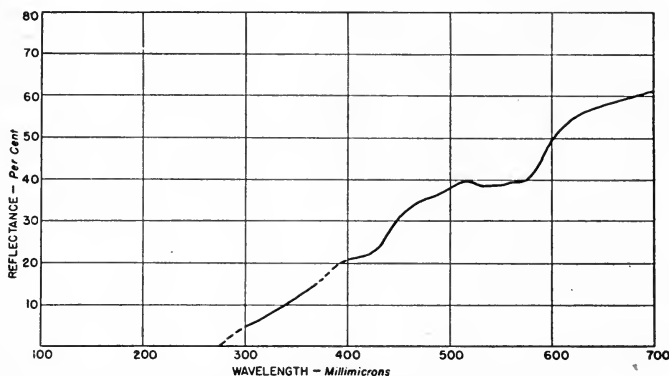
FIG. 2. Reflection factor of skin (upper forearm).

ducing the amount of ripple and increasing its frequency to 360 cycles.

Radio frequency impulses are sometimes produced in circuits supplying electric discharge lamps. These arise from a behavior of the arc stream or in the auxiliaries. Their elimination is completely and easily accomplished by suitable filters.

Operation on d-c is in many cases entirely practicable, in the event that a-c operation presents extreme difficulty.

Sources.—The following commercially available illuminants have been considered:

> Mercury
> 1000-w *AH-6* water-cooled lamp
> 3000-w *AH-9* lamp
> Tungsten filament lamps

Motion picture studio types
Reflector bulb types
Fluorescent lamps

Mercury Lamps.—The merits of the *AH-6* water-cooled lamp have given it a predominant position as a television light source. Its 65,000 lumen output makes it possible to obtain adequate illumination with relatively few lighting units. The water cooling necessary in the operation of the lamp possesses the additional feature of removing the greater part of the infrared or heat radiation, making it by far the most comfortable illuminant on the basis of equal foot-candles of
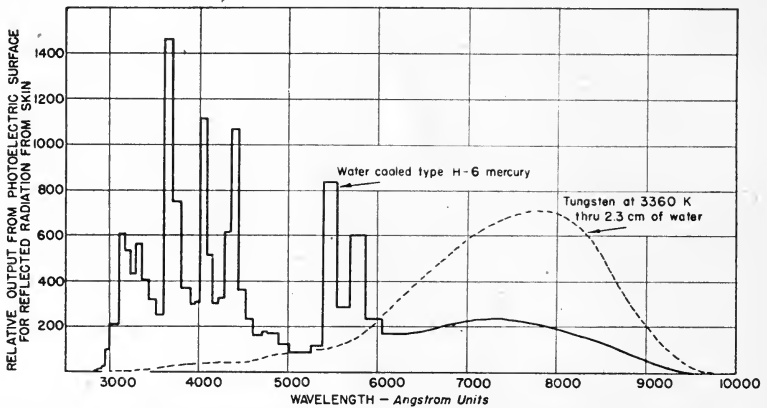
FIG. 3.   Theoretical iconoscope output, making allowance for skin reflection characteristics.

any of those considered. The heat from 1000 ft-c of *AH-6* light is hardly apparent.

Operating at an internal pressure of approximately 110 atmospheres, this source contains considerably more red in its spectrum than other mercury sources, taking some advantage of the caesium cell's peak at 7500 A and the high reflectivity of skin in this region. At the same time, the violets, blues, and even greens and yellows are adequately reproduced. These characteristics can best be suited by reference to the solid curve of Fig. 3, which gives the theoretical iconoscope output, making allowance for skin reflection characteristics.

The rated life of the *AH-6* lamp is 75 hr (for half-hour burning periods) with considerable spread in the life of individual lamps. This

may make necessary fairly frequent removals in a large installation operated for long periods. The multiplicity of water connections, particularly overhead, with the possibility of leakage, might be considered a further disadvantage. However, the water pressures employed are not high and experience has shown that, with frequent inspection, troubles from this cause are few.

A very complete discussion on the use of the *AH-6* lamp for television studio lighting has been given by Breeding.[1] The paper describes 3-lamp equipment adapted to remote control of light direction, as well as an installation of these units at television station WRGB at Schenectady. Operating data are also given.

The 3000-w *AH-9* mercury lamp has been considered as a source for television studio lighting, and a limited amount of test data have shown its practicability, particularly for lighting large areas. Its chief advantages are high light output, 120,000 lumens, and 2000 hr life. The spectral energy distribution of the *AH-9* is similar to that of the *AH-6*, except that there is a negligible amount of energy emitted beyond 6000 A. Thus that part of the solid line curve of Fig. 3 to the left of the 6000 A point may be used in analyzing the results obtained with the *AH-9* lamps.* Faces appear somewhat darker. Possibly the *AH-9* lamp might be used in combination with tungsten filament sources to obtain a better balance in the lighting results.

The *AH-9* emits approximately 13 per cent of its energy in the region beyond 7400 A as compared to less than half that from the *AH-6* lamp, making it noticeably warmer to work under. With the addition of sufficient unfiltered tungsten light to obtain a satisfactory image appearance, working conditions might approach definite discomfort.

Where 3-phase operation is necessary and three *AH-9*'s are grouped closely together, the total of 360,000 lumens may be greater than is desirable from a single unit, particularly if mounting heights are limited.

There are no fixtures available for the *AH-9* lamp specifically designed for television lighting service; however, the large trough reflectors developed for high bay lighting applications of the *AH-9* should be satisfactory with modification of the suspension arrangements.

---

* The 2 curves of Fig. 3 are based on 1000-w lamps. When applying the mercury curve to the *AH-9* lamp, the relative output values should be increased 50 per cent because of the lamp's greater wattage (and lower efficiency).

Tungsten Filament Lamps.—There are 2 general types of incandescent lamps applicable to television lighting—the high-wattage group of 1-, 2-, 5-, and 10-kw rating developed primarily for motion picture studio lighting, and the so-called "reflector bulb" types currently available in 150- and 300-w sizes.

Earlier television studio techniques were patterned after those of the motion picture studios, the television camera being substituted for the motion picture camera. High-wattage "spots" and "floods" similar to those of Hollywood were employed.

However, the necessity of changing smoothly from one setting to the next as the television program progresses made the use of these
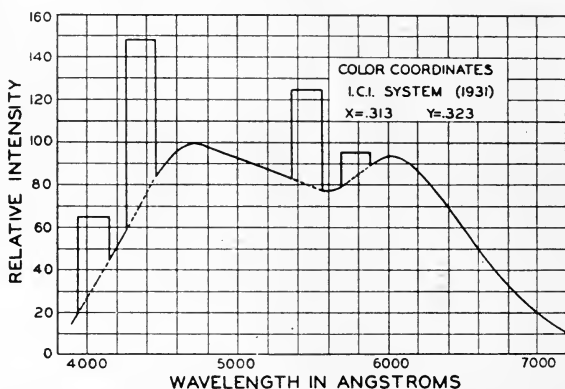
FIG. 4.   Spectral distribution of radiation from daylight
fluorescent lamp (6500 k).

large floor-mounted units impractical and makes desirable the use of lighting equipment suspended from overhead.   Hence, the more recent practice of using large numbers of reflector-type lamps.   As mentioned in the introductory remarks, unfiltered tungsten produces considerable discomfort to the personnel at the illumination levels required for most present-day pickup devices, and large numbers of reflector-type lamps are not well adapted to simple heat filtering methods.   The lens-type motion picture studio spots employing the 1-, 2-, and 5-kw lamps are much better adapted to the use of heat filters, particularly water cells, from 2 standpoints: (*1*) The fewer lighting units required, hence fewer filters, and (*2*) the 5-kw spot as used for motion picture studio lighting, for example, employs a 14-in. diameter lens, making possible a relatively small water filter

unit. It is therefore suggested that lighting equipment similar to that employed for motion picture studio lighting, using 2- and 5-kw lamps, and provided with proper suspension devices to permit them to be mounted overhead, be considered. Attention is directed to the dash-line curve of Fig. 3, which illustrates the theoretical response of the iconoscope to tungsten light after passing through a one-inch layer of water. The great reduction of infrared energy, particularly beyond 9000 A is to be noted.
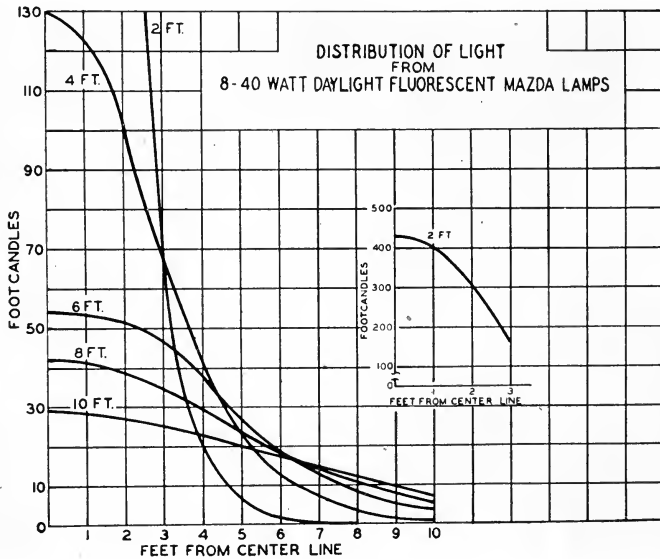
FIG. 5.

However, the weak response from yellow, green, blue, and violet (6000–4000 A) as previously mentioned is quite apparent, hence the suggestion that the tungsten light be combined with that from mercury sources for better rendition of faces and set properties in the television image.

Fluorescent Lamps.—From the standpoint of its spectral energy distribution, the daylight-type fluorescent lamp should be an excellent source for the illumination of television sets. Reference to Fig. 4 shows a well-balanced energy output throughout the visible spectrum resulting in a satisfactory reproduction of all colors, including flesh tones, and a minimum of radiant heat. (Refer also to Table 1 in the Appendix.)

The outstanding difficulty with fluorescent lamps is their relatively low light output per unit area so that it is difficult to obtain the requisite light levels, even if the studio were literally papered with lamps.

This is borne out by reference to Fig. 5 which shows the illumination at different distances in front of a bank of eight 40-w daylight lamps. Even if the bank is extended sidewise as well as vertically, the illumination at 6 ft, for example, in front of the lamps cannot be made to exceed approximately 350 ft-c. Substitution of larger lamps

Fig. 6.   A television studio (WRGB) employing water-cooled mercury lamps, for both overhead and floor lighting equipment.   Each unit contains 3 lamps operating on a 3-phase circuit.

(100 w, 60 in.) will not appreciably alter this value inasmuch as the larger lamps operate at a light output per unit area of the same order of magnitude as the 40-w size.

While future developments in fluorescent sources may make available lamps of somewhat higher brightness, there is nothing at present that would indicate the attainment of 1200 ft-c at 6 ft. The general use of fluorescent lamps for television studios will have to await the adoption of much more sensitive pickup devices.

REFERENCES

[1] BREEDING, H. A.: "Mercury Lighting for Television Studios," *Proc. I.R.E.,* **31,** 3 (Mar., 1943), p. 106.

Appendix

TABLE 1

Energy Distribution of Possible Television Sources
(Data given in per cent of input watts)

(A)

Source	3165–3800 A Near UV.	3800–5000 A Violet Blue	5000–7600 A Green Yellow Red	7600–14,000 A Near Infrared	14,000–26,000 A Infrared (Heat)
AH-6 Mercury	5.3	12.1	11.5	6.1	0
AH-9 Mercury	3.0	4.6	7.6	6.1	6.7
Tungsten 3350 K	...	2.5	14.9	22* (40.0)	0* (31.0)
Daylight Fluor. (40 w)	0.32	6.7	10.6	0.47	...

* Based on use of water filters. Values in parentheses are without the filter.

(B)

The removal of heat from light can be accomplished in 2 ways: (*1*) the use of glass heat-absorbing filters, such as Aklo glass, and (*2*) water cells.

A typical Aklo filter will absorb 80 per cent of the radiant heat and 25 per cent of the light, thus giving definite benefit but requiring an appreciable increase in lamp wattage. The energy absorbed by the filter is radiated into the room making it necessary that the air conditioning system handle the entire lamp wattage in addition to its usual load.

In the case of the *AH-6* lamp, more than 50 per cent of the lamp's wattage is conducted out of the studio by its water-cooling arrangement. A water cell placed in front of the lens of an incandescent spot will absorb approximately 75 per cent of the infrared energy in the beam. This may amount to 15 per cent of the total lamp wattage and is conducted out of the studio, thereby lessening the load on the air-cooling equipment.

(C)

The grid of fluorescent lamps used to obtain the data of Fig. 5 employed 5-in. wide Alzak finish aluminum reflectors. Their contour was such as to give a slightly directional pattern to the light distribution.

The bank of lamps was 40 in. wide and 48 in. high. The starting point of the light measurements was at the center of the bank vertically as well as horizontally, and the meter moved in a direction parallel to the plane of the lamps at the distance indicated.

Assume 9 similar banks arranged in 3 rows of 3 each. With the meter 6 ft in front of the center of the middle bank, the curves of Fig. 5 will show the following foot-candles to be received from each of the 9 banks of lamps:

Center bank	54 ft-c
Left and right banks with centers	$\begin{cases} 45 \text{ ft-c} \\ 45 \text{ ft-c} \end{cases}$
40 in. to right and left	
Top and bottom banks with centers	$\begin{cases} 38 \text{ ft-c} \\ 38 \text{ ft-c} \end{cases}$
48 in. above and below	
Four corner banks with centers	26 ft-c
$62^1/_2$ in. away	26 ft-c
	26 ft-c
	26 ft-c
Estimated from lamps outside the above group	26 ft-c
	350 ft-c

CARBON ARCS FOR MOTION PICTURE AND TELEVISION STUDIO LIGHTING*

F. T. BOWDITCH,** M. R. NULL,** R. J. ZAVESKY†

Summary.—Photometric and spectral energy distribution data are given for typical carbon arc light sources used extensively in motion picture studio lighting. The balanced color quality and low infrared content which make these sources valuable in motion picture photography are reviewed from the standpoint of the requirements of television studio lighting. The conclusion is reached that as television expands to justify adequate studio facilities, the carbon arc should find a place similar to that which it now holds in the motion picture studio.

The motion picture industry utilizes carbon arcs not only as the light source for the projection of film in theaters but also for the illumination of sets during the filming of the picture. The types and applications of carbon arc units for studio lighting have been described previously before this Society.[1] The various spotlights and floodlights have been developed[2,3,4] as the industry grew, to meet special requirements for color, steadiness, light intensity, and freedom from noise. When sound was introduced in the industry there were noise problems which were solved by designing carbons, lamps, and associated equipment to operate quietly. Also, the advent of color in motion pictures made it necessary to use increased light intensities and to have light of the proper spectral quality. These needs were met by improved carbon arc units.

Now that television is assuming greater commercial importance, problems associated with the lighting of television sets will demand increased attention. As these sets become more elaborate and the photographic values become subject to more critical review, it seems probable that carbon arc studio lighting will find advantageous application here for much the same reasons that now give it an important place in the motion picture studio. The purpose of this paper is to describe the operating and radiant energy characteristics of

---

typical carbon arc flood and spot lamps which appear to offer worth-
while advantages in television studio usage, as they do now in mo-
tion picture studios.

Motion Picture Studio Floodlight.—The *M-R* type *40* Duarc
lamp[3,4] illustrated in Fig. 1 is an example of a carbon arc flood lamp
in common use in motion picture studios.   Lamps of this type op-
erate quietly and automatically.   They are equipped to burn 2 arcs
simultaneously, each with an 8-mm $\times$ 12-in. M. P. Studio positive
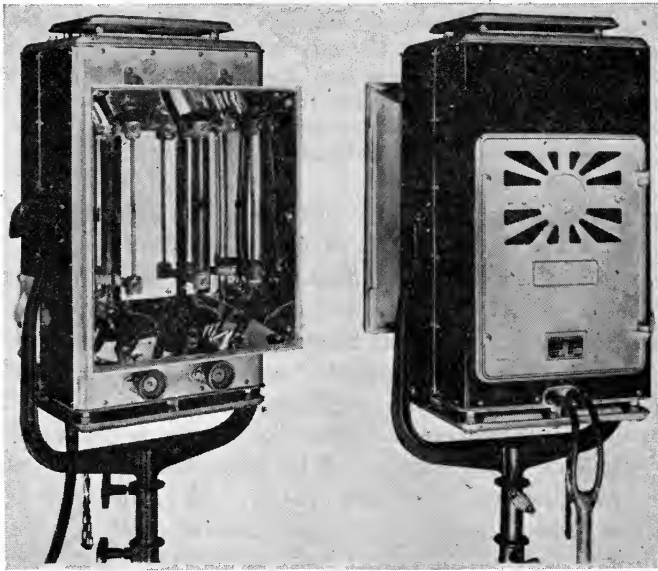
FIG. 1.   *M-R* type *40* Duarc lamp.

and a 7-mm $\times$ 9-in. M. P. Studio negative carbon.   The 2 arcs are
in series and are operated at 40 amp d-c with approximately 37 v
across each arc.   The necessary ballast is incorporated within the
housing, so that the unit need only be connected to a standard 110-
v, d-c power line, to be ready for completely automatic operation.
About 2 hr burning time is afforded by the 2 pairs of carbons.

Fixed reflectors and a diffusing glass comprise the optical system
used with the carbon arcs in this lamp, giving a spread beam which is
used a great deal for general illumination in motion picture studios.

The illumination characteristics of this flood lamp are depicted[5] in Fig. 2. For purposes of illustration the light data are reported for distances of 7 ft and 14 ft from the lamp. A peak value of 700 ft-c is obtained at 7 ft and a peak intensity of 165 ft-c at 14 ft. These peak intensities are obtained at the center of the beam; values for the other portions of the beam are as shown in Fig. 2.

Motion Picture Studio Spotlight.—A typical example of a carbon arc spot lamp in common use in motion picture studios is the *M-R*
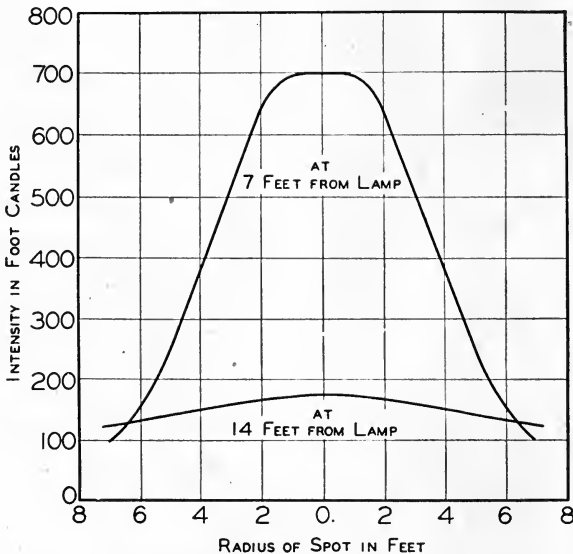
FIG. 2. Horizontal distribution of light intensity for *M-R* type *40* Duarc lamp.

type *170* lamp illustrated in Fig. 3. In this lamp 16-mm M. P. Studio positive and $1/2$-in. copper-coated M. P. Studio negative carbons are burned at approximately 150 amp d-c. Units such as these are semiautomatic in operation and provide a burning time of the order of $1^1/_2$ hr with one pair of carbons.

The studio spot lamps are equipped to give beams of different divergence by adjusting the position of a lens with respect to the light source. A 20-in. diameter Fresnel lens is used for the type *170* lamp. The sketch in Fig. 4 illustrates the simple action of this system. The full lines in this sketch represent the lens position, the angle of light pickup and the beam divergence for maximum spread. By

moving the lens farther away from the positive carbon crater a less divergent beam is obtained; the position of minimum divergence is shown in the sketch by the broken lines.

The distribution of light intensity in the beam of the *M-R* type *170*
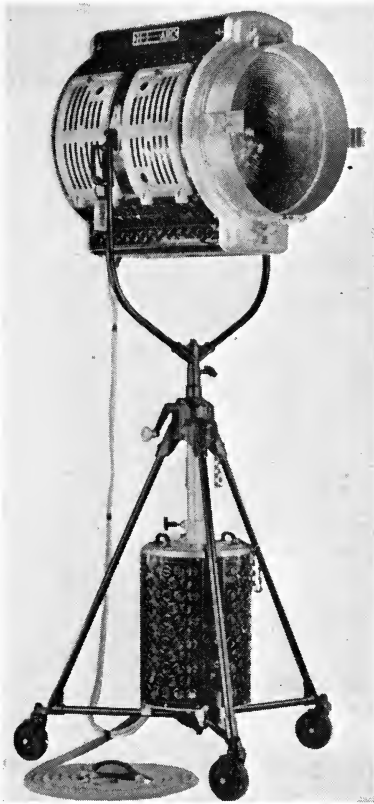
FIG. 3.   *M-R* type *170* lamp.

lamp is shown[6] in Figs. 5, 6, and 7. Fig. 5 shows the light distribution at 25 ft from the lamp for lens adjustments producing 24-, 32-, and 48-deg beams. Figs. 6 and 7 show data at 50 and 75 ft, respectively. It is evident from these figures that the wide range of intensities and distributions obtainable provides a versatile source of illumination for sets of various sizes and for special lighting effects.

Spectral Sensitivity Considerations.—One of the most important characteristics of a source for studio lighting is the spectral distribution of the radiant energy in the beam. Motion picture film and television pickup tubes respond only to radiation of certain wavelengths. Radiation of other wavelengths falling on the set serves no useful purpose and is in fact a definite nuisance, since it is absorbed as heat by all objects which

it strikes.   Further, the relative spectral intensity of the source within the wavelength region to which the receiving device is sensitive is of importance in determining image densities with black-and-white recording, or a proper balance of colors if color reproduction is desired.   For these reasons, the spectral energy distribution curves of Fig. 8 are of particular interest.

The color quality of the radiation of the type *40* Duarc has been

found to be quite satisfactory, either alone or mixed with sunlight, in producing a proper color balance with Technicolor photography.
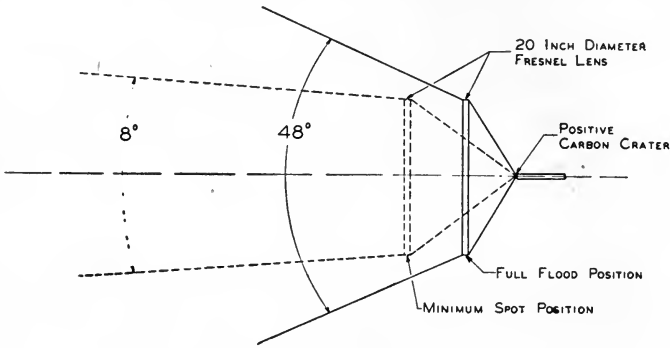
FIG. 4.   Optical system of *M-R* type *170* lamp.

The direct radiation of the type *170* lamp, while very satisfactory for black and white, has been found relatively too intense in the blue and near ultraviolet when used with color, so that it is custo-
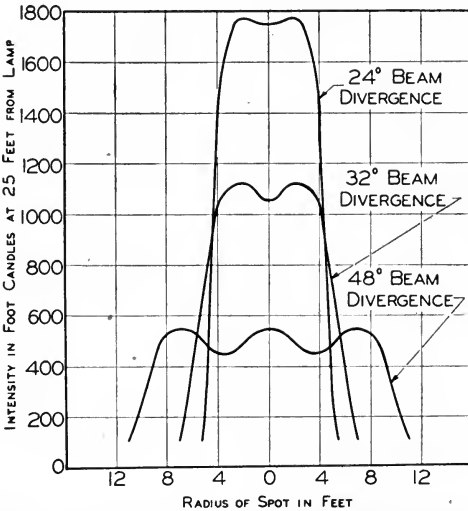
FIG. 5.   Horizontal distribution of light intensity
for *M-R* type *170* lamp (intensity at 25 ft).

marily modified by the use of a yellow filter, placed over the front of the lamp, to produce a color quality almost identical with that of the type *40* Duarc.

The infrared radiation from these sources has been measured by means of a series of filters[7] isolating particular wavelength regions of interest. These data are given in Table 1.

<center>TABLE 1</center>

<center><i>Distribution of Radiant Energy at the Center of the Beam</i></center>

	Percentage of Total in Each Wave Band				
Lamp	$0.34-$ $0.40\,\mu$	$0.40-$ $0.70\,\mu$	$0.70-$ $1.125\,\mu$	$1.125-$ $4.20\,\mu$	$4.20-$ $12.0\,\mu$
Flood M-R-40	4	34	21	34	8
Spot M-R-170	4	36	28	31	1

For purposes of seeing, only the energy of wavelengths between 0.40 and 0.70 μ is of any significant value. All the rest, approximately 65 per cent of the total in this case, is endured for the sake of the useful portion. A similar situation holds with all sources, and the
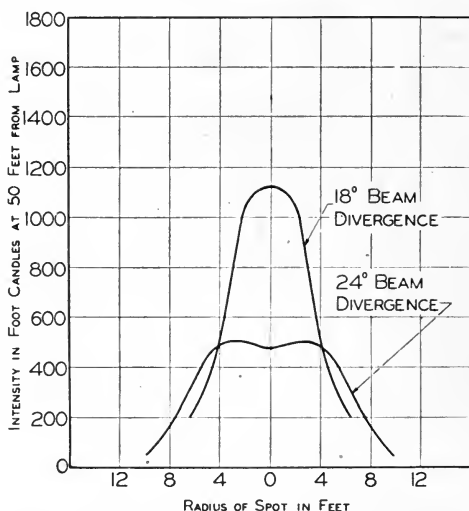
FIG. 6.   Horizontal distribution of light intensity for M-R type *170* lamp (intensity at 50 ft).

ratio indicated for these arcs is typical of a comparatively cool source as commercial units go. This will become apparent from the discussion to follow.

In motion picture photography and in the television studio, the primary purpose of the light source is not to provide good vision, but to stimulate photochemical reactions on film in the first case and the
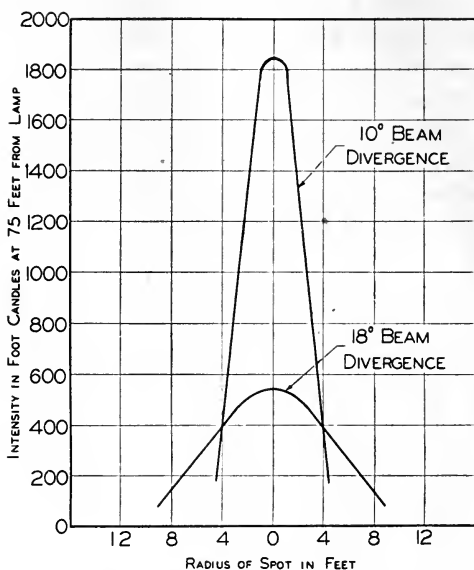
FIG. 7.   Horizontal distribution of light intensity
for *M-R* type *170* lamp (intensity at 75 ft).
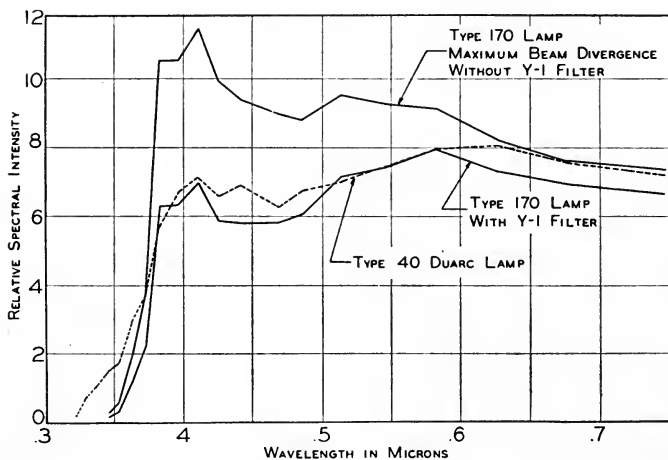
FIG. 8.   Spectral energy distribution of studio light sources.

photoelectric response of the mosaic of the pickup tube in the other. The spectral response of film and of the mosaic are thus the proper measures of light effectiveness, rather than the lumen or foot-candle. The photoeffectiveness of carbon arc sources with motion picture film has previously been discussed before this Society.[8] It is our purpose here to examine in similar fashion the application of carbon arc sources to television studio lighting, in order to obtain some indication of their possible utility in this field.
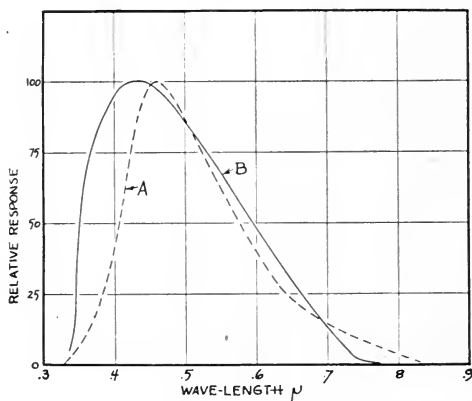
FIG. 9. Approximate spectral sensitivity of the Iconoscope: A—Combined response of the Iconoscope with a light source consisting of a 100-w projection lamp and a Wratten No. 78-AA filter; B—Relative spectral sensitivity of the Iconoscope surface alone.

As a prerequisite to such a consideration, some measure of the spectral sensitivity of the television pickup device is required. This information is shown by the curves of Fig. 9, which give an approximate specification of the spectral sensitivity of the Iconoscope mosaic widely used in present-day television pickup cameras and occupying a position exactly analogous to that of the photographic film in the more conventional camera.

Curve A of Fig. 9 reproduces the relative spectral response characteristic as published by the manufacturer "for an average Iconoscope when used with a light source consisting of a 100-w projection lamp operated at rated voltage, with a Wratten filter No. 78AA to approximate a source at 5500 K within the visible range."[9] Curve B of Fig. 9 has been calculated from the transmission characteristics

of the filter and the spectral emissivity of the source to give the relative spectral sensitivity of the Iconoscope mosaic itself. This latter curve has then served as the basis for the calculations now to be described.
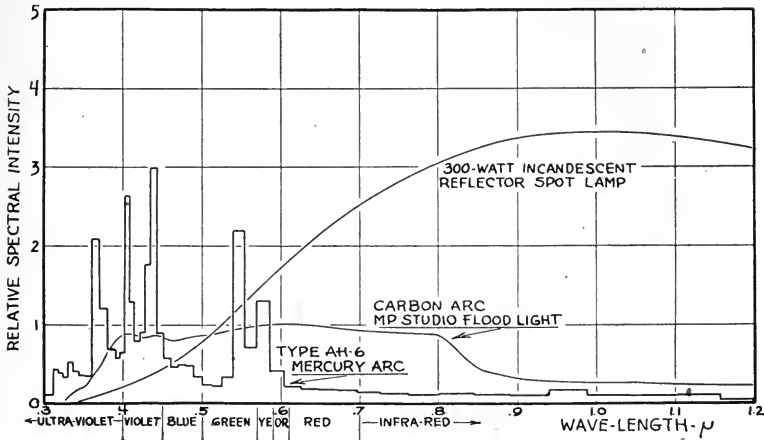
FIG. 10.　Comparative spectral intensities of light sources producing the same Iconoscope response, Pt. 1.
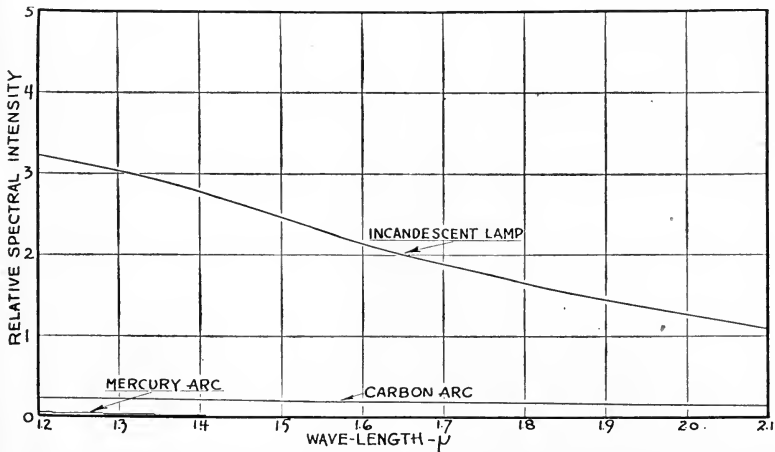
FIG. 11.　Comparative spectral intensities of light sources producing the same Iconoscope response, Pt. 2.

Given the spectral sensitivity of the Iconoscope and the spectral intensity of a light source directed upon it, the product of the two, wavelength by wavelength, gives a measure of Iconoscope response

to direct radiation of this quality. Since reflected rather than direct light from the source reaches the Iconoscope in practical use, it is perhaps more logical to view such a product as the Iconoscope response to radiation reflected from a pure white object, (*i.e.*, one having the same reflectivity at all wavelengths) when illuminated by the source under evaluation. In this present study, such calculations have been made for 3 sources commonly considered for television studio lighting: (*a*) the incandescent tungsten reflector spot lamp, perhaps the one most widely used in present-day experimental television studios, (*b*) the type *AH-6* water-cooled capillary mercury arc[10] and (*c*) the carbon arc motion picture studio flood lamp previously described in this paper. Spectral intensity data for the first 2 sources were obtained through the courtesy of W. E. Forsythe and B. T. Barnes of the Lamp Development Laboratory, General Electric Company, Nela Park, Cleveland, Ohio.

Iconoscope response curves have been calculated for each of these 3 sources, the ordinate at each wavelength being the product of the corresponding radiant energy and Iconoscope response. The areas under the 3 curves, proportional to the total Iconoscope response in each case, were then determined, and a suitable factor chosen for adjusting the intensity of each source, so that all 3 would produce the identical Iconoscope response. Figs. 10 and 11 show a comparison between the spectral intensities of the 3 sources after these factors have been applied to the original spectral energy distribution curves.

These curves are a measure in each case of the spectral intensity of the radiation falling on a white object to produce a given Iconoscope response. Along with the useful radiation within the sensitivity limits indicated by Fig. 9, the curves of Figs. 10 and 11, particularly the latter, show the accompanying infrared energy, which is altogether useless. Since the area under the entire spectral energy distribution curve is a measure of the total radiant energy in each case, the reason for the considerable heat under high-intensity incandescent illumination is quite apparent. If this energy be made the basis of comparison at 100 per cent, then that of the carbon arc is 17.6 per cent and that of the mercury arc only 7.7 per cent, all giving the same total Iconoscope response.

The energy advantage indicated for the mercury arc largely results from the fact that it is water-cooled, about 60 per cent of the total radiant energy[10] being carried off by the water. Similarly, a water-cell filter could be mounted in the beam from the carbon arc to remove

approximately 50 per cent of the total radiant energy and so bring this
source to approximate equivalence with the mercury so far as maxi-
mum Iconoscope response per unit of radiant energy is concerned.
With the incandescent spot lamp, the water cell would remove approx-
imately 60 per cent of the total energy and so still leave this source
about 5 times hotter than the carbon and mercury arcs.

Color Response.—The discussion so far has been concerned alto-
gether with the achievement of maximum Iconoscope response per
unit of radiant energy, without regard to color rendition.   How-
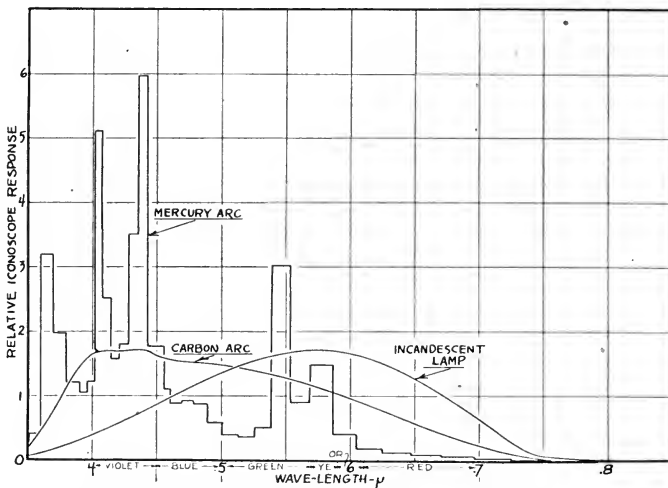
FIG. 12.   Color response of Iconoscope, light source combinations
adjusted to the same total response.

ever, in practice, this cannot be ignored, as reference to the curves
of Fig. 12 will show.   These curves portray the color response of the
Iconoscope with each of the 3 light sources under discussion, the
response at each wavelength ordinate being the product of the
Iconoscope sensitivity and the spectral intensity of the source at that
wavelength.   The curve for the incandescent spot lamp shows a
maximum response to green, orange, yellow, and red colors of wave-
lengths from 0.5 to 0.65 μ and a significant response to reflections in
the near infrared, of wavelengths beyond 0.7 μ.   In contrast, violet
and blue are less effectively reproduced than are the other colors.
Since, as with black-and-white motion picture photography, these
responses can only be effective in determining contrasts in a mono-

chromatic image, the blues will appear unnaturally dark, the oranges, yellows, and reds too bright, and objects which are good infrared reflectors will assume a brightness to which the eye would not have responded at all in the original scene. Similarly, with the mercury arc, unnatural brightnesses of objects which reflect ultraviolet and violet are produced, with low responses in the blue-green, and particularly in the yellow and red. Responses with the carbon arc are somewhat more uniform, although showing a significant response to the near ultraviolet and a lower red as compared with the green and blue responses.
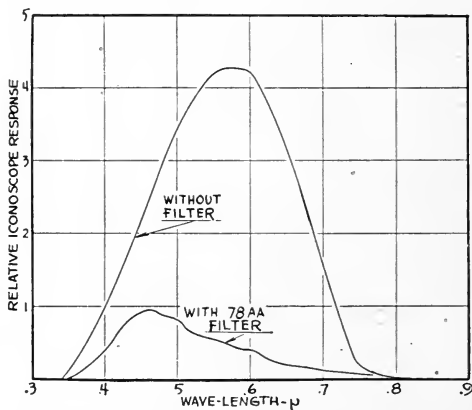
FIG. 13. Iconoscope response with incandescent tungsten lighting with and without color-correcting Wratten 78-AA filter.

Distortions of this character require correction in practical usage in order to achieve natural density gradations in monochrome, or more importantly, if a color process is to be satisfied. With present-day monochromatic television, a type 78-AA Wratten filter is sometimes employed with incandescent lighting to give more natural contrasts. The use of such a filter greatly reduces the Iconoscope response, as the curves of Fig. 13 indicate.

In this figure, the upper curve showing the color response for the incandescent source without filter is identical with that shown on Fig. 12, expanded vertically to illustrate better the loss encountered when the filter is employed. The lower curve of Fig. 13 shows the Iconoscope response with the No. 78-AA Wratten filter and the same source. The total Iconoscope response has fallen to one-sixth its

former value, requiring that 6 times the intensity of incandescent lighting be applied to recover the loss in sensitivity introduced by the use of the filter.

Thus, the necessary use of color-correcting filters can have a very profound effect on the radiant energy requirements for a television set, and calculations such as have been reported here can only be regarded as indicative of experimental possibilities. However, if the better color response with carbon arc lighting suggested by Fig. 12 indicates a correspondingly lower loss in correcting filters, then, in the final analysis, the relative efficiency and comfort of carbon arc lighting should be significantly greater than that previously indicated in this paper. And, as the television industry grows to demand more elaborate stage settings and to achieve a higher quality of photographic reproduction, the carbon arc should come to occupy an important position in television just as it now holds in the motion picture studio.

REFERENCES

[1] LINDERMAN, R. G., HANDLEY, C. W., AND RODGERS, A.: "Illumination in Motion Picture Production," *J. Soc. Mot. Pict. Eng.*, **XL,** 6 (June, 1943), p. 333.

[2] RICHARDSON, E. C.: "Recent Developments in High-Intensity Arc Spot Lamps for Motion Picture Production," *J. Soc. Mot. Pict. Eng.*, **XXVIII,** 2 (Feb., 1937), p. 206.

[3] MOLE, P.: "The Evolution of Arc Broadside Lighting Equipment," *J. Soc. Mot. Pict. Eng.*, **XXXII,** 4 (Apr., 1939), p. 398.

[4] JOY, D. B., LOZIER, W. W., AND ZAVESKY, R. J.: "Recent Improvements in Carbons for Motion Picture Studio Arc Lighting," *J. Soc. Mot. Pict. Eng.*, **XXXIII,** 4 (Oct., 1939), p. 373.

[5] Private communication from Mole-Richardson Co.

[6] Data calculated from Reference[2] above.

[7] COBLENTZ, W. W., DORCAS, M. J., AND HUGHES, C. W.: "Radiometric Measurements on the Carbon Arc and Other Light Sources Used in Phototherapy," *Scient. Papers of the Bur. of Stand.*, **21,539** (Nov., 1926), p. 535.

[8] BOWDITCH, F. T., AND DOWNES, A. C.: "The Photographic Effectiveness of Carbon Arc Studio Light Sources," *J. Soc. Mot. Pict. Eng.*, **XXV,** 5 (Nov., 1935), p. 375.

[9] RCA VICTOR DIVISION, RADIO CORPORATION OF AMERICA: "RCA 1846 Iconoscope," *Descriptive Bulletin 1846-3-46*.

[10] BREEDING, H. A.: "Mercury Lighting for Television Studios," *Proc. I.R.E.*, **31,** 3 (Mar., 1943), p. 106.

AN IMPROVED FILM-DRIVE FILTER MECHANISM*

C. C. DAVIS**

Summary.—*The basic problem of providing constant speed past the scanning point in film machines is briefly reviewed. Two associated types of relatively simple film-drive filters are described. Both are based on the use of controlled compliance which promotes greater freedom from film and mechanical conditions. A new film sprocket is described which reduces the number of sprockets required per machine.*

It has long been recognized that speed variations seriously degrade the finest sound recordings. The harshness caused by high-frequency flutter and the "wows" caused by low-frequency flutter are well known. Less obvious perhaps is the fact that the selective nature of flutter with respect to the ear and to the program material may result in degradation without the appearance of flutter of appreciable magnitude. The public is fortunate that the motion picture industry has shown a continuing tendency toward more strict requirements for the performance of film propulsion equipment. Much has been written on the subject of flutter, frequency modulation, or constancy of speed,[1,2] and the various mechanical filter devices built into recorders and reproducers have been analyzed in detail.[2-5] These analyses are generally made by converting the mechanical circuit into the equivalent electrical circuit since the theory of electrical wave filters is more familiar. Such analogies constitute a useful tool in the development and study of mechanical filters and will be used here to illustrate their functions. Since the solutions of such circuits appear in reference books they will be omitted.

Review of Smooth Drum Filters.—It is believed a description of the new equipment as well as a basis of comparison will be assisted by a brief consideration of the general type of film filter most commonly used at present. In earlier machines it was natural to copy the method of picture projection and record or reproduce on, or adjacent to, a film sprocket. Although a filter was included it

---

was ineffective against the large amount of flutter generated by sprocket and film pitch mismatch, so it was soon recognized this method had severe limitations. While it is necessary to synchronize a motion picture frame precisely with the adjoining sprocket holes, slightly more latitude is permissible in the case of the sound track. Thus the way was opened to ignore the sprocket holes at the translation point and build a somewhat independent filter device as a sort of machine within a machine devoted to maintaining constant film velocity without regard to the instantaneous velocity of the remainder of the machine.

In reviewing the principles used in film machines such as the comprehensive reviews of Albersheim and MacKenzie[2] and Kellogg,[4] it is apparent more recent machines depend for their flutter attenuation upon the ability of a flywheel to revolve at constant velocity. This principle is utilized by rotating the flywheel by means of the film itself running as a belt over a smooth drum rigidly attached to the flywheel and with sufficient freedom or compliance introduced in the incoming and outgoing film paths to permit the flywheel to assume constant velocity. Nonuniformities of rotational motion in the driving mechanism are absorbed in the compliance of the film path, preventing them from altering the constant velocity of the massive flywheel. Damping must be included in such a combination to prevent continued oscillation or "hunting" of the flywheel which will inevitably result from the use of a free-running wheel compliantly driven.

This smooth drum and flywheel filter arrangement, therefore, contains 3 basic elements: a flywheel and drum combination, an elastic or compliant loop of film, and a damping device. These are analogous, respectively, to an inductance, a condenser, and a resistor and are arranged in the form of an electrical low-pass filter passing low frequencies or essentially d-c components only. Theoretically these 3 basic elements are sufficient to meet the most exacting flutter requirements, since all that is necessary to obtain unlimited filtering is to establish a sufficiently low cutoff frequency which will be referred to as the frequency at which attenuation starts. Actually a filter combination composed of a flywheel of small enough proportions to satisfy starting requirements, combined with a comparably large enough compliance to filter the lowest flutter frequencies occurring in the usual driving source, requires careful design consideration. Difficulty lies not in the fact that there are only 3 elements but rather in improper

physical values and particularly in mechanical imperfections, since flutter may be generated by rotational discrepancies such as occur in ball bearings, within the filter parts themselves. Furthermore, if the film does not travel precisely with the drum, momentarily borrowing the motion of the flywheel, the relative motion between the two not only results in flutter but may also permit the sound track to weave.

The compliance element or elastance introduced between the driving sprocket and drum has in general been provided by the nature of the film itself in the form of S-shaped loops.[2, 3] Thus if the loading tension of the film loop is light, the S-shaped bend caused by the film reaction against wrapping around the drum and sprocket in reverse directions, offers a relatively large value of compliance. This is the type of compliance used in many machines because of its simplicity. However, it offers no facilities for the introduction of damping, the alternative being to damp the rotating flywheel directly; but direct flywheel damping of sufficient magnitude to control oscillations results in more constant d-c drag than the film will tolerate. Therefore, direct flywheel damping is applied from a member rotating at approximately flywheel velocity to provide incremental damping without steady state drag. This rotating member may consist of a gear-driven auxiliary drive,[4] or an auxiliary flywheel known as a kinetic scanner or rotary stabilizer.[2, 3] A refinement of the latter type has been developed by Wente and Müller.[5] Thus the usual practice has been to drive the drum simply by an S-shaped loop while damping was applied to the rotating flywheel by a relatively complicated mechanical arrangement.

General Description of New Type of Filter.—The objective in the development of the general design described in this paper was to combine the proved features of former equipment with new features which would prevent the occurrence of troubles, the existence of which has been demonstated by previous experience. The inherent advantages of the smooth drum and flywheel are maintained but it differs in other respects to a considerable extent. It consists of the combination of a relatively simple flywheel driven by deliberately tensioned film with damping applied to the tensioning device. This combination fulfills 4 desirable requirements for good design:

(a) Optimum bearing conditions of rotational parts,
(b) Application of damping to a nonrotating element,

(*c*) A value of compliance largely independent of the varying quality or bent condition of the film,[2]

(*d*) Firm contact between film and drum.

Problems in the utilization of considerable film tension without a corresponding reduction in loop compliance have been overcome by the design of units which produce low cutoff frequencies with flywheels of reasonable size. The drum and flywheel are propelled by film which is deflected from a straight path by a spring-tensioned idler arm and roller with which a damper is associated. This tensioned path of film
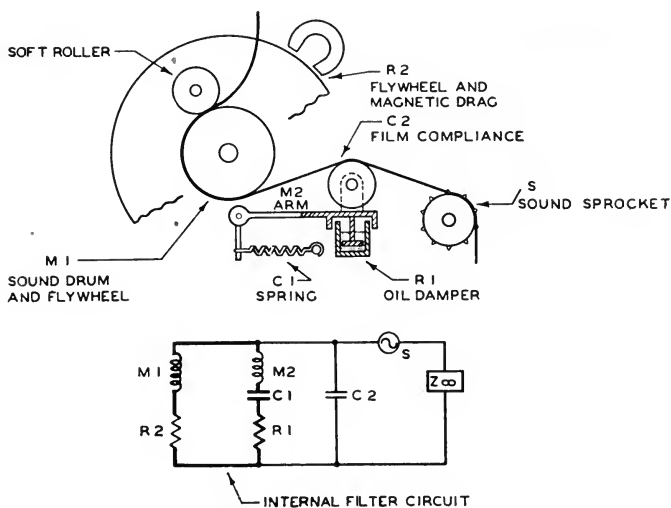
FIG. 1.   Single-arm filter.

together with the idler arm and roller constitutes a compliance as in the case of the *S*-shaped loop and will be referred to as a film loop although the two appear considerably different.

Since substantially equal amounts of tension in some form must exist at either side of the translation point, tension must be introduced to offset that of the lower film loop. Two methods have been developed to accomplish this for 2 different types of application. The first type utilizes the eddy current drag created by the use of permanent magnets mounted near the flywheel periphery. This will be referred to as the single-arm type. The second type utilizes an idler arm and roller on the incoming film loop similar to that in the outgoing film loop. This will be referred to as the double-arm type.

Thus, in either type the flywheel and drum are rotated by a tensioned lower film loop which deflects an arm into normal operating position at normal film speed. Discrepancies in velocity introduced into the film by the driving sprocket tend to deflect the relatively light and compliant arm from normal position rather than introduce flutter into the relatively massive flywheel. Any tendency to oscillate, which would appear as an up and down motion of the arm accompanied by an acceleration and deceleration of the flywheel, is damped by the dashpot associated with the arm.
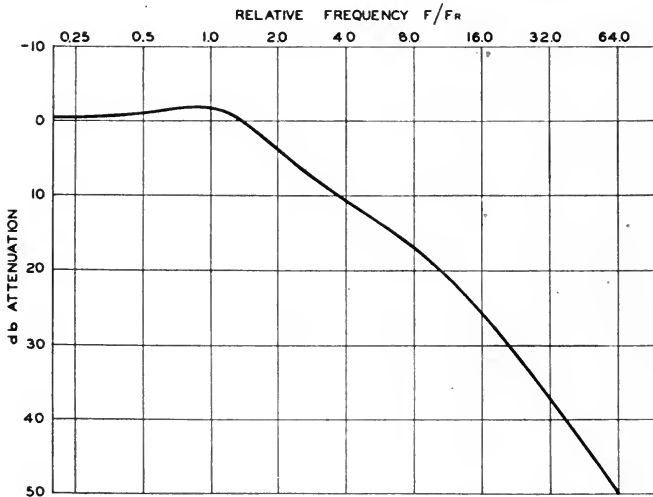
Fig. 2.   Attenuation characteristic of single-arm filter.

Single-Arm Type.—The mechanical schematic of the single-arm type is shown in Fig. 1. This type, using magnetic drag, produces a completely slack or free upper film loop because of the pressure roller which holds the incoming film against the drum. Since a free upper loop isolates the drum from disturbances occurring in the incoming film, this type is particularly applicable to theater reproducers because of the isolation it provides from disturbances in the projector head.

The analogy of the filter circuit shown in Fig. 1 consists of a shunt path containing the flywheel and drag and a second shunt path containing the arm and damper in parallel with the film compliance. The 2 shunt paths are fed in parallel by a sprocket or generator.

Minor elements which produce no appreciable effect on the attenuation characteristic are omitted. The a-c attenuation is equal to the ratio of the disturbing velocity to that reaching the flywheel, or the ratio of current through the generator to the current through the shunt path containing the flywheel. The sprocket is shown as an infinite impedance or constant current generator since it is not af-
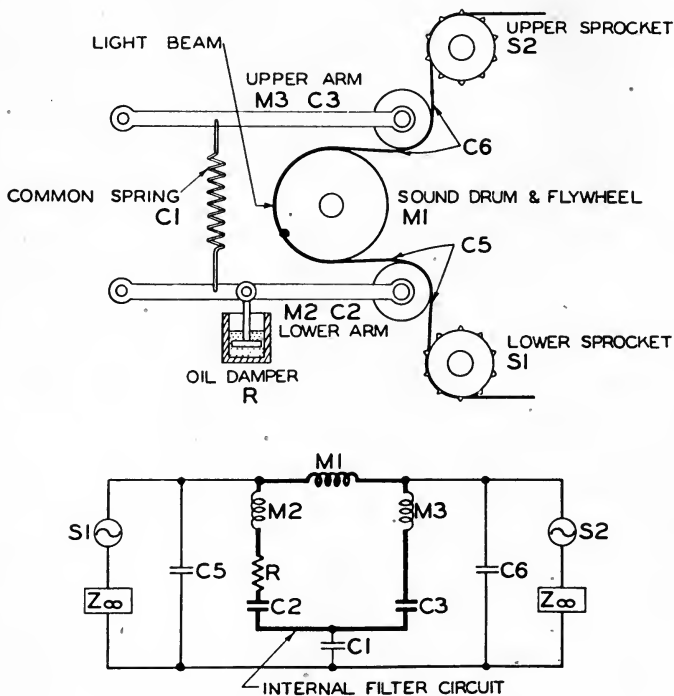
FIG. 3. Double-arm filter.

fected by occurrences in the filter. The magnetic drag R_2 is only of sufficient magnitude to produce the desired d-c film tension and affords no appreciable damping. The mass of the filter arm M_2 has but slight effect on the filter characteristic owing to the limiting effect of R_1. The film compliance C_2 results from the small bends at points of contact with the tensioned film loop and is much smaller than the compliance of the arm C_1.

Fig. 2 shows an attenuation curve for the circuit of Fig. 1. The attenuation of $2:1$ or 6 db per octave which results from the fixed

value of R_1 combined with an increase of 6 db per octave in the reactance of M_1, increases to 12 db per octave at higher frequencies when the reactance of C_2 becomes less than R_1. This fact is not particularly important since experience shows the flywheel mass is sufficient in any event to take care of high-frequency flutter and that most troublesome flutter frequencies are those occurring in the region where filtering is least and where the ear is most sensitive to flutter. Typical curves show the latter to be in the neighborhood of 2 cycles.[2] Therefore, the cutoff frequency and the shape of the filter curve in the vicinity of this frequency are of primary importance. The general characteristic of the present filter is desirable in that the resonant rise is less than 2 db and a low cutoff frequency is provided.

Double-Arm Type.—In Fig. 3 is shown the double-arm or alternative method of applying the damped compliance flywheel drive. It differs from the previous type in that the magnetic drag and pressure pad roller are replaced by an idler arm and plain roller similar to that used in the lower film loop. This makes possible a single unit containing the arms and damper which perform all the functions necessary to drive the drum and flywheel by straightforward belt action. The elimination of the magnetic drag and the pressure pad roller is desirable from a standpoint of simplification and of more convenient and readily controlled operating conditions. Since the operating parts consist of plain rollers and a simple flywheel assembly, desirable conditions for film propulsion without contact with the sound or picture emulsion, and without weaving or danger of runoff, are inherent in the design.

The practical application of the double-tensioned loop drive depends upon a design which supplies the relatively large amount of film tension best suited for flywheel starting and driving while at the same time supplying the amount of loop compliance necessary for a low cutoff frequency. The loops are not tensioned independently but by a differential action, through a single linking or common spring. Tensioning is done by the arms whose reaction to flywheel motion is to move the spring supports in the same direction, thus avoiding a proportionate change in the length of the spring. The only reactance opposing flywheel motion is that resulting indirectly from changes in the working angles through which the spring tension is applied to the loops. This arrangement permits more actual compliance with 2 loops than would result from a single comparable loop, thus facilitating the combination of a small flywheel and low cutoff frequency.

The circuit analogy of Fig. 3 includes the additional arm and additional sprocket since the latter is not isolated by a free upper loop as in the single-arm type. These dual elements are shown separately in order to include the condition wherein a disturbance is introduced by either individual sprocket. Most significant flutter disturbances originate in both sprockets simultaneously and in phase, in which case the circuit may be combined into one similar to that previously described.

The analogy of the common filter spring may require explanation. What might be referred to as its actual value of compliance is shown as C_1 whose value is that seen by the drum through either arm with the other arm stationary and is therefore a function of the spring constant. The compliance values, C_2 and C_3, are seen by the scanner in the respective arms when the arms move together without causing appreciable change in spring length. Therefore, C_2 and C_3 are functions of the angles through which C_1 works combined with the loading tension of C_1. It is interesting to note that if the arms and loops were infinitely long, no operational changes in angles would occur and C_2 and C_3 would be infinitely large. This would indicate the internal filter circuit would be nonoscillatory and have an infinitely low natural period. Therefore the cutoff frequency and the natural oscillatory period of the filter circuit are functions of the geometry of the arms and loops and the loading tension of the spring and are not directly a function of the spring constant. This is of practical assistance in the design of a compact double-arm unit.

A disturbance from a driving source, such as the motor or the main drive gearing, or from varying load conditions in any portion of the machine, is automatically transmitted to both sprockets simultaneously by the intermediate gearing between sprockets. An individual sprocket may contain a disturbance originating in the intermediate gearing between sprockets. These 2 types of disturbances constitute 2 types of drive side input; dual sprocket input and single sprocket input.

When a dual sprocket input occurs both sprockets accelerate and decelerate simultaneously relative to constant sprocket velocity indicating in the analogy each passes the same current. Therefore the branch through C_1 carries no current and has no effect on the circuit if the small film compliances C_5 and C_6 are considered equal or ignored. A dual sprocket input then represents a current input equal to that generated by either sprocket alone superimposed upon the filter, with

the same general attenuation characteristic as the single-arm type shown in Fig. 2.

Fig. 4 shows the attenuation curve of the double-arm filter mechanism. Disturbances arising in individual sprockets produce individual attenuation curves because of the application of damping to one arm only. In general the attenuation curve resulting from disturbances introduced by S_1 associated with the damped arm is similar to that of dual sprocket input. Disturbances from S_2 receive considerably more attenuation because the reactance of the arm is not limited by the
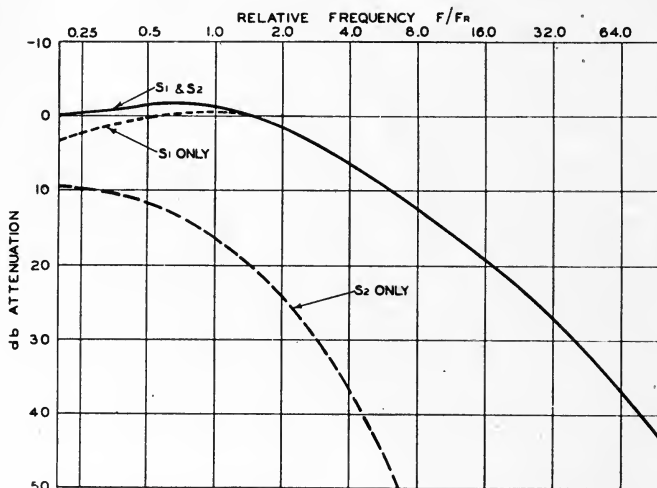
Fig. 4.   Attenuation characteristic of double-arm filter.

resistance of the damper.   This attenuation is especially large 3 or 4 octaves above cutoff where the reactance approaches zero.

New Sprockets.—Since a film does not pass over a sprocket as a perfect belt, additional disturbances exist in the movement of the film in the filtered film path, the most serious of which has been called "cross-over." This condition results from alternate shifting of the free play between sprocket holes and sprocket teeth, usually forward and backward as a result of surging load conditions of film reels or take-ups. These varying inertia loads, whether or not combined with varying take-up friction, cause cross-over unless a free loop exists on one side of the sprocket. The usual procedure is to add an additional holdback sprocket with a free intervening loop of

film. A solution has been devised to avoid the inconvenience of the additional sprocket as well as to maintain the smooth characteristics of sprocket operation with tensioned film in either direction.

This solution is a sprocket having as great a tooth width as will freely pass the 2 extremes of film pitch for a given set of operating conditions. Thus a 16-tooth sprocket with 74 mil teeth and with 90 degrees wrap will propel film ranging in pitch ± 0.4 per cent and the greatest free play will be 4 mils as compared to 20 or more mils with a standard sprocket. The wide tooth combined with a large tooth
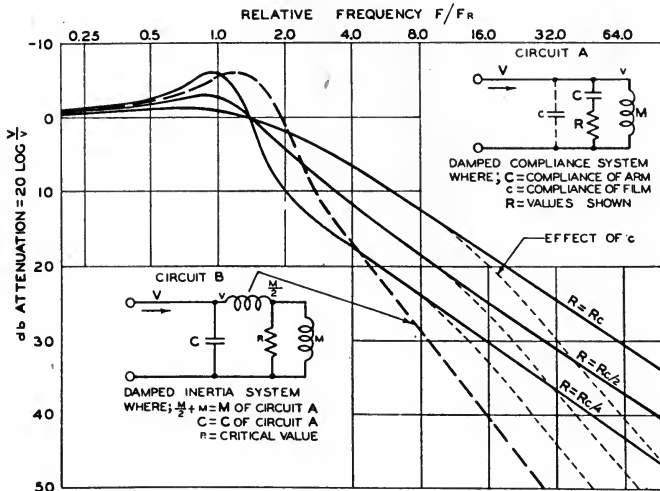
FIG. 5. Comparison of damped compliance and damped inertia systems.

radius is convenient to thread and results in a sprocket operating equally well in a feed or pull-down position with standard positive film stock.

Transients and Load-Side Disturbances.—The transient response of the single-arm and double-arm filters is that of a series resonant circuit and may therefore be computed on the basis of similar electrical circuits. Actually, while increased damping decreases transient response, optimum flutter performance results from an amount of damping determined by recurring disturbances. Disturbances caused by the transient nature of film splices are minimized by the relatively well-damped nature of the circuit and by the fact that

there is little change in compliance in the presence of large disturbances.

Load-side disturbances or those originating within the filter circuit proper, such as ball-bearing disturbances, are introduced into the internal filter circuit and are attenuated in proportion to the impedance of this circuit. Therefore the attenuation is minimum at the natural resonant frequency of the flywheel and arm combination.

A comparison between a typical kinetic scanner and a solid wheel of equal total proportions and driven by equal compliances is shown in Fig. 5. The kinetic scanner is referred to as the damped inertia system and the solid wheel as the damped compliance system. An inspection of the curves shows that the damped compliance system offers more attenuation in the low-frequency range where the ear is most critical to flutter. Three values of damping are plotted for the damped compliance system, one-half critical damping representing a typical value.

The application of values in rotational mechanical units to the circuits of Figs. 1 and 3 has facilitated development of the single- and double-arm filters. Substantial agreement was obtained between computed values of elements and those obtained by physical measurements. The resulting filter characteristics were in turn checked by graphic charts on a laboratory flutter measuring instrument[6] which also provided the means for measuring flutter performance. Application of the foregoing methods has made it possible to predict the design performance of recorders, rerecorders, and reproducers with less dependence on the experimental approach than has generally been required in the past.

REFERENCES

[1] Shea, T. E., MacNair, W. A., and Subrizi, V.: "Flutter in Sound Records," *J. Soc. Mot. Pict. Eng.*, **XXV**, 5 (Nov., 1935), p. 403.

[2] Albersheim, W. J., and MacKenzie, D.: "Analysis of Sound-Film Drives," *J. Soc. Mot. Pict. Eng.*, **XXXVII**, 5 (Nov., 1941), p. 452.

[3] Cook, E. D.: "The Technical Aspects of the High-Fidelity Reproducer," *J. Soc. Mot. Pict. Eng.*, **XXV**, 4 (Oct., 1935), p. 289.

[4] Kellogg, E. W.: "A Review of the Quest for Constant Speed," *J. Soc. Mot. Pict. Eng.*, **XXVIII**, 4 (Apr., 1937), p. 337.

[5] Wente, E. C., and Müller, A. H.: "Internally Damped Rollers," *J. Soc. Mot. Pict. Eng.*, **XXXVII**, 4 (Oct., 1941), p. 331.

[6] Scoville, R. R.: "A Laboratory Flutter-Measuring Instrument," *J. Soc. Mot. Pict. Eng.*, **XXIX**, 2 (Aug., 1937), p. 209.

A SIMPLIFIED ALL-PURPOSE FILM RECORDING MACHINE*

G. R. CRANE AND H. A. MANLEY**

Summary.—This paper describes a completely new recording machine for 16- or 35-mm film having a minimum of weight and bulk with a maximum of simplicity and excellent basic performance. A new sealed light valve is used in a simplified modulator and optical system employing a prefocused lamp for variable-density recording. A microscope is available for observing the valve in the modulator, and photocell monitoring and other accessories may be added if desired.

Recorder.—The RA-1231 film recording machine described in this paper has been designed for the purpose of providing the industry with a versatile machine for recording any of the standard original or release type of sound tracks on either 35-mm or 16-mm film.

The recorder consists of a base on which is mounted the film compartment, modulator housing, main drive motor and the necssary plug connectors, relay and motor disconnect switch. All other controls are external. The machine is shown in its standard form by Fig. 1 which is a front view with the doors open showing the inside of the film and modulator compartments. Fig. 2 is a rear view of the recorder with the cover removed showing the drive motor, chain drive, hand wheel, and plug connectors. The total weight of the recorder, less the film magazine, is approximately 76 lb.

A footage counter is provided on the film compartment door. Space has also been provided for additional accessories such as a photographic slater and film punch. A simple lever lock has been designed to retain the film magazine on the machine which reduces the time necessary for the operator to change magazines.

The machine will accommodate either synchronous or ac–dc interlock motors. The drive from the motor to the main drive shaft of the film pulling mechanism is by silent chain. In this drive assembly, any of the normal motor drive speeds that are used in the

---

industry can be accommodated, by a simple change of chain sprockets.

The film drive unit as seen in Fig. 3 is a complete assembly that is readily removable from the film compartment. For converting to a 16-mm film recorder a similar unit completely assembled and tested may be installed in its place in the machine. The 2 film sprockets differ in tooth design from the standard film sprockets that are in use today. Their design is discussed elsewhere in the JOURNAL.[1] These 2 film sprockets are driven from the main drive shaft through right-
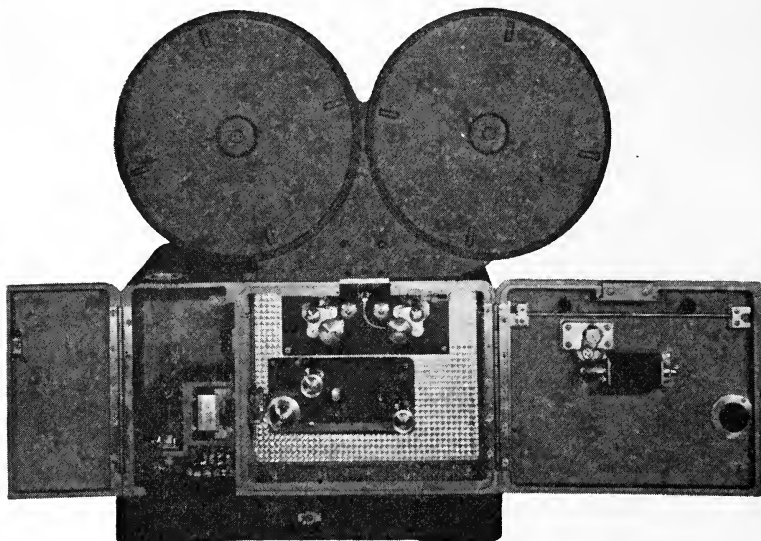
FIG. 1. The *RA-1231* film recording machine, showing front doors open.

angle helical gears, the pinion gear being steel and the large gear being nonmetallic to reduce mechanical noise.

In this same drive unit is located an adjustable multiple disk clutch for the film magazine take-up drive. The take-up from this clutch to the film magazine is accomplished through a small *V*-belt. Using a *V*-belt working through the multiple disk clutch assures a relatively smooth take-up. For those who prefer the permanent arm pin drive-type magazine take-up in place of the *V*-belt drive the machine has been so designed that it may be added as an accessory. Mounted on the front of the film drive unit plate, between the 2 idler rollers and extending down and around to the right-hand film sprocket, is the antibuckle trigger mechanism. This trigger operates a motor "dis-

connect" relay that locks itself in electrically, so that once the anti-buckle trigger is tripped the motor is disconnected and cannot become operative until the main motor disconnect switch is turned off, which allows the relay to drop back to normal operate position. A buzzer connected across the coil of the relay gives an audible signal in the event of a film buckle. A hand wheel is attached to the end of the main drive shaft and extends through a hole in the right-hand end of the main case.

The recording drum unit, as seen in Fig. 3, is also a complete assembly that is readily removable from the main case of the recorder.
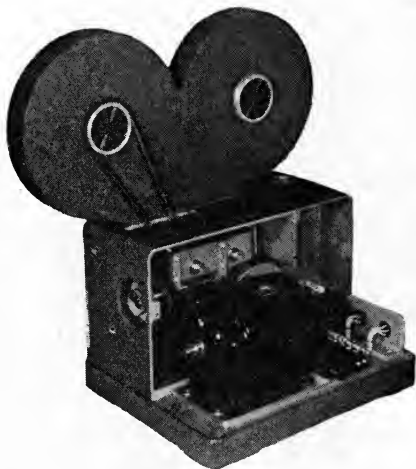
FIG. 2.   Rear view of film recorder, with
cover removed.

It consists of the recording drum, shaft, flywheel and support casting. The drum and flywheel are rigidly coupled to the shaft which is ball-bearing mounted in the support casting.

The film drive filter mechanism, as seen in Fig. 3, is a compact unit assembly that is readily replaceable or may be converted to accommodate 16-mm film. This type of filter is described elsewhere in the JOURNAL.[1] The filter mechanism was designed for this machine with the view toward keeping the film compartment clear of obstructions and easy to thread as shown in Fig. 1. Only the 2 filter rollers extend into the film compartment. These rollers are flanged and guide the film onto the drum in the proper position for recording. No appreciable amount of weave has been encountered in using this

method of guiding. The dash pot, whose plunger is attached to the upper filter arm, is made of transparent plastic and an opening is provided in the mounting plate so that the fluid level is readily visible from the film compartment. The dash pot has been so designed that it will not lose fluid even if the machine is turned upside down. Film threading indicators are provided and are visible from the film compartment also.

The recorder, as seen in Fig. 1, is provided with a small modulator; however, the section of the recorder which houses the modulator is removable and may be replaced by appropriate housings for other more complex modulators.
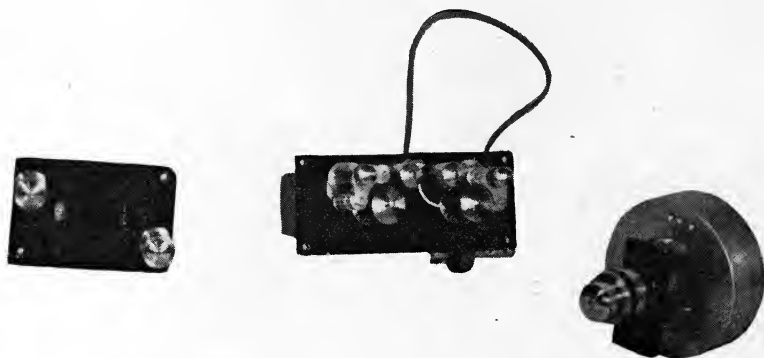
Fig. 3. Filter unit, drive unit, and recording drum unit.

Modulator.—The modulator for this recorder has been designed to provide the simplest possible assembly containing the light valve, the lamp, and the optical system required to record either 16- or 35-mm single variable-density track. Photocell monitoring and other accessory devices frequently found in modulators have been eliminated in the interests of simplicity, but there has been no compromise with the quality of the items and performance achieved with regard to either the light valve or the optical system. Photocell monitoring can be added as an accessory if desired.

As shown by Fig. 4, the modulator consists of a chassis which is intended to be screwed onto a flat surface of the recorder and contains all of the necessary elements in one assembly. It is provided with a milled slot in the mounting surface which rides on a key attached to the film recorder case so that the recorded track position

may be laterally adjusted without disturbing other adjustments. The range of lateral movement is sufficient to permit recording on either edge of 16-mm film and the standard position on 35-mm. Provision can also be made for recording on the opposite side of 35-mm film if required. In this application there is no cover over the modulator since the recorder case provides this facility, but if it is used for other applications a suitable cover is available. This modulator differs from its predecessors with respect to the 4-amp lamp, improved optics of the anamorphic type, the use of a sealed permanent magnet light
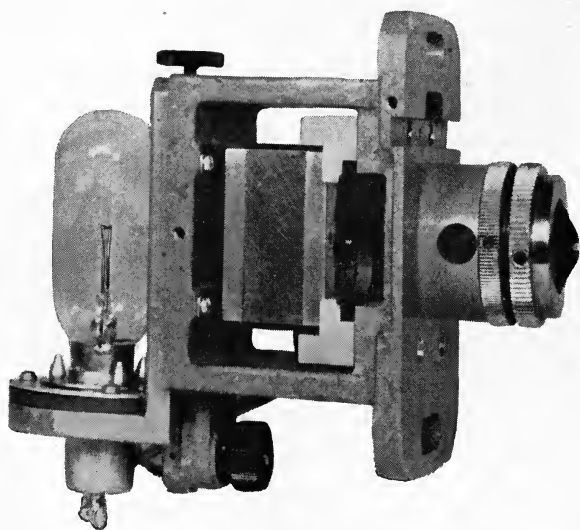
Fig. 4.   Modulator unit.

valve, and facilities for mounting a special microscope to observe the ribbons without removing the valve from the modulator.

The condenser lens system is designed to accommodate the relatively short and large diameter filament of the standard 9-v, 4-amp prefocused theater lamp. This lamp is chosen because of its wide use and availability in all parts of the world and also because of the fact that the short, heavy filament is rugged and not subject to deformation with use. The prefocusing feature is also of value, since it reduces the lamp adjustments necessary to a single vertical screw adjustment which can be eliminated without appreciable loss of light or introduction of lamp noise. One of the condenser lens ele-

ments is mounted in the end of the light valve and therefore serves
to seal up one end of the valve. A small subassembly containing this
lens also contains the effective aperture of the valve which deter-
mines sound track width, so that by changing this subassembly, the
track width may be altered. This permits any valve to be converted
from 35-mm, 100-mil track to 16-mm, 80-mil track by changing this
item only from the outside of the valve.

The objective employed is a high-quality achromatic lens and
works in combination with a short focus cylindrical lens located near
the film. The light valve ribbons are brought to a focus on the film,
giving an effective slit height of approximately 0.25 mil for a 1.0-mil
valve. The objective and the small auxiliary cylinder are mounted
in such a manner that the azimuth of the cylinder is separately ad-
justed and fixed, permitting the focus to be adjusted in the usual
manner. These adjustments are controlled by 2 knurled rings which
are located in the film compartment when the modulator is assembled
on the recorder. The light valve azimuth is not adjustable, but it is
accurately controlled in relation to the modulator and the recorder.

Just ahead of the surface on which the light valve is mounted, a
pair of grooves is provided which accepts an inspection microscope,
described later in this paper.

Light Valve.—The light valve used in this modulator has been
coded *RA-1241-A* for 35-mm, 100-mil track, and *RA-1241-B* for 16-
mm, 80-mil track. These 2 valves are basically identical and differ
only in the masking device which determines the track width. This
valve, shown by Fig. 5, is the sealed permanent magnet type, approxi-
mately $1^5/_8$ in. sq and $^{15}/_{16}$ in. thick. It is 2-ribbon, bi-planar and is
provided with silver contacts at the front edge of the rear surface.
In the modulator it is held against a reference surface by 2 springs and
is located by means of 2 dowel pins anchored in the modulator.
The front surface of the valve is provided with ramps so that it may be
pushed in easily and lift itself over the dowel pins while entering.
The springs cause it to snap in place over the pins and it is readily
removed by pressing the valve back against the springs, so as to clear
the pins, and then pulling forward. As previously mentioned, the
rear of the valve is sealed by a condenser lens and the front surface is
sealed by a cover glass so that the interior is effectively sealed against
dirt or magnetic particles. It is not intended that the valve should be
opened by anyone except the manufacturer unless equipped with the
proper type of magnetizing equipment, since the valve is magnetized

after it is assembled and cannot be readily pulled apart without damage.

This valve is normally tuned to 9000 cycles and in view of its small size, every effort has been made to produce the highest possible flux density in the air gap which results in good sensitivity and a relatively low resonance peak as compared to other valves of similar size. When tuned to 9000 cycles the average sensitivity is approximately $+7.0$ dbm. The rise at resonance is approximately 12 db when the valve is used in the usual simplex circuit with a matched impedance transformer. The circuits employed in associated equipment provide facilities for feeding the valve through a circuit containing a correc-
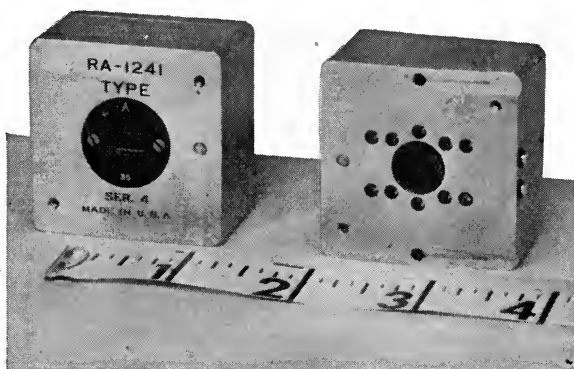
FIG. 5.   Light valve, seen from front and rear.

tive, constant impedance equalizer having a frequency characteristic which is the inverse of the light valve. In addition, limiting facilities are provided which prevent serious overloading of the valve and experience to date with this type of equipment has indicated the light valve to be quite stable and dependable over considerable periods of time.

Microscope.—The light valve microscope developed for this modulator is shown by Fig. 6. The purpose of the microscope is to provide a convenient tool for observing the valve ribbons without removing the valve from the modulator. This provides a facility for checking ribbon modulation, noise reduction, ribbon spacing, and azimuth. The microscope consists of a lightweight dural case attached to a steel tongue which is inserted in the slots provided in the modulator. Two small ball pressure points insure registration

with one reference guide surface which guides its movement back and forth to check ribbon azimuth. This movement is aided by the use of a small lever located on the side of the microscope. When it is set in the position toward the operator, the microscope may be pushed in to a point where a stop is engaged and which corresponds to optical registration with one end of the light valve slit. Then by operating the lever to the vertical position where a detent is felt, the center of the light valve is in register and by moving the lever to its forward position the other extreme end of the valve may be viewed. For quick checks the lever may be left in the center position.
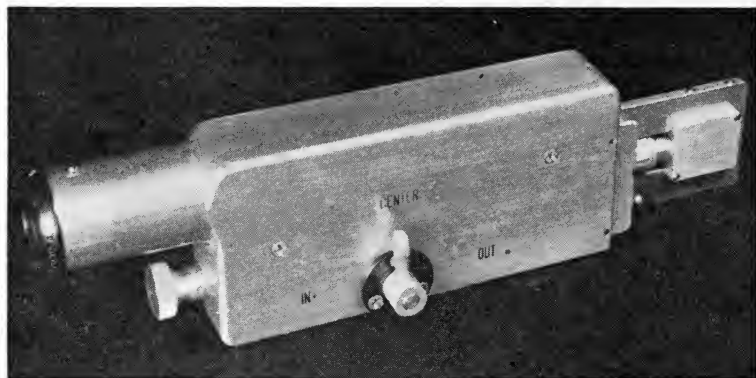
Fig. 6. Light valve microscope.

The optical path is fundamentally simple and consists of a 32-mm microscope objective to view the ribbons through a small prism which turns the beam 90 deg between the light valve and the objective. In order to maintain a reasonable working distance for the objective and yet obtain a 10 to one magnification at the eyepiece, a long rear focal distance is used and this is obtained by folding the optical system twice by means of totally reflecting prisms. The objective is adjustable for focus and is controlled by a small focusing knob just below the eyepiece. The eyepiece is a 15-power hyperplane equipped with a reticle which contains 2 concentric circles for comparison with the image of the light valve ribbons. These 2 circles are of such size that their diameters correspond to a valve spacing of 0.8 and 1.2 mils, respectively. They are located off center in the reticle so that by a

rotation of the eyepiece the operator may bring the reticle pattern
into register with the valve slit image. It has been found that an
operator can quickly judge the valve spacing in terms of this pattern.
The modulator cannot, of course, be operated for recording while the
microscope is in place but it may be quickly inserted between takes
if a check on valve performance is desired.

Conclusion.—The design of the complete recorder appears to be
very satisfactory with regard to its simplicity of mechanical parts
and freedom from critical adjustments.   The unit assembly con-
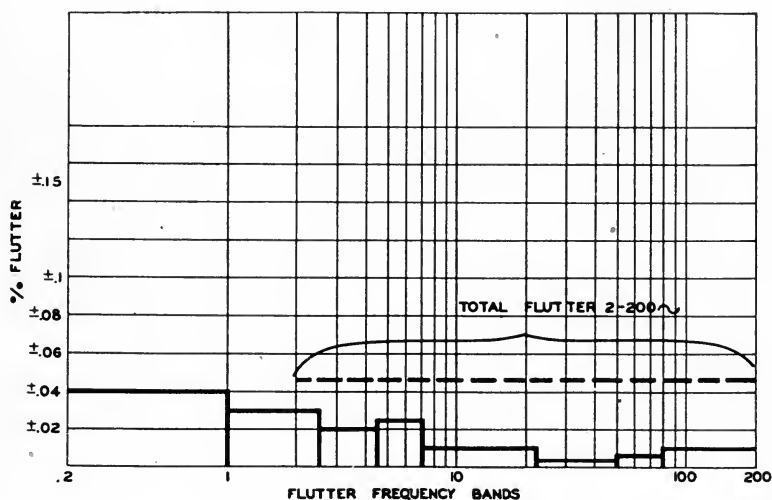
FIG. 7.   Flutter values.

struction of the film propulsion mechanisms has reduced servicing
and maintenance considerably. A clear film compartment and the
elimination of unnecessary controls facilitate the operation of the
machine.

Studies of flutter performance made to date indicate that it com-
pares very favorably with the highest quality film recording machines
in use today. As seen in Fig. 7, the total flutter for all frequency
bands from 2 to 200 cps is approximately ± 0.05 per cent. The amount
of 96-cycle flutter caused by sprocket hole disturbances is essentially
negligible. The low-frequency flutter has been reduced to values that
are not audible to the ear in high-quality music reproduction.

It is believed that the over-all performance of the recorder combined with its simplicity and versatility will amply meet the long felt needs of the industry for this type of film recording machine.

<div align="center">REFERENCE</div>

[1] DAVIS, C. C.: "An Improved Film-Drive Filter Mechanism," *J. Soc. Mot. Pict. Eng.*, **46,** 6 (June, 1946), p. 454.

THE USE OF DESICCANTS WITH UNDEVELOPED PHOTO-GRAPHIC FILM*

C. J. KUNZ AND C. E. IVES**

Summary.—*With the packaging materials now available it is possible for the manufacturer of photographic film to provide almost complete protection from unfavorable atmospheric humidities up to the time of use. Management of the film moisture content after the moisture impervious package is opened involves adoption of suitable techniques and in some cases the use of desiccants.*

Several materials of outstanding interest as desiccants have been studied as to moisture capacity and rate of absorption under suitable conditions. The rate of moisture exchange as influenced by disposition of the film, the presence of membranes, circulation of air, maintenance of reduced atmospheric pressure, etc., has been measured.

Recommendations are made as to methods of minimizing moisture uptake, choice of desiccant, care of desiccant, utilization of material available in the field, and avoidance of the effects of overdrying.

Technology has made its greatest strides in regions of temperate climate and its products are, for the most part, fitted to use in such regions. Difficulties are frequently encountered, therefore, when they are used in other regions such as the humid tropical belt and so it is not surprising that a material designed to respond to forces so slight as a momentary exposure to light should be affected by heat and humidity. While photographic science has endowed these materials with increased speed and more finely balanced properties without disproportionate sensitiveness to atmospheric conditions, the photographic literature gives ample warning of the risk of speed loss and latent-image fading incurred when conditions are extreme. The present work was undertaken to obtain specific information as to measures which would be effective in the management of humidification and dehumidification when applied to the needs of the film user. Such measures may be required for the undeveloped film either before or after exposure.

On occasion, these measures may also be applied in conditioning processed film; for instance, dehumidification may be used to retard fungus growth or to eliminate stickiness which would prevent motion picture film from traveling smoothly through the projector. The use of desiccants with processed motion picture film is not generally advisable however, because of the danger of embrittling the film if desiccation is carried too far. Effective and safer procedures are known but consideration of them is outside the scope of the present paper. Humidification, on the other hand, may be required to overcome a tendency toward brittleness resulting from storage under extremely dry conditions. While the same general principles as set forth here for the case of undeveloped film apply to developed film, the situation will differ quantitatively with the latter.

Condition of Film.—For the present purpose it will be sufficient to consider that raw film as supplied by the manufacturer has, in general, a moisture content which permits it to withstand, for reasonable periods before and after exposure, temperatures around 70 F and middle-range humidities without serious loss of speed or deterioration in image quality. It will be assumed here that the absorption of additional moisture is a contributing factor in deterioration, especially if the film is to be kept at high temperature for any considerable time previous to development.

Climatic Conditions.—Available information indicates that film may encounter temperatures from -80 F to $+140$ F, and relative humidities from a few per cent to practically 100 per cent. The high humidities are not ordinarily met at temperatures above 100 F. In this paper attention is centered on the control of film moisture content and temperature is considered only incidentally.

Problem of Moisture Control.—To the extent that facilities permit, recommendations as to temperature can be followed successfully by using a thermometer and by exercising ordinary care and good judgment. In contrast, there is no such simple instrument by the use of which the moisture content of film, desiccants, *etc.*, can readily be determined. Estimates of the amount of moisture taken up by film and desiccants, as well as of the influence of a number of factors on the rate of moisture transfer, may have to be made in the field with reasonable accuracy but without the aid of any instruments. Because of the lack of information, opportunities for shielding the film from unfavorable treatment may be overlooked and measures adopted for desiccation may be unsuitable. Indeed, it now appears

doubtful that much, if anything, has been accomplished when some of the procedures suggested in the literature were followed.

PSYCHROMETRIC PRINCIPLES

Photographic film, like paper, cotton, silk, leather, and many other organic substances, may contain several per cent of water while appearing dry by ordinary standards. This moisture is not held fast but tends to increase or decrease in amount with the rise and fall of the humidity in the immediate surroundings. Since film is usu-
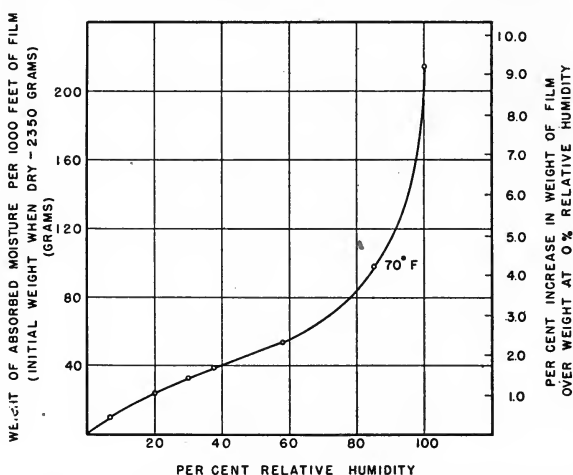
FIG. 1. Relationship between relative humidity and moisture absorbed by nitrate negative-type motion picture film starting from the dry condition.

ally surrounded by an atmosphere which is composed of a mixture of air with varying proportions of water vapor, gain or loss of moisture therefore involves an exchange between it and this atmosphere, the moisture content of which may, in turn, be controlled by contact with a desiccant, by passage through an air-conditioning apparatus, *etc.*

Moisture Content of Film.—A typical motion picture negative film will attain the maximum of about 10 per cent moisture content* in this way when it remains for a sufficient time in contact with an atmosphere which is fully saturated with moisture (100 per cent

* Only the readily exchangeable moisture content is considered in this paper.

relative humidity). As atmospheric relative humidity is reduced, the moisture content of the film decreases but not in direct proportion. The amount of moisture taken up at various relative humidities by a typical motion picture negative film, starting from the dry state,* is shown for a temperature of 70 F by the curve in Fig. 1. (Hysteresis effects causing a small difference in moisture content, according to whether the film has previously been dryer or more moist, can be overlooked here.) The effect of temperature at constant relative humidity is relatively slight over the range of interest. Considering the uncertainties resulting from other factors in the usual desiccating problem, it is permissible to neglect the effect of temperature in this respect.

Relative Humidity and Atmospheric Moisture Content.—Relative humidity is defined as the actual water vapor pressure in a given atmosphere divided by the maximum vapor pressure which water can exert at the prevailing temperature. Since the maximum vapor pressure which water can exert increases with increase in temperature, the vapor pressure at every value of relative humidity likewise increases proportionately. However, this increase represents only a greater availability of moisture in the space in question but not any tendency to increase the equilibrium moisture content of photographic film. The quantity of moisture in grains per cubic foot of space is directly proportional to the existing vapor pressure and can be obtained from the usual charts and tables. It is assumed in this paper that such psychrometric charts are available to the reader.

The presence or absence of air can be ignored in considering the equilibrium moisture content of film at any given temperature and per cent of vapor pressure saturation (relative humidity). In spite of its passive character as regards the equilibrium moisture content of the film, the air, constituting upwards of 90 per cent of the atmosphere, forms an important obstacle to the movement of moisture by diffusion and makes up the bulk of the material which moves when convection takes place. The air is thus a factor tending to retard movement of moisture when conditions favor stagnation and, on the other hand, is the medium in which moisture vapor is conveyed from one place to another when conditions are conducive to circulation.

In the open, local short-term fluctuations in vapor pressure are

---

* Dried to substantially constant moisture content over concentrated sulfuric acid.

accommodated by displacement of air which is always at hand to maintain full barometric pressure. Within tight enclosures, such accommodation is impossible except insofar as changes in the shape of the container occur. Even if no accommodation is made, the greatest possible change in total pressure which would result (about 10 per cent) is not very great when it is considered that the barometric fluctuation is about 10 per cent and the effect of a 5000-ft ascent from sea level about 15 per cent. The moisture conditioning of film, therefore, always takes place in an atmosphere comprising a small proportion of moisture in a large proportion of air unless the latter is reduced by operating under a vacuum.

Such are the atmospheres which serve as the medium of moisture transmission and in a small degree as a moisture reservoir. The small storage capacity of air is evident from an example. One cubic inch of motion picture negative film might contain about 10 grains of moisture when in equilibrium with an atmosphere containing only 0.004 grain per cu in. (70 per cent RH at 70 F). If one cubic inch of this film was to be dehumidified by being sealed in an enclosure with sufficient air at 30 per cent RH and 70 F to provide for eventual equilibrium of both at 50 per cent RH, the enclosed space would have to be about 2900 cu in. (1.68 cu ft).

Moisture Exchange and Equilibrium.—It may be assumed that the moisture content of film is adjusted during manufacture to a value which makes it suitable for normal use. It is possible, furthermore, with modern moisture-resistant packaging, to prevent gain or loss of moisture until it is opened for use. If the atmosphere to which the film is then exposed is unfavorable in respect to humidity, it will be desired to handle the film in such a way as to retard change in moisture content and then later to hasten the return to a suitable moisture content. In the humid tropics, for example, the film may be exposed during a few minutes or a few hours to relative humidities up to 90 per cent and then stored for days or weeks before development. In such a case excess moisture can be removed shortly after the film comes from the camera by enclosing it with a desiccant in a tight container. The desiccant should not come in direct contact with the film.

Before considering the choice of desiccants and operating methods it will be desirable to consider some of the factors which govern the rate of exchange of moisture between the film and its surroundings as follows:

(1)   The humidification or dehumidification potential,

(2)   The length and cross section of diffusion paths,

(3)   Circulation,

(4)   Temperature.

By implication are included such factors as the disposition of the film, that is, in a roll or stack of sheets, *etc.*, the character and arrangement of wrappings or other membrane, the location of desiccant, and limitations of moisture capacity of elements in the system.

Humidification Potential.—Moisture equilibrium between a substance and its surroundings is reached when the moisture vapor pressure which tends to exist inside the substance equals that prevailing in the system surrounding it.   Only when a vapor pressure difference exists does moisture exchange take place.   This is so in the case described when the film absorbs moisture from a humid outdoor atmosphere or later when the film and desiccant within an enclosure exchange moisture through an intermediary atmosphere, the relatively small moisture content of which is controlled by them.   Difference in vapor pressure in 2 substances, whatever the cause, is a measure of the tendency of moisture to transfer between them and will be termed the humidification or dehumidification potential. It should be recognized that the moisture vapor pressure in a substance such as photographic film increases with increase in temperature and also with moisture content but not in a simple fashion.

Length and Cross Section of Diffusion Paths.—At one or more points along the path of moisture exchange, the mode of transport is one of diffusion.   In diffusion processes the rate of transfer at any point in the path is directly proportional to the concentration gradient and the cross-sectional area.   If the humidification potential is fixed, the rate will decrease with increase in length of the diffusion path.

In the case of desiccation, the rate is therefore increased by spreading out the film for access, using a desiccant of such open structure as to introduce minimum constriction of the diffusion path, placing the desiccant close to the film (but not in contact!) and eliminating moisture-impervious wrappings, or if mechanical membranes are indispensable, choosing the most pervious.

If humidification of film is to be retarded without the aid of desiccants, the measures to be adopted will generally be the opposite of those listed.

Diffusion through air is slow so that transfer is accelerated by re-

moving any kind of obstruction to circulation which forms paths through which transfer must be by diffusion. Since the presence of air provides resistance to moisture diffusion, the process is speeded up by pumping the air out of the enclosure in question.

Diffusion through the thickness of the film itself is also slow so that when the other limiting factors are largely eliminated (under vacuum), it still requires about an hour to effect a large change in the moisture content. On the other hand, such a change may require up to several days or weeks if the other factors have full play.

Experimental results to be described in a later section will illustrate the magnitude of some of the effects mentioned here.

Circulation.—In contrast to the slow movement of moisture by diffusion through stagnant air, the effect of any noticeable degree of air movement is large. A really stagnant condition prevails less frequently than might be supposed except where space is cut up into small cells by solid material. In spaces having dimensions of a few inches, convection may be considerable as a result of heating and cooling, or differences in atmospheric density in accordance with difference in moisture content. Most rapid moisture transfer occurs not simply when circulation is maintained in the container as a whole but when the air stream moves rapidly over all the surfaces of film, desiccant, or other bodies where moisture effusion or extraction occurs. Moisture transfer is therefore retarded greatly by the mere presence of wrapping material so far as it obstructs circulation, and even more so by wrappings of moisture-impervious material which permit exchange only by diffusion along the folds and between layers.

Temperature.—Temperature effects are of several kinds. In the first place, diffusion rates increase with temperature. Rise and fall of temperature in the surroundings produce convection in small vessels, especially if heating and cooling are rapid and localized. At higher temperatures, the atmosphere can contain more moisture and hence is a better transfer medium. The decrease in moisture content of film with elevation of atmospheric temperature at constant relative humidity is not large enough to be of much practical significance in the management of film moisture content. Most desiccants lose their moisture absorption capacity with elevation of temperature but usually not so much over the range of interest as to affect the choice of agent or the manner of use.

Practices in which humidification or desiccation occur as a result of change of relative humidity brought about by heating or cooling of

air, including those cases where moisture is extracted as dew or frost, will be discussed in a later section.

Combination of Several Factors.—Since diffusion of moisture through the film itself is slow, movement of moisture to and from the inner layers of film in wound rolls or in stacks of sheets is affected greatly by the tightness of winding or packing. In a very loosely wound roll the rate may be one tenth of that for an open sheet and in a tight roll even less. Similar effects must be expected with sheet films although the closeness of adjacent sheets will be a matter of considerable uncertainty. Another consequence is that the outer edges will
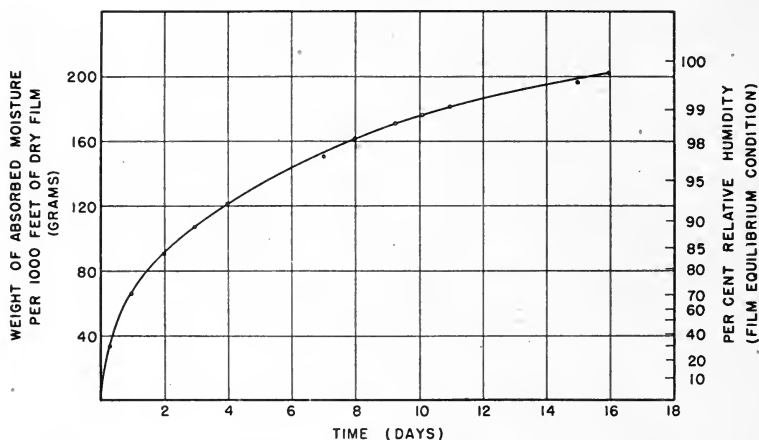
Fig. 2. Absorption of moisture by a loosely wound roll of nitrate negative motion picture film, circulation not forced.

experience more rapid humidification and dehumidification than the inner portions.

The effect of the presence of metal foil and waxed paper wrappings as well as magazines, metal film-pack cases, *etc.*, is to create long narrow diffusion paths which so reduce the rate of transfer as to offer substantial protection from humidification if used properly and, on the other hand, to demand special procedures in desiccation.

For like reasons, the desiccating chamber must provide for exposing a large area of desiccant and avoiding obstruction of circulation by the contents.

As will be shown in a later section, the rate of moisture removal may be reduced if the desiccant is not in excess. Limitations in the

capacity of the system must also be respected when the space for desiccant is small or the desiccant is bulky or low in capacity.

Rate of Moisture Absorption.—An open strand or sheet of film in air which is moving even at a very slow rate can absorb moisture from a humid atmosphere at such a rate as to effect a large proportion of the total adjustment within about an hour and almost all of the adjustment in 3 or 4 hours. The rate of absorption is reduced greatly by the presence of any kind of barriers to circulation and diffusion. Fig. 2 shows the slow progress of moisture absorption by motion picture film in a roll, starting from the bone-dry state and exposing the roll to high humidity under conditions where circulation was very little. The effect of tightness of winding is demonstrated by the data in Table 1, which shows the progress of moisture

TABLE 1

Effect of Tightness of Winding on the Rate of Absorption of Moisture with Nitrate Negative Motion Picture Film

Weight of Moisture Absorbed by 1000 Ft of Film (Gm)	Time Required to Absorb a Given Weight of Moisture (Min)		
	Tight	Loose	Thread
50	66	52	27
60	117	90	42
70	180	132	63
80	258	177	87
90	345	231	117
100	468	303	153
110	648	400	216
120	840	540	285

absorption in 3 rolls of film, one of which was tightly wound, the second loosely, and the third with an interwinding of No. 8 cotton thread for spacing. The film was originally of very low moisture content and during the test was held over water in a jar of ample dimensions to permit convective effects. A rough estimate of the time required for a change of intermediate degree can be made from this. Greater degrees of retardation are obviously possible by the use of tightly wound and closely folded wrappings of metal foil, heavy waxed paper, and the like. Where wrappings of this kind can be used and especially if film holders can be dried before loading, it should be possible to reduce to a very small amount the absorption of moisture when the film is out of the camera.

DEHYDRATION METHODS

Having considered the factors which influence absorption and removal of moisture and the harm which excess moisture can do, we shall now turn our attention to detailed consideration of methods for removing moisture as they may be applied to such material.

In general, dehydration of a space containing air and a solid body can be accomplished by any one of, or a combination of, certain of the following processes:

(1) Condensation of water vapor by refrigeration and subsequent reheating of the air,

(2) Drying at reduced atmospheric pressure,

(3) Desiccation involving chemical action (absorption),

(4) Desiccation involving physical attraction (adsorption).

Although seemingly somewhat outside the scope of this paper, the first 2 methods listed require consideration since they offer advantages in some film dehydration problems.

Dehydration by Refrigeration and by Vacuum—General Principles.—All methods of dehydration involve reduction of the moisture vapor pressure in the space surrounding the object to be treated, below that prevailing in that object.

In the case of refrigeration, the vapor pressure of the space is decreased by reducing the temperature in a portion of that space to the dew point or lower; the method of dehydration employing a vacuum depends on the action of a pump to reduce the pressure within the given space either to the extent of removing the moisture mechanically or of facilitating its removal by desiccants.

Application of Refrigeration to the Dehydration of Film.—The following comments can be made with reference to dehydrating film by the method of refrigeration:

(1) A system of refrigeration employing melting ice is unsuited for the dehydration of film because it tends to keep the atmosphere near saturation with moisture so that humidification is more likely to occur. This is demonstrated by the fact that fruits and vegetables, stored in an ice refrigerator, seldom dry out but remain firm and crisp.

(2) Mechanically operated refrigerating systems employing a cooling medium which circulates through suitably disposed piping is capable of dehydrating film only when the vapor pressure of the latter exceeds that existing at the cold surface. Since vapor pressure is dependent on temperature, the problem is one of maintaining the temperature of the film well above that of the cold surface. Because of the nature of the sensitized film, the methods for accomplishing this are restricted. One method consists in circulating air within the refrigerating chamber in such a manner that, after passing over the cooling surface and giving up its moisture,

the air is warmed before continuing on to the film whether another load of moisture is taken up.

Following dehydration to the desired moisture content, the film should be wrapped in black paper, sealed in a metal container, and stored until ready for processing, preferably under refrigerated conditions.

Effect of Refrigeration on the Relative Humidity within a Sealed Film Container.—It is appropriate to consider the case in which film, in equilibrium with an atmosphere of, say, 60 per cent RH at 70 F, is sealed in a container and placed in refrigerated storage. The question arises, will the relative humidity within the sealed container increase as the temperature is lowered, with the attendant danger of condensation of moisture? An analysis of existing conditions shows that the relative humidity within a sealed container of normal packing size will remain substantially constant over any temperature range which will ordinarily be encountered. For instance, if the film package contained no film, the enclosed space would, in fact, be saturated at 55 F since this is the dew point of the 60 per cent, 70 F atmosphere. However, when film and wrappings are present and sufficiently accessible to the air in the container, moisture is removed from the space by the film and the paper as the relative humidity begins to rise, as a result of the lowering of temperature. Obviously, if the moisture in this space is thus reduced in quantity, saturation will not occur at 55 F. Since the moisture capacity of the film and paper is great compared with that of the surrounding space, a substantial reduction in temperature changes the existing relative humidity only a very small amount. In this adjustment the change in moisture content of the film is relatively minute.

Dehydration by Vacuum.—The utility of the method of dehydrating in a vacuum is demonstrated when one considers that the rapid dehydration of many of the food products for overseas shipment during the war was accomplished by this method applied in one form or another.

When applied to the partial dehydration of overhumidified film, the method is attractive in many respects but primarily because it is rapid. Since the extent of latent-image impairment is a function of the time of exposure to unfavorable conditions, acceleration of the dehumidification process is desirable. Also, since the operation may be reduced in time from days to hours, a smaller amount of drying space is needed.

The necessary equipment need not be bulky in itself, since the es-

sential parts consist merely of a pump for creating the vacuum, and a dehydrating chamber of a size consistent with the quantity and type of film to be treated.

The simplest method of utilizing a vacuum for the purpose is merely to evacuate the film chamber to a pressure substantially less than the existing vapor pressure of the film. As soon as vaporization commences, the temperature of the film will fall for reasons already given so that the initial rate of dehydration will decrease somewhat. However, the final temperature attained after starting from 70 to 100 F is still such as to permit sufficient dehydration in 5 to 10 hr, provided a low pressure (one millimeter of mercury or less) (one millimeter = 0.04 in.) is maintained. This vacuum method is effective with firmly wound rolls of motion picture film and is the method preferred in all cases where the disposition of the film is similarly unfavorable.

Although the use of a trap for water vapor, *i. e.*, a refrigerated condenser, between the pump and the desiccating chamber permits the use of a pump of much lower capacity, such a system would not appear desirable for field application, because what might be gained in the size of the pump, would be sacrificed in refrigeration equipment.

Another method for utilizing a vacuum for dehydrating film consists in decreasing the pressure to a value which is equal to or even somewhat greater than the vapor pressure of the moisture in the film while providing a suitably disposed moisture-absorbing body—for instance, a desiccant or refrigerated surface condenser. In this case the effect is merely that of reducing the resistance to the passage of water vapor from the film to the absorbent or the extracting surface, by removing most of the interfering air molecules. Practical aspects of this subject are considered further in a later section.

Dehydration by the Use of Desiccants.—We now return to the consideration of the remaining methods of dehydration, broadly classified as methods employing desiccants. In simplest terms, a desiccant may be described as any agent having a greater affinity for absorbed moisture than the substance to be dehydrated so that water vapor passes from the latter to the former until a state of moisture equilibrium is attained.

Properties of a Desiccant Suitable for Dehydration of Film.—The properties of a desiccant which is suitable for the dehydration of film are not, in every case, the same as those required for other applications. In fact, even with film, properties which are essential

when the desiccant is to be used in one way are unimportant when it is employed in another. However, in general, the following properties would normally be considered desirable in a desiccant which is to be used in the partial dehydration of film, especially when used in the field:

(1) The moisture absorption capacity of the desiccant should be large.

(2) The velocity of absorption should be high, at least down to the level of relative humidity considered suitable for safe film storage.

(3) The specific volume should be low for minimum space requirements.

(4) The physical form of the desiccant should not change in an undesirable manner, even when fully saturated. As an example, liquefaction or expansion should not occur. Freedom from the tendency to form dust or powder is desirable.

(5) The effect of temperature on absorption velocity and capacity should not be great over the range of working temperatures.

(6) For some applications, the desiccant should be capable of regeneration without deteriorating.

(7) The desiccant should not, in itself, produce undesirable changes in the sensitometric properties of photographic film. For instance, certain substances which might conceivably be used as desiccants have been shown to produce vapors which have considerable effect on the latent image. In general, neutral drying agents are to be preferred to those which are acidic or basic.

(8) The substance should be essentially inert, especially in the sense that it should be incapable of inducing or supporting combustion. This is of special importance, considering the combustible nature of film. The very effective perchlorate desiccating agents are examples of a type to be avoided for this reason.

It may be recognized that one of the properties ordinarily associated with a good desiccant—"drying efficiency"—is lacking from the list. In the literature of desiccants, this is a measure of the ability of an agent to dehydrate to a condition approaching complete dryness. Since this factor is of little importance in the present application where a vapor pressure corresponding to a relative humidity of 20 or 40 per cent is all that is required, certain desiccants of wide reputation fall into a class of only academic interest. For instance, phosphorous pentoxide is often referred to as a standard of drying efficiency in view of its ability to produce a vapor pressure of practically zero; however, it has a very small capacity for moisture—less than 10 per cent—because of the formation of gummy metaphosphoric acid on its surface, which effectively seals the agent against further absorption, at least at reasonable rates. Barium oxide is another exceedingly powerful desiccant of very low capacity.

Factors Affecting the Action of a Desiccant.—Before proceeding to consider particular agents and methods of use, we shall discuss

briefly certain factors which determine their suitability according to the type of use.

As already stated, desiccants can be divided into 2 general groups, one depending on chemical action (absorption) and the other on physical action (adsorption). Except where classification in this regard is discussed, the general term "absorption" is used inclusively.

The first of these 2 groups can be divided into 2 subgroups; in one of these, the desiccant absorbs moisture by virtue of a shift in primary valences, thus creating another molecular species; in the second subgroup, the desiccant absorbs by virtue of hydration, thus involving only the use of secondary bonds or valences.

Examples of each of these types of desiccant are shown in Table 2:

TABLE 2

Examples of Desiccants Involving (a) Absorption and (b) Adsorption

(A) Absorption—(Chemical)
- (a) Reaction in the usual sense
  $$P_2O_5 + 3H_2O \rightarrow 2H_3PO_4$$
  $$BaO + H_2O \rightarrow Ba(OH)_2$$
- (b) Hydration
  $$CaCl_2 + (x)H_2O \rightarrow CaCl_2 \cdot (x)H_2O$$

(B) Adsorption—(Physical)
- (a) Silica Gel
  Charcoal

The highest drying efficiency is possessed by agents which owe their effectiveness to a chemical action involving molecular rearrangement. The temperature coefficient of decrease in dehydrating efficiency with increasing temperature is lowest with this type of agent. In general, desiccating agents of this type are not readily regenerated. Unless some adsorptive effect occurs simultaneously, the capacity of these agents is ordinarily low, being limited to that represented in familiar chemical reaction equations. Barium oxide is an agent of this type which owes part of its limited capacity to adsorption.

The drying efficiency of agents relying on the formation of hydrates depends on the vapor pressure of the hydrate formed. The vapor pressure capable of being attained by this method varies from practically zero with, for example, anhydrous magnesium perchlorate, upward through 0.14 mm mercury at room temperature with granular calcium chloride. The hydration-type reaction results in greater moisture capacity since the number of molecules of hydration is usually large. Moreover, adsorption effects are often associated with

chemical hydration, increasing the capacity and rate of absorption of this type agent considerably. The temperature coefficient of change in dehydrating efficiency is somewhat more than when molecular rearrangement is involved. Many of the agents included in this group are capable of being regenerated, especially if only a small to moderate amount of water has been absorbed. However, some agents tend to melt or fuse at the elevated temperatures required for regeneration at normal pressure, thereby altering their physical form so that they no longer have favorable pore structure or particle size.

The second general group is made up of those agents which depend for their action merely on adsorption. These agents consist of materials which, by their nature or manner of preparation, have a porous structure consisting of capillary openings which are in size often beyond the resolving power of optical microscopes. Condensation of moisture in these capillaries results in a very great diminution in the vapor pressure of the material adsorbed. The drying efficiency of many of these agents (for very small amounts of moisture absorbed) can be shown to be high, in some cases being equal to or greater than, for instance, that of concentrated sulfuric acid. The capacity for moisture of such substances varies from comparatively small (18 per cent with activated alumina—Al_2O_3) to very substantial amounts (45 per cent with silica gel). In becoming saturated, the physical appearance of most of these substances remains unaltered. As a class they can be regenerated readily by heating to a temperature somewhat over 250 F.

Desiccants Suitable for Dehydration of Film.—In view of the special requirements of a desiccant to be used for the partial dehydration of film, the choice of suitable agents is considerably restricted. The following list, however, includes some of the agents which are either (1) generally well adapted for the purpose, or which have outstanding individual properties, or (2) which have been recommended in the past for the purpose of dehydrating film:

Calcium Chloride
Calcium Sulfate (Drierite, Anhydrite)
Silica Gel
Aluminum Oxide (Activated Alumina)
Tea
Rice
Paper
Absorbent Cotton
Charcoal

Calcium chloride and calcium sulfate are widely used desiccants of the hydrate-forming type having some adsorptive properties, while silica gel and activated alumina are representative of the purely adsorptive type.   Tea, rice, paper, absorbent cotton, and charcoal are substances having some absorptive capacity which have been mentioned in the past for use in dehydrating film.

Absorption of Moisture by Typical Useful Desiccants.—The percentage increase in weight of certain of these desiccants over
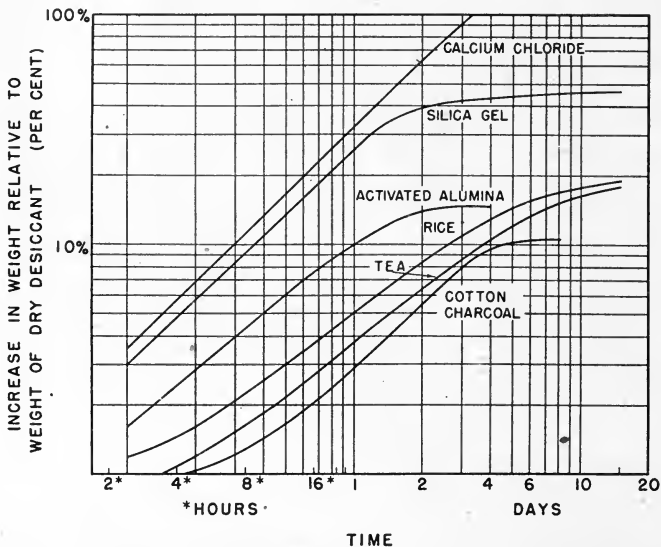
Fig. 3.   Increase in weight of various desiccants at high relative humidity, circulation not forced.

their initial dry weight, under conditions of high (approximately 100 per cent) relative humidity, has been plotted against time in Fig. 3. In making these measurements, the weight of a sample of desiccant (initially 10 grams) enclosed in a small desiccator (20 cu in.) containing distilled water at 70 F was taken at intervals until a constant weight was indicated.   These measurements therefore are based on a static condition, such as might be encountered in a closed chamber containing only film and a desiccant.

Fig. 3 also shows what we have chosen to term the "ultimate moisture content" of these desiccants, that is, the maximum weight of

moisture which a desiccant can absorb at a stated relative humidity and temperature.

It is seen that under these conditions the ultimate moisture content of calcium chloride exceeds a 100 per cent increase in weight of the dry desiccant. Because this particular agent liquefied after absorbing about 60 per cent of its dry weight in moisture, measurements were discontinued when it had increased in weight by 100 per cent; therefore the ultimate moisture content is not shown.
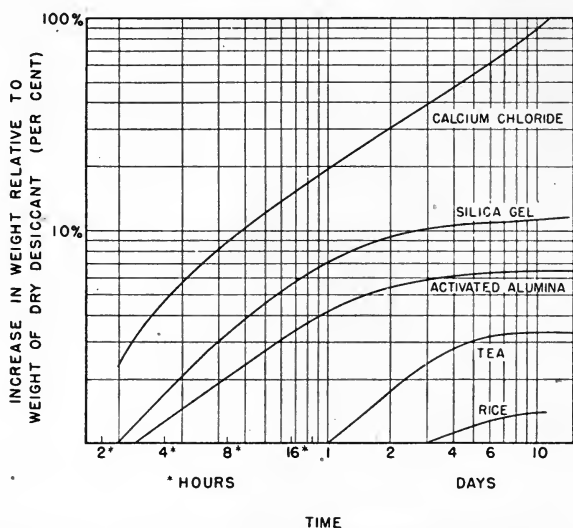
FIG. 4. Increase in weight of various desiccants at low relative humidity, circulation not forced.

With silica gel, the weight increases in much the same manner as with calcium chloride but reaches a maximum after increasing by about 45 per cent.

The ultimate moisture content of the rest of the agents included in these measurements, for practical purposes lies between a 10 to 20 per cent increase in weight, though the time required to reach this condition varies with the different desiccants.

Other samples of these agents were brought from the dry state to equilibrium with an atmosphere of about 30 per cent relative humidity by the use of a suitably adjusted solution of sulfuric acid in the desiccator. Fig. 4, plotted to the same scale as Fig. 3, shows the course of absorption under these conditions. The decrease in ulti-

mate moisture content at the lower value of relative humidity is evident by comparison of Figs. 3 and 4.

Effect of Circulation on Rate of Absorption and on Ultimate Moisture Content.—Another of the factors referred to earlier as affecting the rate of exchange of moisture between film and its surroundings was circulation. The same effect is shown, of course, when a desiccant is considered instead of film. This is illustrated by comparison of Figs. 3 and 5. The conditions existing in collecting data for Fig. 5 were basically similar to those described in relation to Fig. 3; however, a small fan circulated the air within the desiccator in the
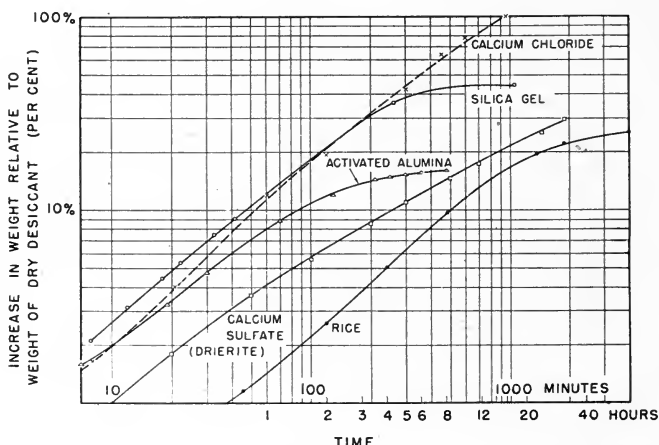
Fig. 5. Increase in weight of various desiccants at high relative humidity, forced circulation.

case of Fig. 5. It will be noted that the rate of absorption was increased 8 to 10 times by the use of circulation. (Note that the time scale in terms of "days" in Fig. 3 compares with "hours" in Fig. 5.)

It will also be noted that the ultimate moisture content of these desiccating agents remained substantially unchanged, showing that, if given sufficient time, the same ultimate moisture content can be attained, whether or not circulation is used.

Ultimate Moisture Content of Typical Desiccants over Whole Range of Relative Humidity.—The increase in weight of some of these desiccants, resulting from the absorption of moisture at various levels of relative humidity (ultimate moisture content) is

shown in Fig. 6. These measurements were made at 70 F. While an increase in temperature would decrease the moisture content, at a stated value of relative humidity and a decrease in temperature would increase the moisture content, the effect in no case would exceed ± 5 per cent of the values given for a temperature variation of ± 20 F.

Disposition of Desiccant with Respect to the Film.—Another factor affecting the rate at which moisture transfers from film to
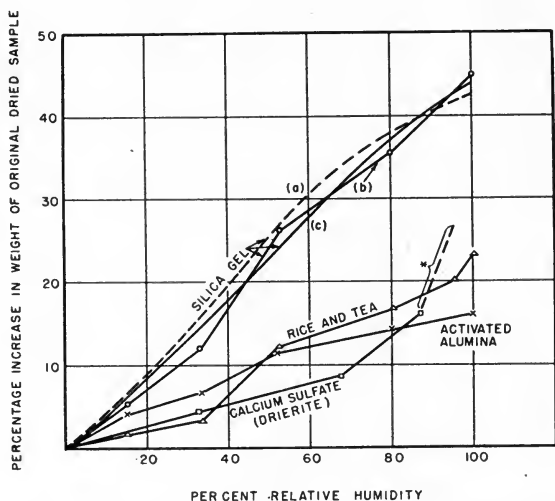
* SURFACE MOIST IN THIS RANGE. MOISTURE CAPACITY NOT WELL DEFINED

FIG. 6. Increase in weight of desiccants resulting from the absorption of water vapor at various levels of relative humidity. Increase in weight referred to weight of sample conditioned at zero per cent relative humidity, temperature, 70 F. Curve (a) plotted from data published by manufacturer; Curve (b) plotted from data obtained in the present work; Curve (c) same as (b), averaged results.

desiccant is the size and shape of the desiccating chamber or of the cells or subdivisions within such a container. While it is true that moisture will eventually diffuse from one section to another as long as the parts are connected, the rate at which such diffusion occurs is highly dependent on the relative proportions. This was shown in a simple experiment in which moisture was allowed to diffuse upward through a glass tube, one inch in diameter, 8 in. long, and closed at the top. The tube was supported above a small vessel of water at

room temperature (70 F). Punchings from a blotter which previously had been soaked in a solution of cobalt chloride and then dried, were arranged at various levels in the tube, so that a color change from blue to pink indicated that a relative humidity of at least 50 per cent had been attained at a particular level. These tests showed that, at constant temperature, at least 24 hr were required to fill the tube with water vapor. Similarly, when concentrated sulfuric acid was substituted for water, the same period of time was required to dehydrate the entire tube, from top to bottom.

While this test showed that moisture transfer takes place somewhat slowly through a long channel or tube, another similar experiment showed that it occurs quite rapidly in a more favorably proportioned chamber. Small cobalt-chloride impregnated punchings, arranged at various levels in a squat laboratory-type glass desiccator jar all changed color within an hour or two, whether the process was one of desiccation or humidification.

TABLE 3

Desiccating Agents Arranged in Order of Increasing Specific Volume

		Specific Volume (Cu In. Per Lb)
(1)	Calcium Sulfate	29
(2)	Black Photo Wrapping Paper Arranged Sheet upon Sheet	32*
(3)	Rice	32*
(4)	Activated Alumina (14–20 mesh)	32
(5)	Silica Gel (8–20 mesh)	43
(6)	Calcium Chloride	44
(7)	Tea	60*
(8)	Charcoal	
(9)	Crumpled Black Photo Wrapping Paper	280 or more

* Approximate, depending on sample and treatment.

These 2 tests have been cited to illustrate the type of condition to be avoided, in one instance, and to be sought in another.   Practically, it might be pointed out that the size and shape of wound rolls of motion picture film tend to dictate that a desiccant (1) be arranged in the form of a ring with the film roll resting in the center or, better, (2) be spread out in a layer above and below the roll of film which lies flat in its container.   Either scheme distributes the desiccant with respect to the film and provides a short path.

With some film products other than motion picture film, their size

and shape are such that they could be packaged to form a long constricted channel between the more remote parts and the desiccant. Such a condition is, of course, to be avoided.

Volume-Weight-Packing Relationships.—One of the factors affecting the space in a film desiccating container which must be devoted to the desiccant is the specific volume of that agent—that is, the volume occupied by a unit weight of the substance in question. Table 3 is made up of those agents listed as typical of more satisfactory agents, and is arranged in order of increasing specific volume— the space required by agents farther down in the list is greater than that required by those above.

Closely allied to the specific volume of the bulk material is the manner in which the desiccant tends to pack in its container. Coarse, granular particles, such as silica gel,* rice, alumina,* calcium chloride,* or calcium sulfate,* pack in such a manner that connected voids exist between particles which permit the passage of moisture, thus promoting a higher rate of desiccation. The internal structure of the particles is important in this same respect. Tea leaves tend to pack with smaller connecting voids while stacked paper offers a very poor circulatory path. Crumpling the paper improves this situation but the specific volume increases greatly. The use of paper confetti would improve the circulatory path somewhat without increasing the bulk to the extent caused by crumpling the paper.

Membrane Separating Film from Desiccant.—The last of the factors to be discussed, which influences the rate of diffusion of moisture from film to desiccant, is the effect of any film wrapping or membrane separating the 2 materials. In any case where the film dehumidifying chamber is to be moved about during use, it is necessary to shield the film from even small particles of the desiccant. Such particles are likely to cause mechanical damage or spots on the developed image. Sheet or membranelike materials which will transmit water vapor but filter out the dust offer an effective means for separating the 2 materials. In some cases they can be used to wrap the film, provided all openings are cemented shut; in others, they may be used to confine the desiccant in a chamber of its own.

While the use of such moisture pervious membranes may be necessary under some circumstances, they all have a restraining effect on diffusion. This is evident from Table 4, in which the rate of diffusion

---

* In the forms supplied for drying.

of water vapor through various materials is compared with the rate existing when no membrane was present.

The test membrane was cemented over the opening in a small wide-mouth jar in which was an ample supply of desiccant. Moist air was circulated over all of the jars by means of a desk fan to avoid the effects of local depletion, uncontrolled convection, *etc*.

TABLE 4

Rate of Transfer of Moisture by Membranes under Effect of Large Humidifying Potential

	Membrane Material	Relative Rate of Transfer of Moisture (Per Cent)
(1)	No membrane	100
(2)	Filter Paper (Will Corp. No. 7679)	25
(3)	Matted Fiberglas pad ($1/_{16}$ in. thick)	20
(4)	Chamois ("Photo Chamois" E. K. Co.)	20
(5)	Thin interleaving paper (black photo)	18
(6)	Blotter (Photo-Blotter, E. K. Co.)	16
(7)	Film Pack Paper (E. K. Co.)	16
(8)	Film Wrapping Envelopes (various weights)	13 to 8

It is evident from these results that the comparatively heavy papers used for film envelopes and wrappings are among the more impermeable to the passage of moisture. The Fiberglas pad, chamois, filter paper, and interleaving paper make up a group of more permeable materials which offer a minimum of resistance. The filter paper and lightweight paper may suffer from the disadvantage of becoming somewhat brittle.

Methods of Utilizing Desiccants in Dehydrating Film.—Up to this point the discussion has involved (*a*) the factors affecting the absorption of moisture by film, and (*b*) the factors applying to the choice of desiccant. At this time, therefore, we turn to consideration of the use of suitable desiccants in the partial dehydration of film.

Two general methods of utilizing desiccants for removing moisture from film can be used. The first, capable of the more rapid action, consists in holding the film temporarily in a suitable container with a large excess of a powerful desiccant. When sufficient time has elapsed to dry the film to a proper moisture content it is removed and sealed in another container without desiccant until processing is undertaken. This procedure will be referred to in the future as the "temporary desiccator" method.

The second method, which should only be considered when the need for rapidity in desiccating is less, involves packing the film immediately after use with a quantity of desiccant estimated according to the particular situation to provide for eventual equilibrium at a selected value of relative humidity.   The film container is not reopened until the time of processing.   This will be referred to as the "permanent packaging" method.
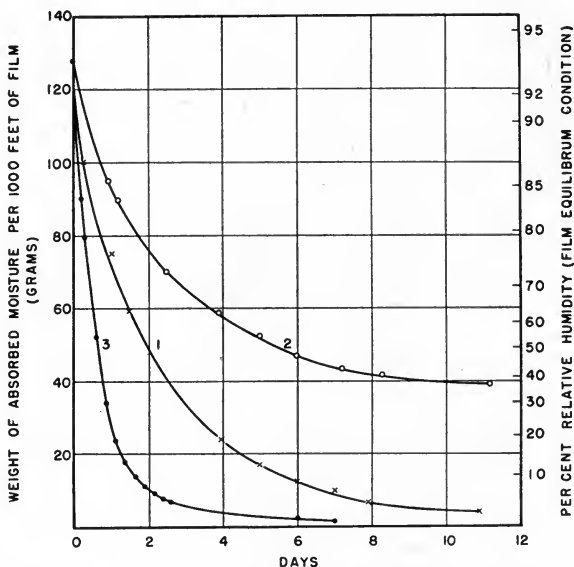
FIG. 7.   Desiccation of a loosely wound roll of nitrate negative motion picture film, circulation not forced. Film initially in equilibrium with 93 per cent relative humidity temperature 70 F.   Curve (1) film desiccated over large excess of concentrated sulfuric acid, normal pressure;   Curve (2) film desiccated over a limited amount of silica gel, normal pressure;   Curve (3) same as (1) but at reduced pressure (2 in. mercury, absolute).

A variation of the second method seems to be the one most often recommended in the past when a film desiccating problem arose. However, in many cases the benefit which could be gained from the quantities of such low-capacity desiccants as dried tea, rice, or paper sometimes suggested could hardly have been noticeable.   This will become more apparent as we consider the quantitative factors concerned.

To illustrate the operation of these 2 methods of utilizing desiccants, the following experimental evidence may be cited.

Laboratory Test Involving Temporary Desiccator Method.—
In an experiment involving the temporary desiccator method, a loosely (but not openly) wound roll of motion picture film (nitrate negative) in initial moisture equilibrium with an atmosphere of about 93 per cent relative humidity was suspended in a desiccator over a large excess of a powerful desiccant—in this case, concentrated sulfuric acid. The film was arranged in such a manner that its weight could be measured without opening the desiccator. A room temperature of 70 F was maintained. Circulation was not forced in any way but the size and proportions of the container were favorable for spontaneous convection.

The results of this test are shown in Fig. 7, Curve *1*. It is seen that under the conditions used, the moisture content of such a wound roll can be reduced from high to moderate values quite rapidly, $2^1/_2$ days being required to reduce the equilibrium condition of the film from 93 to 40 per cent RH. At values less than 40 per cent, desiccation proceeds at a rapidly decreasing rate.

·**Laboratory Test Involving Permanent Packaging Method.**—
Another test involving the permanent packaging method was carried on under conditions identical with the test just described except that the film and the desiccant, in this case silica gel, were of such quantities relative to each other as to come to equilibrium at about 40 per cent RH. The results of this experiment are shown in Fig. 7, Curve *2*. It will be observed that, instead of $2^1/_2$ days, nearly 10 days were required to reach the desired relative humidity.

Temporary Desiccator Method at Reduced Pressure.—A third test illustrates the increase in rate of desiccation which can be attained by the use of a moderate vacuum. Conditions during this test were identical with those described in connection with the temporary desiccator method except that the pressure in the vessel was reduced to about 2 in. of mercury. Such a pressure can often be attained by using a water aspirator pump. Curve *3*, Fig. 7, when compared with Curve *1*, illustrates the increase in rate of desiccation which can be obtained simply by reducing the resistance offered by the air to the diffusion of water vapor. Equilibrium with an anmosphere of 40 per cent RH was attained in about 18 hr, compared with $2^1/_2$ days at normal pressure.

Relative Usefulness of Typical Desiccants.—It now becomes

evident that, of those requirements listed in the section "Properties of a Desiccant Suitable for Dehydration of Film," the principal ones are "high moisture-absorbing capacity" and "rapid rate of absorption." These are true whether the desiccant be packed with the film in the temporary or the permanent manner.   Another requirement applying only to the permanent method is that the desiccant should not liquefy.   Considering these major requirements, we can now evaluate the usefulness of those desiccants selected as typical.

Silica gel appears to be the most generally satisfactory of the desiccants considered for the purpose.   Its capacity for moisture and rate of absorption are good, and it retains its original physical form, even on becoming fully saturated.   It is inert chemically and presents no serious problem in packaging or handling except the usual one of confining the dust.'   If necessary, it can be regenerated, even under field conditions.

Calcium chloride has a great moisture-absorbing capacity and a high rate of absorption so that in cases where its tendency to liquefy is unimportant, as in the case of the temporary desiccator method, it can be used to advantage.   It must be kept in mind, however, that calcium chloride is an expendable material since, after liquefaction, the steps necessary to return it to useful physical form are generally impractical for field application.

The low to moderate moisture-absorbing capacity and rate of absorption of activated alumina and calcium sulfate, especially in the intermediate range of relative humidity, reduces the usefulness of these agents in the present application in spite of the fact that they can be regenerated easily.   In cases where added weight and bulk are not important considerations, these agents would be satisfactory otherwise.

Readily available materials, such as tea, rice, paper, *etc.*, are generally deficient in both capacity and rate of absorption.   To obtain useful results, large quantities (volumes) are ordinarily required. The use of such materials will be considered, however, in the next section, in view of the possibility that, under some circumstances, they may be the only materials available for the dehydration of film.

Besides desiccants belonging to the groups listed, many other agents might, under certain circumstances, be used for the purpose. In general, these can be classed as agents which have satisfactory desiccating properties, but which are unsuited for field use because of other undesirable properties.   For instance, concentrated sul-

furic aid is an excellent desiccant but cannot be recommended for general field use because of its corrosive nature. However, should such an agent be the only one available, it can be used if suitable precautions are taken. Sodium or potassium hydroxide and quicklime are other examples of this type of agent.

RECOMMENDED PRACTICE

The best advice which can be given when film is to be exposed to humid atmospheres and heat is: "Do everything possible to prevent the film from absorbing excess moisture. If conditions are unfavorable, avoid long storage of film." Then, if in spite of every precaution, the preservation of the latent image is not assured, an adequate dehydrating procedure should be applied immediately. It should be kept in mind that, while suitable dehydration can retard the progress of change in sensitometric properties, it can do nothing to correct changes which have already occurred.

Film packaged by the manufacturer in tightly sealed sheet metal or flexible metal foil containers may be considered safe from change in moisture content at least while the film remains in the package. Such a film container offers no protection from the effects of high temperature, so that it should be stored in as cool a place as possible. However, if this is done, the film should be allowed to warm up to the temperature of the atmosphere in which it is to be used for a period of about a day; otherwise, moisture from the humid atmosphere is likely to condense on the film as soon as the package is opened.

The film container should not be unsealed before it is necessary to do so. If possible, film holders, magazines, cassettes, *etc.*, should be dried before use and should be loaded promptly and sealed with moisture-proof tape. In addition, they may be enclosed in one or more moisture-proof containers, capable of being sealed. Cameras should also be enclosed in moisture-proof containers, especially if they are loaded with film. Watertight slide fastener closures have recently been introduced which may prove to be well suited for use on moisture-tight bags.

After exposure, the film holder should be temporarily sealed again until protective measures or final packing can be undertaken.

Whenever possible, film handled under unfavorable conditions should be processed promptly, if necessary using a tropical processing procedure. Such processed film should then be adequately desic-

cated and sealed in a moisture-proof container to avoid growth of mold, fungus, or other damage.

Special care should be given to motion picture film, once the manufacturer's seal is broken, since lack of adequate equipment will often delay processing for many days or weeks under some field conditions. The raw film should be kept as cool as possible, although there is little practical benefit to be gained at temperatures below 50 F unless film is to be stored for many months.

If the film has been exposed to high humidities, the protection of desiccation should be given unless it is to be developed immediately. In the event that the exposed film must be kept more than a week or two and that the storage temperature may exceed 85 to 90 F, it is advisable to dehydrate the film even if it has not been subjected to high humidity conditions. Any film which has been subjected to desiccating procedures should be rehumidified before handling to avoid markings caused by static electrical discharge.

Practical Use of Refrigeration.—Refrigeration equipment can be used effectively for desiccating film if conditions are set up so that the moisture given up by the film to the atmosphere in contact with it is removed therefrom as dew or frost on the cold surface. In order that the moisture content of the film shall be brought to the 40 per cent RH level which is recommended by one manufacturer the temperature of the cold surface should be 25 to 30 F lower than that of the film which is assumed to be in the range of temperatures above 60 F. In order to ensure drying within about a day, the air should be in rapid circulation and should have access to all of the film surface. With rapid circulation it will be necessary that the air leaving the cold surface be reheated (to ambient temperature) so that it will not cool the film and thus lower the vapor pressure of the moisture in it. If the operation is carried on more slowly without circulation in an uninsulated container, the film probably will receive enough heat from the surroundings to maintain its temperature. The usual insulated domestic refrigerator, in which the cold surface is small and at a temperature below the frost point while the stored material more or less surrounds it and is at a temperature 15 or 20 F higher, can be used but will be slower. On the other hand, the film will have the protective effect of the lowered temperature during dehydration. There is no need for an insulated container for the drying operation. It is necessary only that an airtight (and probably light-tight) box enclose the film and cool surface and that provision be made for

circulation and for keeping the film temperature high enough, probably best above the dewpoint of the outdoor atmosphere to avoid having the film wetted as it is removed for repacking. There is no disadvantage in having the cold surface lower in temperature than that given above except that the precipitated moisture may be held as frost instead of draining away.

Practical Use of Evacuation.—Methods involving the use of a vacuum are of 2 types, those in which the pressure in the chamber is much less than the moisture vapor pressure corresponding to the desired condition of the film, and those in which it is higher, usually a few inches of mercury. In order to meet the 40 per cent RH requirement, the maximum allowable moisture vapor pressure of equilibrium at the end of the operation ranges from 0.56 in. of mercury for film at 90 F to 0.21 in. at 60 F.

The procedures and equipment in the first-mentioned method are simple, consisting essentially of a pump, McLeod gage, and a tight evacuating chamber. This method is in many respects preferable to all other dehumidification methods but can be considered only when one-half to 2 hp is available either from a central service, a portable unit, or automotive take-off. No desiccants are needed in this procedure. It is worth some effort to have the use of this method if extreme conditions demand prompt action, especially with film unfavorably disposed as in wound rolls, film packs, *etc.*

The specification of pumping equipment is somewhat involved because of the interdependence of working pressure, pump capacity, moisture load, and chamber size. In using this method it is suggested that the assistance of someone familiar with the practices of vacuum pumping be enlisted. In order to maintain the pressures of the order of one millimeter (0.040 in.) of mercury or a little lower necessary for a reasonably high rate of moisture extraction, the pump chosen is likely to be one offered by the laboratory supply houses for medium high-vacuum pumping. However, a large volumetric capacity in the range down to 0.1 mm mercury is to be preferred over the ability of a pump to reach extremely low pressure as the pressure actually attained with a reasonable choice of equipment is likely not to range below 0.1 mm until most of the moisture is withdrawn from the film. Pumps which have a capacity of 10 to 20 liters per sec (20 to 40 cfm) should be capable of dehydrating a 1000-ft roll of motion picture negative film well below the safe upper limit in 5 to 8 hr. To avoid the uncertainties arising from estimates of moisture taken up pre-

viously by the film, it is advisable to pump long enough to remove most of the water which could possibly be present. The film will require rehumidification according to a procedure given later, before being handled again.

Aspirator pumps and many of the ordinary vacuum pumps are incapable of maintaining a sufficiently low pressure for this purpose.

Pressures of a Few Inches.—In the second case where pressures of a few inches of mercury are employed, various types of mechanical vacuum pumps are acceptable. The reduction of pressure is used to remove most of the air so as to facilitate the movement of moisture through the space between the film and the desiccant which are in the evacuated enclosure. Since in this method the burden of absorbing the moisture given off by the film is taken entirely by the desiccant, a pump of small capacity is adequate and need not be kept in operation after the required pressure is attained. It might therefore even be of the hand-powered type. A single pump can serve a number of drying chambers if a valve is closed after evacuating and the pump transferred from one chamber to another.

With the proper quantity of desiccant in this system, the moisture content can be reduced in 24 hr from any concentration to a safely low level even from motion picture film in a wound roll, as shown in Fig. 7 which was discussed in an earlier section. Unlike the previously discussed lower pressure method, it is important in the present case that all obstacles to diffusion such as impervious wrappings be eliminated if retardation of the process is to be avoided. This method demands nothing beyond the small pump, the desiccant, and a working supply of tight containers, and should be adaptable to many situations. The quantity of desiccant required is the same as when normal pressure exists.

Practical Use of Desiccants.—It would seem that decisions as to desiccants and procedures may have to be made in the field under 2 conditions. In one, a photographic expedition might unexpectedly find it necessary to keep exposed undeveloped film when operating under adverse atmospheric conditions. The need for dehydration might be recognized but unless certain easily obtainable materials could be utilized, regardless of their efficiency, grave danger to the latent image might exist.

In the second case, the need for dehydration might be anticipated when planning an expedition so that the choice of methods for com-

bating unfavorable atmospheric conditions would be limited only by difficulty of transport or similar factors.

In the practical use of desiccants, 2 steps are necessary:

(1) An estimate must be made of the approximate weight of moisture to be removed. A knowledge of the relationship existing between equilibrium moisture content and relative humidity for the particular film being treated is useful. This relationship has been shown (Fig. 1) for a typical negative motion picture film.

(2) The weight of desiccant required to reduce the moisture content to a desired value must be calculated (permanent packaging method) or the time necessary for an excess of a powerful desiccant to accomplish the same result must be estimated (temporary desiccator method).

It is apparent that only the most approximate estimate of film moisture content is possible without elaborate instrumentation. However, in view of the fact that an error in the direction of overdehydration has no severe penalty, provided the film is rehumidified before handling, such an estimate is entirely adequate.

The factors which should be considered in estimating the quantity of moisture absorbed by the film have already been discussed in the sections following "Moisture Exchange and Equilibrium." Hence such materials as sheet film, small roll films, film packs, and similar products can be expected to approach moisture equilibrium with the relative humidity of the atmosphere to which they are exposed within a day under usual handling conditions. It is not unreasonable, therefore, to anticipate equilibrium with an atmosphere which is as high as 90 per cent RH with these materials. Motion picture film, on the other hand, in wound roll form has been shown to offer a diffusion path of high resistance even when the roll is wound loosely. It would therefore appear that a wound roll of undeveloped motion picture film given reasonable care in handling might attain equilibrium with a relative humidity of only 80 per cent and usually less, in the same circumstances. In fact, if the factors of time, temperature, and relative humidity were such as to cause the film to reach equilbrium with a relative humidity higher than 80 to 85 per cent, it is most likely that the film would simultaneously be damaged by mold.

If conditions have been such that equilibrium with a relative humidity higher than 75 per cent is suspected, the more rapid acting, temporary packaging method or evacuation at low pressure is to be preferred. For an estimated equilibrium relative humidity of less than 75 per cent, the slower acting permanent packaging method

should prove adequate, unless temperature conditions are to continue at 90 F or more.

In view of the fact that a wound roll of motion picture film responds more slowly than some other types of film to dehumidifying measures, the application of desiccating data already presented will be considered for that case.

Temporary Packaging Method.—On the assumption that a moisture content corresponding to a relative humidity of 85 per cent is the highest which is likely to be encountered with motion picture film, the minimum time required to reduce the moisture content to relatively safe values can be determined. Fig. 7, Curve *1*, shows that under conditions similar to those which might be employed in applying this method, using a large excess of a powerful desiccant, concentrated sulfuric acid in this case, approximately 2 days would be required to reduce the moisture content from that of equilibrium with 85 per cent RH to equilibrium with about 40 per cent. The presence of wrappings would require more than if the film was not wrapped.

Errors in overestimating the moisture content of the humidified film and thereby choosing a length of time for desiccating which is in excess of the minimum required for safe storage are not serious since the rate of moisture removal at levels corresponding to relative humidity values below 30 per cent is comparatively slow. This is shown in Fig. 7, Curve *1*.

Though detailed data relative to the rate of dehydration were not collected for other types of film in the course of the present work, similar considerations apply. These films should be arranged in a desiccator so that all surfaces are exposed to the drying action. The somewhat confined conditions existing in film packs or magazine wound miniature camera films would retard drying considerably. In such instances, parts of the film holder should, if possible, be removed to provide better access.

The minimum weight of desiccant which can be used effectively with the temporary desiccator method depends principally on the moisture-absorbing capacity and rate of absorption of the desiccant being considered. While it is true that the use of a greater weight of a less active desiccant is capable of attaining the same rate of dehydration as a smaller quantity of a more active agent, a practical limit is reached when the volume required is such as to create long diffusion paths. For instance, a deep bed of an agent, such as rice, would

hardly produce an effect equivalent to that of a shallow bed of calcium chloride, even though a similar rate might be attainable if these agents could be utilized under equivalent conditions of access.

As a practical guide to the use of desiccants with the temporary desiccator method, it appears that, with a large excess of an effectively utilized desiccant, the time required for the dehydration of mot on picture roll film is not less than 2 to 3 days; individual sheets of film may attain a satisfactory moisture content in 4 to 8 hr, while confined films (film packs, cassettes, *etc.*) should be treated at least one or 2 days, provided the moisture-proof cases confining such films are opened.

Permanent Packaging Method.—Probably the most direct way of illustrating the use of data already presented as it may be applied to the permanent packaging method is by the solution of a typical problem.

Let us assume that it is desired to know the quantity of silica gel which will be required to reduce the moisture content of 1000 ft of negative motion picture film from that existing in equilibrium with 80 per cent RH to that present at 40 per cent RH.

On referring to Fig. 1 which shows the weight of water vapor absorbed by 1000 ft of negative motion picture film in equilibrium with atmospheres of varying relative humidity, it is seen that the moisture content of the film at 80 per cent RH is about 83 grams; at the equilibrium condition desired, 40 per cent RH, it is 40 grams; therefore the weight of moisture to be removed is 43 grams per 1000 ft of film.

Referring now to Fig. 6, it is seen that at the desired terminal condition, 40 per cent RH, 0.175 gram of moisture will be absorbed by each gram of silica gel. Since 43 grams are to be absorbed, the weight of silica gel required will be 43 divided by 0.175 or 246 grams (approximately $1/2$ lb).

This result for silica gel can be obtained more readily by reference to Fig. 8. By selecting the curve representing the initial moisture content of the film (specified in terms of the relative humidity with which it would be in balance), the quantity of silica gel required to reduce the moisture content to any other equilibrium condition can be read directly.

Curves similar to those of Fig. 8 could be constructed for other desiccants by derivation from data presented in Figs. 1 and 6. It is interesting to note that if tea or rice had been used in the example just

given, approximately $1\frac{1}{2}$ lb would have been required to attain the same equilibrium moisture content as was obtained with $\frac{1}{2}$ lb of silica gel. However, since the rate of absorption with such agents is low, it would be advisable to increase the weight of desiccant used to assure an adequate rate of dehydration. An increased weight of desiccant would be used similarly to offset the retardation caused by the presence of a membrane, wrappings, *etc.* The fact that a lower equilibrium moisture content would eventually be obtained would
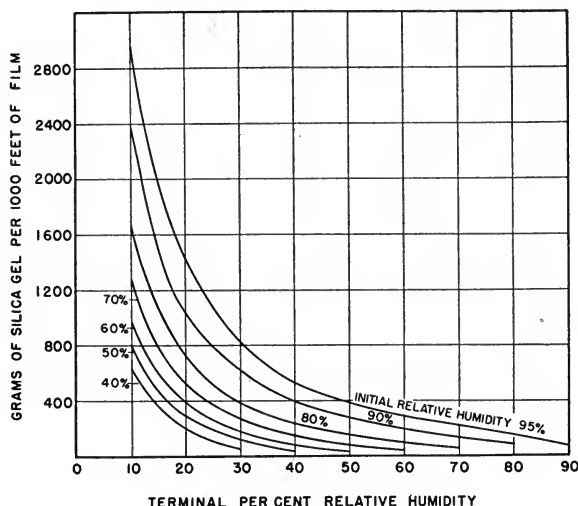
Fig. 8. Amount of silica gel required to reduce moisture content of nitrate negative motion picture film in equilibrium with a given value of relative humidity to that of any other desired relative humidity.

ordinarily be unimportant. The space requirement with tea, for example, would be increased also by its high specific volume.

This practice can be extended to other films by determining the relationship existing between moisture content and equilibrium relative humidity with the film being considered.

Handling Desiccated Film.—The effects of rewinding or otherwise handling unprocessed film which has been overdried are well known. One of the most serious of these effects is the markings caused by static electrical discharges.

Because of the uncertainty involved in determining the actual moisture content of the film under field conditions, it is best to handle all film which has been subjected to dehumidification treatment as if

it were overdried.   Therefore, before such film is rewound or handled in any other way it should be rehumidified so that it attains equilibrium with an atmosphere of 60 to 65 per cent RH.   One method for accomplishing this is as follows: The roll or the sheets of film should be removed from the sealed container in the darkroom with care to prevent cinching or sliding.   Film in film packs or in cassettes should not be removed from the holder until after it is humidified, although parts of the holder not in contact with the film which might impede diffusion should be removed.   The film should then be laid on an open grill or screen arranged so that air can circulate both above and below. The humidifying air should be at 60 to 65 per cent RH (not higher) and should be circulated in the vicinity of the film by means of a fan.

The time required to rehumidify a wound roll of motion picture film depends, of course, on its initial moisture content.   However, under the conditions described, one day (24 hr) should be sufficient to rehumidify such film, even though it has attained equilibrium with a low value of relative humidity.   Failure to circulate the air increases the time required many times.   Other types of film would normally respond somewhat more quickly than wound motion picture film because of better access to the humidifying atmosphere.

Care of Desiccants.—It is necessary that the desiccant be stored in a sealed container up to the time of use.   Products sold specifically for the purpose are ordinarily fully activated and are supplied in suitable containers by the manufacturer.   Obviously, provisions must be made for resealing a large stock container if only part of its contents are removed at one time.   A better plan is to provide many small packages so that the unused portion of the stock will remain unaffected.

If it becomes necessary to reactivate used desiccant, or to activate such substances as tea or rice, this can be accomplished in an oven such as is used to bake or roast foods (bread or meat).   Ovens designed for reactivating are generally intended for large-scale operations and require a large source of heat or electrical power.   Inorganic desiccating agents should ordinarily be heated to a temperature between 300 and 500 F.   One or 2 hr treatment at the higher temperature and 4 to 5 hr at the lower temperature should be sufficient.   Inorganic desiccants which have become contaminated with oil or other organic matter should not be reactivated in the field because there is no protection against fire when the material is heated.

Some organic agents, such as tea or rice, however, cannot be heated much above 250 F without decomposing; this is indicated by the evolution of an abundance of smoky fumes. Rice may be considered ready for use when, on stirring during heating, it becomes uniformly light brown in color. Photographic black paper has been heated nearly to 500 F before smoking, while one grade of white paper scorched within one to 2 min at about 600 F.

Certain commercial desiccants are available in an "indicating" form—that is, they are impregnated or coated with an agent which changes color as the moisture content exceeds a critical value. Cobalt chloride is sometimes used as an indicator, undergoing a color change from blue to pink as moisture is absorbed. The transition occurs in the range of moisture content corresponding to 30 to 60 per cent RH. Therefore the mere fact that the color is blue does not necessarily indicate that the desiccating agent is fully activated; however, a neutral or pink color does indicate that, for practical purposes, the drier is entirely spent.

Certain transparent or window-type packages supplied commercially are not intended to withstand the high temperatures used in reactivation.

Improvised methods of activating, such as drying the intended desiccant on a shovel held over a fire, or pouring it over heated rocks, have sometimes been described. Such methods are capable of limited success but results are rather uncertain. It would seem that they should be applied only if the need for desiccating had not been foreseen when planning an expedition and the use of available materials and methods was later found necessary. The following suggestions may be found useful in this situation.

Activation should be carried on so that the temperature of the mass of desiccant is above the boiling point of water. While glass thermometers can be obtained for temperatures up to 400 F, and all-metal-type thermometers up to 1000 F, it seems likely that, under unforeseen conditions, such equipment would be lacking. In this case it can be made certain that the temperature of boiling water has at least been attained by embedding a few small pebbles in the desiccant; when these are removed and dropped into water, momentary sizzling indicates that a temperature of at least 212 F has been reached. In some cases, lead-tin solders may be available. These have their melting point in the range of temperatures between 212 and 500 F and therefore may be used for indicating temperatures.

The temperature of activation should not exceed that at which decomposition of the desiccant takes place.

The temperature within a mass of the desiccant during treatment rises slowly because the material is a poor heat conductor and heat is taken up in the process of evaporating water. For these reasons the oven air temperature can be considerably higher than the safe upper limit for the dessicant. If the temperature of the bed increases rapidly later in the drying process, it is a likely indication that evaporation has ceased and that the agent is substantially dried.

During treatment, the material should be spread out in a layer 1 to 2 in. thick, if possible. Two to 4 hr treatment should be sufficient under suitable temperature conditions. After the heating has been completed, the substance should be transferred immediately to a sealed container and allowed to cool there before use.

AMERICAN STANDARD 16-MM TEST FILMS

As part of its wartime standardization work, the Society of Motion Picture Engineers prepared rigid specifications for nine 16-mm test films to meet fundamental test and performance requirements laid down by our armed forces.

Excessive equipment failures and the lack of suitable test standards for 16-mm projection were the reasons behind the request of the services to both the Society and the Research Council of the Academy of Motion Picture Arts and Sciences for aid in this War Standards project. During the war and shortly thereafter, most of the test films produced were required for government obligations, but now that the service contracts have been substantially completed, it is possible for the Society to begin supplying these films to civilian industry in this country and abroad.

Six of the American War Standards, 5 specifying test films and one covering a projection type of resolution test plate, were reviewed under the regular procedure of the American Standards Association's Sectional Committee on Motion Pictures Z22, in October, 1945. They were approved by Z22 and subsequently by the SMPE to continue as American Standards rather than as American War Standards. The Z52 number designations have been superseded by Z22 numbers and all 6 standards appear in the April, 1946, JOURNAL in American Standard format. The 6 standards specify 6 individual test films and the one resolution test plate, as listed below.

For the convenience of those who worked on, or are otherwise familiar with, the War Standards, the Z52 numbers are shown in the list that follows as subordinate references. They should *not*, however, be used when ordering either the standards or the films.

The printed standards are now available from the general offices of the Society, either as individual sheets at 15 cents each, or in combination with the other 14 American Standards which were published in the April, 1946, JOURNAL. The latter are furnished in an attractive leatherette covered, loose-leaf binder at $4.50 per set. The binder may be purchased separately at $2.50; however, the combination of binder with all of the current American Standards

represents a saving of $1.00 per set. (All subsequent American Standards on Motion Pictures will be issued punched to fit this binder and may be purchased either from the American Standards Association, 70 East 45th Street, New York, N. Y., or the Society of Motion Picture Engineers, Hotel Pennsylvania, New York 1, N. Y.)

The American Standard Test Films are made to extremely close tolerances, certain of them are individually calibrated, and all are packed in sealed metal containers with complete instructions for use. They are available from the general offices of the Society, and the prices quoted include shipping charges within the United States.

Sound Focusing Test Film.—*Sound Focusing Test Films for 16-Mm Sound Motion Picture Projection Equipment, Z22.42-1946* (Z52.11*). Service Type, 100 ft at $27.50; Laboratory Type, 100 ft at $27.50.

This test film carries a special "square wave" track, chosen because its output changes more rapidly with changes in the focus of the sound optical system of the projector than the output from the usual "sine wave" high-frequency track. The "square wave" track also gives a more sensitive indication of the errors of the "azimuth" adjustment of the sound reproducing light beam.

The Sound Focusing Test Film is an original negative and is made in 2 types: *Laboratory Type*, being a 7000-cycle record for manufacturing and precision adjustment of the focus and azimuth of the sound optical system, and *Service Type*, being a 5000-cycle record for quick service adjustment.

3000-Cycle Flutter Test Film.—*3000-Cycle Flutter Test Film for 16-Mm Sound Motion Picture Projection Equipment, Z22.43-1946* (Z52.9*). 380 ft at $104.50.

This test film is a direct-positive original recording that carries a 3000-cycle record having extremely low flutter content for use in measuring the flutter introduced by 16-mm sound reproducers. The recorded frequency is within 25 cycles of the 3000-cycle frequency, the output level is constant within $1/4$ db, and the total flutter content of the film at the time of shipment is less than 0.1 per cent.

Multifrequency Test Film.—*Multifrequency Test Film for Field Testing 16-Mm Sound Motion Picture Projection Equipment Z22.44-1946* (Z52.8*). 150 ft at $41.25.

This test film contains the following series of frequencies each preceded by a spoken announcement:

Frequency Cycles	
400	2000
50	3000
100	4000
200	5000
300	6000
500	7000
1000	400

* The Z52 number is included for reference only and is not a part of the American Standard title.

This is a direct-positive original recording and the several frequencies are re-corded in such a manner that if reproduced by a scanning light beam of negligible width, they would produce constant light modulation at the phototube.

Each film is individually calibrated on equipment correct within $\pm^1/_4$ db up through 3000 cycles and within $\pm^1/_2$ db above 3000 and through 7000 cycles. The deviation from the intended flat response characteristic (assuming negligible reproducing light beam width) is stated as a correction for each frequency which will give the true level when it is added algebraically to the output level measure-ment obtained when using the film.

400-Cycle Signal Level Test Film.—*400-Cycle Signal Level Test Film for 16-Mm Sound Motion Picture Projection Equipment, Z22.45-1946* (Z52.17*). 100 ft at $27.50.

This film is a direct-positive original recording designed to furnish as nearly as is practical an absolute standard of recorded signal level for use in measuring the effective amplification and sound output of 16-mm sound motion picture pro-jectors taking into account the sound optical system and phototube, as well as the amplifier and loudspeaker.

A definite output level is determined by specifying the amplitude of the re-corded signal, the density of the image, and the combined base and fog density of the clear part of the sound track within narrow limits. The specified level is approximately 2 db below the maximum level possible and is about equal to the highest level that is to be expected in most recording, since in commercial practice the image density is usually not so great and the fog density not so low as the values specified for this film.

The actual measured values of signal amplitude, image density, and fog density are given with each film, together with the corresponding calculated value of over-all deviation from the intended standard signal level.

Resolving Power Test Target.—*Method of Determining Resolving Power of 16-Mm Projector Lenses, Z22.53-1946* (Z52.5*). Glass test plate at $10.

This target is a high resolution glass plate carrying a series of 19 groups of line patterns suitably spaced within the standard 16-mm projection aperture area. Each pattern consists of 7 sets of parallel lines indicating lens resolving power of from 20 to 90 lines per mm. This plate is intended for use with a special test projector designed to hold both the test target and the 16-mm projection lens under test. The resolution of the lens may then be read directly from the pro-jected image on a screen.

Travel Ghost Test Film.—*Method of Determining Freedom from Travel Ghost in 16-Mm Sound Motion Picture Projectors, Z22.54-1946* (Z52.4*). 100 ft at $12.

This film carries a pattern consisting of 9 small diamond-shaped transparent areas on a black background. Three of these areas are at the top of the picture near the frame line, three of them are on the horizontal center line of the frame, and three are near the frame line at the bottom.

---

* The Z52 number is included for reference only and is not a part of the Ameri-can Standard title.

Light streaks (travel ghost) running upward or downward on the screen from the projected diamond-shaped areas show that the projector shutter is improperly adjusted. With a properly designed and properly adjusted 16-mm projector, no travel ghost will be seen.

AMERICAN WAR STANDARD 16-MM TEST FILMS

There are 5 American War Standard Test Films now available to the industry in this country and abroad from the Bell and Howell Company, 7100 McCormick Road, Chicago, Ill.; the Research Council of the Academy of Motion Picture Arts and Sciences, 1217 Taft Building, Hollywood, Calif.; and the Society of Motion Picture Engineers, Hotel Pennsylvania, New York 1, N. Y. These 5 test films are specified in detail in the 4 American War Standards listed below. Printed copies of these War Standards are available only from the American Standards Association, 70 East 45th Street, New York, N. Y., at 10 cents each.

Selected Sample Test Film.—*Test Film for Checking Adjustment of 16-Mm Sound Motion Picture Projection Equipment, Z52.2-1944.*

This is a sound test film with accompanying picture for checking the adjustment of 16-mm sound motion picture projectors and for judging the acoustics of the room in which the projectors are operated. The film is a 16-mm print rerecorded from a 35-mm original, containing main title music, 3 excerpts from studio feature releases recorded on variable-density track, and 3 excerpts from studio feature releases recorded on variable-area track. There is also a piano section recorded on variable-area track.

This film is 380 ft in length, and is available from the Research Council of the Academy of Motion Picture Arts and Sciences, 1217 Taft Building, Hollywood, Calif., at a price of $30 each. However, an inquiry concerning delivery should be directed to the Research Council before placing an order.

Picture Unsteadiness Test Film.—*Method of Determining Picture Unsteadiness of 16-Mm Sound Motion Picture Projectors, Z52.6-1944.*

This is an opaque film with circular punched holes of uniform diameter precisely located in the picture area. Picture jump and weave is determined directly by projecting the image of these holes against vertical and horizontal scales placed at the projection screen.

This test film is 100 ft in length and may be purchased from the Bell and Howell Company, 7100 McCormick Road, Chicago, Ill., at $11 each.

Scanning Beam Illumination Test Film.—*Method of Determining Uniformity of Scanning Beam Illumination for 16-Mm Sound Motion Picture Projectors, Z52.7-1944.*

This test film carries a narrow sound track (0.005 in. wide) modulated at constant level by a 1000-cycle tone. The location of this sound track changes at a uniform rate along the length of the film from a position just inside one edge of the scanned area to a position just inside the opposite edge of the scanned area.

The narrow 1000-cycle sound track sweeps across the scanning light beam from one end to the other at a uniform rate, the position of the sound track relative to the ends of the light beam at any instant being shown by an animated diagram appearing in the picture area.

If the scanning beam illumination were absolutely uniform across the width of the scanned area, the output level of the 1000-cycle tone would be constant. In practice, however, some variation of an output meter reading will always be observed.   By running a loop of the film continuously and observing the indications of the output meter while adjustments are made, it is usually possible to correct unevenness of illumination and bring the variation of output within a limit of ±1.5 db.
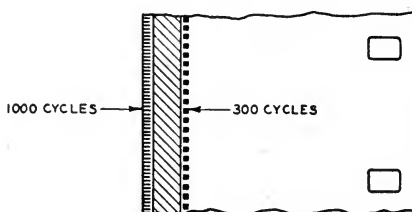
FIG. 1.   Buzz track.

The *Service Type* may be spliced into continuous $3^1/_2$-ft loops and the *Laboratory Type* may be spliced into 34-ft loops.   Each type is 100 ft long and is priced at $27.50.   They are available from the Society of Motion Picture Engineers.

Buzz Track Test Film.—*Buzz Track Test Film for 16-Mm Sound Motion Picture Projectors, Z52.10-1944.*

This test film is an original negative that carries a track as shown in Fig. 1. It is made on a special recording machine, is extremely accurate in position, and almost entirely free from weave.

When the film is run on a projector in correct adjustment and free from weave, no sound is heard.   Either or both the 1000- and 300-cycle tones will be heard; however, if the scanning light beam is out of adjustment.

This film is available from the Society of Motion Picture Engineers in 100-ft lengths at $27.50.

STANDARDIZATION AND THE ANTITRUST LAWS*

JAMES D. HAYES**

Summary.—The following discussion and interpretation of recent changes in the attitude of the courts and the Federal Trade Commission toward standardization was presented before the first meeting of the Conference Committee of Staff Executives of Member Bodies and Associate Members of the American Standards Association on March 7, 1946. The author is a recognized authority on the legal aspect of industrial standardization, and the editors of the JOURNAL *feel that this frank discussion will be of particular interest to members of the Society who are manufacturers, or who have participated in the 30 years of standardization history of the SMPE.*

As a result of the first World War and the tremendous demands made upon industry, standardization became an increasingly important cooperative activity of industry, and the Department of Commerce lent all its influence to promoting industry activity in this field. In 1922, Herbert Hoover, as Secretary of Commerce, requested an informal opinion of the Attorney General as to the legality of trade association activity in general and included in his request the following question:

"May a trade association, in cooperation with its members, advocate and provide for the standardization of quality and grades of product of such members, to the end that the buying public may know what it is to receive when a particular grade or quality is specified; and may such association, after standardizing quality and grade, provide standard form of contract for the purpose of correctly designating the standards of quality and grades of product; and may it standardize technical and scientific terms, its processes in production, and its machinery; and may the association cooperate with its members in determining means for the elimination of wasteful processes in production and distribution and for the raising of ethical standards in trade for the prevention of dishonest practices?"

This was the first occasion upon which any authority had ventured an opinion on the legality of standardization, or rather, it was the first occasion upon which legality, theretofore assumed, had been ques-

---

tioned. The Attorney General did not give a very satisfactory
answer to Mr. Hoover's inquiry in the light of subsequent develop-
ments.   He said:

> "I can now see nothing illegal in the exercise of the other activities men-
> tioned, *provided always* that whatever is done is not used as a scheme or device
> to curtail production or enhance prices, and does not have the effect of sup-
> pressing competition."

It is obvious that with such hedging almost *any* group activity would
be proper under the antitrust laws.

Accepted as Green Light for Standardization.—Be that as it may,
this correspondence between the heads of the Department of Com-
merce and the Department of Justice was accepted as giving a green
light to technical standardization activity by industry groups and,
therefore, for several years, it was often referred to by the Department
of Commerce in its efforts to encourage industry activity in this field.

The first, and almost the only, mention made by the Supreme
Court of standardization activity occurred in 1925 in the familiar case
of *Maple Flooring Manufacturers Association* versus *United States*.[1]
In that case a price-fixing conspiracy was charged against maple
flooring manufacturers.   One of the means alleged to have been used
to effectuate the conspiracy was standardization of grades of flooring.
A decree against the Association was entered by the district court,
but the decree made no reference to the standardization activities of
the Association.   On appeal to the Supreme Court, the Court in
reversing the decree of the lower court took notice of the Association's
standardization activities.   The Court said:

> "The defendants have engaged in many activities to which no exception
> was taken by the government and which are admittedly beneficial to the
> industry and to commerce; such as cooperative advertising and standardiza-
> tion and improvement of the product."

In its discussion of the facts it made no other reference to standardiza-
tion.   At the least, the Court thought standardization beneficial to
industry and commerce.   However, it is important to note in this
case, as I shall point out more fully, that the Association was found
not guilty of any price-fixing conspiracy.

In the years following this decision, standardization by joint action
of industry thrived, and as far as can be determined no question was
raised as to its legality.

Standardization Legal; Illegal When Used for Illegal Purposes.—
In 1923, a consent decree was entered in a case in which the govern-

ment complained against the *Tile Manufacturers' Credit Association, et al.*,[2] alleging a price-fixing agreement. The complaint listed 17 practices as the subject of the conspiracy. Among these was the allegation that the defendants conspired "to standardize the shapes, *etc.*, of tile made, eliminating many now sold, and establish the use of standardized catalogs of said association (catalogs now being prepared)."

The decree provided that nothing therein should be deemed to restrain the defendants from maintaining an association for certain enumerated purposes including "to secure and maintain the standardization of quality and of technical and scientific terms, and the elimination of nonessential types, sizes, styles or grades of products."

On the other hand, the consent decree entered versus the *Carpet Manufacturers of America, Inc.*, in New York in 1941 prohibited agreements "to limit the kinds, quality, grade, quantity or the number of lines of merchandise to be manufactured and sold."

The conclusion to be drawn from these cases was that standardization when used as a means to further a price-fixing conspiracy or a restraint of production or an elimination of competition was illegal whereas standardization, as such, was unobjectionable. This conclusion was buttressed by various pronouncements of the Federal Trade Commission, the chief one being a statement by the chairman of the Commission, made in 1931 that "in no matter has the Commission ever held standardization of commodities by members of an industry to be violative of any of the statutes it has the duty of enforcing."

Perhaps the FTC has had a change of heart. Since 1938, hardly a complaint involving trade associations has been issued by the Commission which did not allege standardization as one of the means utilized in advancing and perfecting the alleged conspiracy.

The convenient division of the authorities theretofore thought possible was, however, made somewhat questionable by the Milk Can Institute case. The original complaint in that case was issued in June, 1934, under the title of *Keiner Williams Stamping Co., et al.*[3] It contained an allegation that in furtherance of an alleged competition-suppressing and price-fixing conspiracy the respondents (members of a trade association) had standardized the construction of milk and ice cream cans so that they were of uniform material, weight, and general construction. Following this allegation appeared a caveat to the effect that "The Commission is not here complaining

against the alleged standardization as such, but only against the use thereof as a means of carrying out the price-fixing conspiracy hereinbefore charged."

No decree was ever entered on this complaint and in July, 1941, it was dismissed without prejudice and a new complaint was issued. The matter was now entitled "*In the Matter of the Milk and Ice Cream Can Institute, et al.*"[4]   The amended complaint also alleged a price-fixing conspiracy and as one of the activities engaged in "pursuant to and in furtherance of the aforesaid combination," the elimination of models and styles of cans, the change in designs of cans and other standardization of products independently of and beyond any requirements for standardization prescribed by the Federal or State Governments "*for the purpose of eliminating competition in the attractiveness of their products to buyers.*"   Significantly the caveat contained in the original complaint was missing from the amended complaint.

FTC Attacks Standardization as Such.—It is particularly to be noted that the language quoted indicates that for the first time the Federal Trade Commission was attacking standardization as such. Any standardization program naturally results in some elimination of competition of attractiveness of product and in some restraint of production in that it standardizes the product available to prospective purchasers.   But that end has always been thought to be a justification for standardization.   In other words the benefit of standardization to the consumer arises from the very fact that the product is standardized, enabling him to buy with confidence and giving to him the advantage of low prices owing to savings in manufacturing costs and interchangeability of parts.   These advantages have long been thought to far outweigh any incidental restraint of production arising from the elimination of special items.

Following hearings in the *Milk Can* case, the Commission made findings of fact and conclusions of law.   Among these was a finding that the respondents *had* engaged in standardization and simplification "as a further means of establishing a basis upon which price differences might be eliminated, and for the purpose of eliminating competition in the attractiveness of their products to buyers."   The findings set forth an example of the standardization activity of the Institute which, so far as appears, is a typical association activity. The specific language of the findings is:

"At a meeting held June 14, 1932, the respondent, D. S. Hunter, as commissioner, called attention to the desirability, in the work of standardization,

of eliminating if possible some styles and sizes of milk and ice cream cans, especially those for which there was a small demand, and also that consideration should be given to standardizing the weight, as well as the gages, of the various styles and sizes of cans. The Commissioner was instructed to communicate with members to determine what lines of cans could be eliminated. Subsequent thereto, at a meeting held on July 12, 1932, the committee on standards submitted a table of standardization of various styles and sizes of cans by weight and on motion made, seconded, and carried, this recommendation by the committee on standards was adopted by the respondent members. Subsequent to that time, the committee on standards had made various recommendations with reference to gages and weights of milk and ice cream cans which were adopted by the respondent members."

The order to cease and desist entered by the Commission pursuant to the hearings and findings made no specific reference to the standardization activity of the Institute. It did specifically prohibit the members of the Institute from fixing or maintaining prices or adhering to such prices and it prohibited a sales and price-reporting service and a freight equalization system used in connection with price fixing, *etc.* The decree did contain a general paragraph prohibiting the members from engaging in "any other practice or plan which has the purpose or effect of fixing or maintaining prices..."

The Institute and its members appealed from the order of the Commission to the Seventh Circuit Court of Appeals and on January 7, 1946, the Circuit Court rendered its opinion upholding with minor modifications the Commission's order.

The court treated the standardization activity of the Institute and its members as evidence of the conspiracy. The court noted that the only basic question before it was whether the members had conspired to fix prices. The court discussed the standardization activities of the defendants as being one of the pieces of evidence supporting the Commission's finding that the defendants had acted in concert and by agreement.

There was no discussion or intimation by the court to show that it thought that standardization by itself would result in a restraint of trade, but its whole discussion was directed to the point that the members had agreed on standardization and that this agreement supported the Commission's finding of a conspiracy. The court said:

"We think it is true that they were standardized in the instant situation, but this was the result of the activities of the Institute and its members. In fact, there was a continuing effort and urging on their part that the cans be manufactured in uniform classifications. It may be, as argued, that much of this effort was to comply with various governmental regulations and for

health purposes, but the fact still remains that it was easier to reach the goal of uniform prices on a standard product than on one which was not. The meticulous effort disclosed by the record by which petitioners standardized their products is also a strong circumstance in support of the Commission's findings that their activities were the result of an agreement."

It is true that in the *Milk Can* case there were the usual other factors present which theretofore had been present in every case where the Commission had attacked standardization, namely, a price-fixing conspiracy, restraint of production, and elimination of competition.

The language of the Federal Trade Commission findings was that a table of standardization "was adopted" by the members of the Institute.   There is nothing either in the findings, the order to cease and desist, or the decree of the Circuit Court of Appeals to indicate what the members did when they "adopted" the table of standardization recommended by the Milk Can Institute Committee on Standards. It would seem fair to conclude that what was complained of was merely the fact that the members agreed to adopt certain sizes, styles, and types of cans as standard and that there was no agreement to adhere to the standardized line.   If there had been both, the Commission and the Circuit Court of Appeals had many authorities on hand to support a holding that such activity was a restraint of trade. Since no reference was made to an agreed restraint it seems fair to assume that there was none.

On the foregoing assumptions one must inevitably conclude that the court utilized an agreement theretofore considered perfectly legitimate, namely, an agreement on what the standard shall be, to convict the defendants of a price-fixing conspiracy.   Therefore, under this case, no longer will legality of standardization depend upon whether the program is misused and made a part of restraint of trade, but on whether the Association happens to be prosecuted for a restraint of trade arising from any one or more of its other activities.

Prior to the *Milk Can* case, most lawyers active in the trade association field felt safe in advising trade associations that activity in the field of standardization was legitimate as long as the standards were arrived at on sound engineering and technical considerations (as well as considerations of safety and public health) as long as the activity was carried on in good faith and without any intent to fix prices, restrict production, and eliminate competition, and finally, as long as there was no agreement express or implied among the members to adhere to the standards agreed upon.

It is to be noted that the Attorney General, back in 1922, based his clearance of standardization on the premise that the standards were voluntary and that any member was left free to adhere to or depart from standards as he might from time to time see fit.   It was never thought to be illegal to agree on what the standards should be.   In fact it is obvious that no standardization can be carried on except on the basis of agreement as to what the standards shall be.

Find Danger in Agreement on What Standard Shall Be.—Now, however, it appears that there is danger even in an agreement on what the standard shall be in that the Federal Trade Commission and the courts will accept that agreement as evidence of agreement on other matters upon which the law forbids competitors to agree.

I mentioned above that most Trade Commission cases since 1941 against trade associations have contained an allegation that standardization was one of the means utilized to promote the conspiracy.   It is interesting to note in the *Milk Can* case that the Commission found that the standardization work was done "as a further means of establishing a basis upon which price differences might be eliminated and for the purpose of eliminating competition in the attractiveness of their products to buyers."   This limitation does not mean much when one remembers that the Commission can always make such an allegation after the fact.   In other words, if a restraint of trade exists, a standardization program can always be pointed to as a means of effectuating the restraint.   There never has been any doubt that price fixing or restraint of production is facilitated by uniformity of product.

The only comforting thing about the *Milk Can* decision in the Seventh Circuit Court of Appeals is that the court deleted the general catch-all provision of the order to cease and desist, thereby leaving the order without any possible prohibition against the standardization activity of the Institute.

Summary of Present Legal Status of Standardization.—To summarize the present state of the antitrust law as it applies to standardization: (*1*) the activity is legitimate in the absence of any agreement by the participants to limit their production to the standard items; (*2*) if an association or other group is prosecuted or complained against for a conspiracy to restrain trade either by fixing prices, restraining production, or eliminating competition, or any of the variables or combinations thereof, it is almost certain that their standardization activity will be cited as evidence of the conspiracy; (*3*) it

is highly improbable that a trade association or other group will ever be prosecuted or complained against solely for carrying on a standardization program in the absence of any other restraint of trade.

Since the attack on standardization in the *Milk Can* case was accompanied by allegations of price fixing and restraint of production by means of other more serious methods, one cannot state positively what the result would be of a complaint addressed to standardization alone. I do not believe that a court would hold that trade and commerce had been restrained by the incidental elimination of "competition in the attractiveness of products to buyers." I think the courts would hold that such restraint, if any, was a restraint of trade under the rule of reason.

Whether the Federal Trade Commission will ever bring a complaint based upon that type of restraint alone and what conclusion the Commission would reach remains to be seen. The language in the *Milk Can* case indicates that the Commission believes standardization for the purpose of eliminating competition in the attractiveness of their products to be a violation of law. It is impossible to tell from the *Milk Can* case whether the Commission really believes that. One word of warning is appropriate. If the Commission should bring a proceeding and issue a cease and desist order based upon such a restraint, it is doubtful whether the court would upset an order of the Commission in view of the well-known rule that the Commission's conclusions are conclusive on appeal if supported by substantial evidence.

"Standardization" Needs Exact Definition.—One of the greatest sources of confusion and doubt on this question of the legality of standardization arises from the looseness with which the term "standardization" has been used. Perhaps I should have defined the term at the beginning of my talk, but it seemed to me that it would be more advisable to leave you with a proper, exact definition. A standard is a "definition of a product or process with reference to composition, construction, dimension, quality, operating characteristics, performance, nomenclature, and other like factors." And standardization, as I have used it here, is "the formulation of such definition or standard." Standardization has nothing to do with an agreement to adhere to the standard so formulated and it behooves every association engaged in this type of activity to make clear beyond question both to its members and to the public generally that the promulgation of a standard or standards by it does not preclude

any member or nonmember from making his own determination as to whether or not he will manufacture in accordance with the standard.

Of course, it is natural that a manufacturer who has taken part in setting up standards will in all probability manufacture in accordance with the standards.   As long as each manufacturer freely, voluntarily, and in good faith does this, whatever restraint of trade results is incidental and is far outweighed by the economic benefits accruing to consumers, distributors, and manufacturers from a standardization program.   It is only where the freedom of the individual has been taken from him by an agreement express or implied to adhere that the restraint becomes direct rather than incidental.

Voluntary Nature of Standardization Eliminates Use of Compulsion.—A natural corollary of the voluntary character of standardization is that an association engaged in standardization activity take no steps to compel compliance with its standards.   This, of course, does not mean that the association cannot investigate to see whether its standards are being followed—for the purpose of ascertaining and verifying the validity of the standards and the possible necessity of amendment.   Such activity is proper if carried on in good faith.   Members are not likely to be confused as to the real purpose of any investigation along these lines.

How the Party-at-Interest Procedure of ASA Affects Legality.— There is a question related to the voluntary use of standards of special interest to this group.   This question has not yet been answered by legal decision, but in my opinion it can have but one answer.   That question is, "Does the procedure of the American Standards Association, in which all parties at interest are represented in the development of a standard, change the picture as far as the legality of a standard is concerned?"   Although there has been no legal ruling on such a question, it is my opinion that this procedure does give a standard greater protection than if the standard is developed by a private group.   If a standard is arrived at after consulting not only the interests of the manufacturers but also of the marketers of the product, of the consumers of the product, and of the government agencies, if any, which may be interested in the use or disposition of that product, then whatever restraint results from the adoption of that standard would, in my opinion, be reasonable.   I do not believe it could ever be successfully attacked.

One should not infer, however, from the fact that a government agency has participated in any way in the adoption of a standard that

the standard so adopted carries with it any license to violate the law in the use of that standard. This is true even though the government agency might request that the particular wrongful conduct be done. If, for example, a government agency should ask an industry to adhere to the standard and not to manufacture articles which do not comply with the standard and if, pursuant to such request the industry should so agree, the agreement thus made would still be subject to attack. The reason is that no government official no matter how highly placed has the authority to authorize any individual or group of individuals to violate the law or to invite them to do so.

Confusion Equally Great on Status of Simplification.—Finally, I should say a word about simplification. The confusion on this subject is even more extensive than on standardization and again arises primarily from the wide variety of activities that has been called simplification. Everything that I have said regarding standardization applies to simplification, as I define simplification.

Simplification is "the formulation of standard product lines consisting of types, sizes, shapes, grades, colors, and varieties of product most frequently demanded by consumers."

Same Limitations Apply to Simplification.—What I have just defined as simplification is sometimes called type standardization. It has also been defined as an agreement to eliminate in accordance with agreed product lines. The same limitations that apply to standardization also apply to simplification. It is legitimate for an association to formulate standard product lines and as an integral part thereof for competitors to agree on what standard product lines should be. Just as in the case of standardization, it is illegal if the program is misused in order to fix or raise prices, restrict production, or eliminate competition, and it is obvious that an agreement by the participants in such a plan to adhere to the standard product lines and to limit their manufacture thereto is an illegal restraint of trade.

REFERENCES

[1] 268 U. S. 563 (1925).
[2] S. D. Ohio, 1923.
[3] Docket 2199.
[4] Docket 4551.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y., at prevailing rates.

Acoustical Society of America, Journal
    17, 4 (Apr., 1946)
Stereophon Sound Recording System (p. 356)   H. B. LEE

Bell Laboratories Record
    24, 4 (Apr., 1946)
A Wide-Angle Fastax (p. 139)   J. H. WADDELL
Demountable Soundproof Rooms (p. 150)   W. S. GORTON

Electronics
    19, 5 (May, 1946)
Where Color Television Stands (p. 104)   D. G. FINK

International Photographer
    18, 3 (Apr., 1946)
Two-Color Photography (p. 5)   K. MARCUS
Film Patrol for Race Tracks (p. 12)

International Projectionist
    21, 4 (Apr., 1946)
50-Mm Film Tests Seen as Industry Effort to
    Neutralize Competitive Threat (p. 8)
A New Super H.I. Positive Carbon (p. 10)   M. T. JONES, R. J. ZAVESKY,
    AND W. W. LOZIER

The Barrel-Type, Cyclindrical Shutter (p. 14)   L. DANIELS
The W.U. Concentrated-Arc Lamp (p. 16)
Basic Radio and Television Course, Pt. 22—
    Transmitter Components (p. 20)   M. BERINSKY

Motion Picture Herald
    163, 4 (Apr. 27, 1946)
Color Television Transmitted via Coaxial Cable
    (p. 51)

Philips Technical Review

8, 2 (Feb., 1946)

The Formation of Stereophonic Images (p. 51)   K. de Boer

RCA Review

7, 1 (Mar., 1946)

Improved Cathode-Ray Tubes with Metal-   D. W. Epstein and L.
    Backed Luminescent Screens (p. 5)   Pensak

Local Oscillator Radiation and Its Effect on
    Television Picture Contrast (p. 32)   E. W. Herold

Image Orthicon Camera (p. 67)   R. D. Kell and G. C. Sziklai

SOCIETY ANNOUNCEMENTS

RE-ESTABLISHMENT OF MIDWEST SECTION

The Board of Governors of the Society, at its meeting on May 5, 1946, approved the petition from qualified members in the Chicago area to re-establish the Midwest Section.   Activities of the Section had been suspended since January, 1943 owing to the absence of many members serving with the Armed Forces.

Early this year, a group of Society members in the area held an organization meeting to discuss the possibilities of re-establishing the Section, elected temporary officers, and took steps to re-organize the Section.   The present officers are:

A. Shapiro, *Chairman*
C. E. Phillimore, *Vice-Chairman*
R. E. Lewis, *Secretary-Treasurer*

G. W. Colburn, *Manager*   S. A. Lukes, *Manager*
E. W. D'Arcy, *Manager*   R. T. VanNiman, *Manager*
O. B. Depue, *Manager*   C. H. Stone, *Manager*

Several technical meetings have already been held and the enthusiasm of both officers and members promises a successful organization and future for the Section. Members in the Chicago area who are interested in receiving notices of meetings and have not received previous notices should communicate with the Secretary-Treasurer, R. E. Lewis, Armour Research Foundation, Illinois Institute of Technology, Technology Center, Chicago 16, Ill.

Previous speakers at Section meetings have been F. E. Carlson, General Electric Co., Cleveland, Ohio, who recently discussed "Tungsten Filament Light Sources for Picture Projection and Sound Reproduction," Hugh Knowles, Jensen Radio Manufacturing Co., Chicago, who discussed "Loudspeaker Design Trends," W. T. Strickland and E. E. Bickel, both of the Simpson Optical Manufacturing Co., Chicago, who discussed ' Coated Optics" and "Correlation of Optical and Mechanical Design," and H. C. Froula, Armour Research Foundation, discussed "Electron Microscope Photography."   Many interesting meetings are planned by the Board of Managers for the coming Fall season.

The Board of Governors extends a hearty welcome to the new Section, and assures it of the utmost cooperation.

MAY TECHNICAL CONFERENCE

One of the most successful meetings ever held by the Society was concluded on May 10, 1946, when the 5-day Fifty-Ninth Semi-Annual Technical Conference was adjourned by President D. E. Hyndman, at the Hotel Pennsylvania, New York.   Over 400 paid registrations were recorded.   All of the pre-war social functions were resumed and contributed in large measure to the success of the Conference.   Both the Get-Together Luncheon, at which the guest speaker was William F. Rodgers, Vice-President in charge of Distribution, Loew's Incorporated, New York, and the Dinner-Dance were outstanding.   At the latter, a citation and scroll were presented to Thomas Armat in recognition of the fiftieth anniversary of the first exhibition of motion pictures in a theater.   They were received by Lt. Brooke Armat.

A citation and scroll were also presented to the Warner Brothers in recognition of their pioneering courage and efforts in the development of sound recording and sound reproduction for motion pictures.   Major Albert Warner received the scroll in behalf of himself and his brothers.

Because of the difficulties in obtaining sufficient papers by the Papers Committee in advance of the Conference to permit mailing of a final program to the membership, the editors are publishing in this issue of the JOURNAL the complete program as followed for the 5-day meeting.   All technical sessions were held in the *Salle Moderne* of the Hotel Pennsylvania, unless otherwise indicated.   The papers listed will be scheduled for early appearance in the JOURNAL.

Program

Monday, May 6, 1946

Open Morning.

12:30 p.m.   *Penn Top:* **Get-Together Luncheon.** Guest speaker, **William F. Rodgers,** Vice-President in charge of Distribution, Loew's Incorporated, New York.

2:00 p.m.   **Opening business and technical session of Conference.**

Frank E. Cahill, Jr., *Chairman*

Session opened with a 35-mm motion picture short.
Welcome by President Donald E. Hyndman.
Report of the Convention Vice-President, W. C. Kunzmann.
"Sensitometric Control of the Duping Process," by J. P. Weiss, Photo Products Dept., E. I. duPont de Nemours and Co., Parlin, N. J.
"Rapid Test for Ferricyanide Bleach Exhaustion," by L. E. Varden and E. G. Seary, Pavelle Color, Inc., New York.
"A Processing Control Sensitometer," by G. A. Johnson, Eastman Kodak Co., Rochester, N. Y.

"An Improved Method for the Determination of Hydroquinone and Metol in Photographic Developers," by H. L. Baumbach, Paramount Pictures, Inc., Hollywood.

"Application of Methyl Ethyl Ketone to the Analysis of Developers for Elon and Hydroquinone," by V. C. Shaner and M. R. Sparks, Eastman Kodak Co., Hollywood.

8:00 p.m.   Evening Session.

Earl I. Sponable, *Chairman*

Session opened with a 16-mm motion picture short.

"Lighting a Subject for Color Photography," by R. M. Evans Eastman Kodak Company, Rochester, N. Y. This was an illustrated lecture in joint session with the Inter-Society Color Council.

Tuesday, May 7, 1946

9:30 a.m.   Morning Session.

John L. Forrest, *Chairman*

Session opened with a 35-mm motion picture short.

"Color for Producer and Consumer," by I. H. Godlove, General Aniline and Film Corp., Easton, Pa.

"Light Sources and Colored Objects," by R. M. Evans, Eastman Kodak Co., Rochester, N. Y.

These two papers and the lecture above were arranged through the courtesy of the Inter-Society Color Council.

2:00 p.m.   RCA-NBC television demonstration at Radio City, New York. George L. Beers, *Chairman*, and in charge of arrangements.

8:00 p.m.   Evening Session.
Nathan D. Golden, *Chairman*

Session opened with a 35-mm motion picture short.

"The Agfacolor Negative-Positive Method for Professional Motion Pictures," presented by H. C. Harsh, on behalf of the U. S. Department of Commerce. Members of the Technical Mission who were present are N. D. Golden, Chief, Motion Picture Section, U. S. Department of Commerce, sponsor of this program, H. W. Sachs, Remington-Rand Corp., and H. C. Harsh, Ansco.

Wednesday, May 8, 1946

9:30 a.m.   A visit to DuMont's John Wanamaker Television Studios including a look "back stage" into studio operation. D. R. White, *Chairman*, and in charge of arrangements.

2:00 p.m.   Afternoon Session.

Hollis W. Moyse, *Chairman*

Session opened with a 16-mm motion picture short.

"Report of the Committee on Motion Picture Instruction," by J. G. Frayne, *Chairman*, Electrical Research Products Div., Western Electric Co., Inc., Hollywood.

"Zoom Lens for Motion Picture Cameras with Single-Barrel Linear Movement," by F. G. Back, Research and Development Laboratory, New York.

"A Combination 16-Mm and 35-Mm Film Processing Machine for Black-and-White or Color," by W. L. Prager, Solar Aircraft Co., Fonda Film Processing Equipment Div., Hollywood.

"Light Control by Polarization," by J. A. Norling, Loucks and Norling Studios, New York.

"Naval-Type Training Epidiascope for Universal Projection of Solid Objects," by Jacques Bolsey, Bol, Ltd., New York.

7:15 p.m.   *Georgian Room (Foyer):*   A social hour with the Board of Governors preceding the Dinner-Dance.

8:30 p.m.   *Georgian Room:* **Fifty-Ninth Semi-Annual Technical Conference Dinner-Dance.**

President Donald E. Hyndman, *presiding*

Citation and scroll presented to Warner Brothers, represented by Major Albert Warner.

Citation and scroll presented to Thomas Armat, represented by Lieutenant Brooke Armat.

Dancing and entertainment until 1:30 a.m.

Thursday, May 9, 1946

Open morning.

2:00 p.m.   Afternoon Session.

John G. Frayne, *Chairman*

Session opened with a 35-mm motion picture short.

"Modernization Desires of a Major Studio," by L. L. Ryder, Paramount Pictures, Inc., Hollywood.

"A New Professional 16-Mm Camera and Sound Recorder," by J. A. Maurer, J. A. Maurer, Inc., Long Island City, N. Y.

"Factors Governing the Frequency Response of a Variable-Area Film Recording Channel," by M. Rettinger and K. Singer, RCA Victor Div., Radio Corporation of America, Hollywood.

"Post-War Test Equipment for Theater Servicing," by Edward Stanko and P. V. Smith, RCA Service Co., Camden, N. J.

"Dubbing and Post-Synchronization Studios," by W. A. Mueller, Warner Bros. Pictures, Inc., Burbank, Calif. .

8:00 p.m.   Evening Session.

Lawrence W. Davee, *Chairman*

Session opened with a 35-mm motion picture short.

"An Improved 200-Mil Push-Pull Variable-Density Modulator," by J. G. Frayne and T. B. Cunningham, Electrical Research Products Div., Western Electric Co., Hollywood.

"Tone Control for Rerecording," by C. O. Slyfield, Walt Disney Productions, Burbank, Calif.

"The High Cost of Poor Projection," by C. E. Lewis, Showman's Trade Review, New York.

"Characteristics and Applications of Concentrated Arc Lamps," by W. D. Buckingham and C. R. Deibert, The Western Union Telegraph Co., Electronics Div., Water Mill, New York.

Friday, May 10, 1946

9:30 a.m.   Morning Session.

Frank E. Carlson, *Chairman*

Session opened with a 35-mm motion picture short.

"Technical Problems of Film Production for the Navy's Special Training Devices," by H. S. Monroe, Atlas Educational Film Co., Oak Park, Ill.

"The Photometric Calibration of Lens Apertures," by A. E. Murray, Bausch and Lomb Optical Co., Rochester, N. Y.

Report of Engineering Vice-President, J. A. Maurer, J. A. Maurer, Inc., Long Island City, N. Y.

"Report of Committee on Standards," by F. T. Bowditch, *Chairman*, National Carbon Co., Cleveland, Ohio.

"Report of Committee on 16-Mm and 8-Mm Motion Pictures," by D. F. Lyman, *Chairman*, Eastman Kodak Company, Rochester, N. Y.

"Report of the Subcommittee on 16-Mm Splices," by W. H. Offenhauser, Jr., *Chairman*, Columbia Broadcasting System, Inc., New York.

"Report of Committee on Studio Lighting," by C. W. Handley, *Chairman*, National Carbon Co., Los Angeles, California.

2:00 p.m.   Afternoon Session.

Ralph B. Austrian, *Chairman*

Session opened with a 35-mm motion picture short.

"Report of Committee on Television Projection Practice," by P. J. Larsen, *Chairman*, Washington, D. C.

"A Unified Approach to the Performance of Photographic Film, Television Pickup Tubes, and the Human Eye," by Albert Rose, RCA Laboratories, Princeton, N. J.

"Color Television," by P. C. Goldmark, Columbia Broadcasting System, Inc., New York.

"A New Film for Photographing Television Monitor Tubes," by C. F. White and M. R. Boyer, E. I. duPont de Nemours and Co., Inc., Research Division, Parlin, N. J.

"Color Television Film Scanning," by Bernard Erde, Columbia Broadcasting System, Inc., New York.

"Television Reproduction from Negatives," by Emery Meschter, E. I. duPont de Nemours and Co., Inc., Research Division, Parlin, N. J.

"Television and the Motion Picture Theater," by L. B. Isaac, Loew's Incorporated, New York.

Adjournment of Fifty-Ninth Semi-Annual Technical Conference, President D. E. Hyndman.

SPECIAL ARRANGEMENTS

In addition to the visit to DuMont's John Wanamaker Television Studios and the RCA-NBC Television Demonstration listed in the program, the Local Arrangements Committee, in cooperation with the Engineering Vice-President, J. A. Maurer, and D. R. White, Chairman of the Television Committee, arranged the following special events for members attending the 59th Semi-Annual Technical Conference:

(*1*) Visit to **DuMont's John Wanamaker Television Studios** during television broadcast. Two programs were given nightly with the exception of Wednesday evening, May 8.

(*2*) **The General Electric Company** arranged to have SMPE members inspect their television studio and facilities at Schenectady during the week of May 6. Programs were scheduled on the nights of May 6 and May 8 at Station WRGB. Arrangements were in charge of P. G. Caldwell.

LADIES' PROGRAM

A reception parlor for the ladies' daily get-together and open house, with Mrs. O. F. Neu, chairman of the Ladies' Reception Committee, as hostess, was available during the conference.   A Get-Together Tea was held on Tuesday afternoon, May 7, from 3:00 to 6:00 p.m.

OTHER EVENTS

Several other events of interest to SMPE members were held in New York during the Conference week: (*1*) The Acoustical Society of America held their 31st national meeting at the Hotel Pennsylvania on May 10 and 11, inviting all SMPE members to attend sessions of interest; (*2*) The 15th annual meeting of the Inter-Society Color Council was held at the Pennsylvania Hotel on May 6 and 7. Members of both the ISCC and the SMPE exchanged visits to technical sessions; and (*3*) A 16-mm Industry Trade Show was held at the Hotel New Yorker, May 9–11, and was of considerable interest to Society members.

Conference identification cards issued to registered members and guests were honored through the courtesy of the following *de luxe* motion picture theaters in New York: Capitol Theater, Paramount Theater, Radio City Music Hall, Roxy Theater, and Warner's Hollywood and Strand Theaters.

EMPLOYMENT SERVICE

Position available for Optical Designer, capable of handling the calculation and correction of aberrations in photographic and projection lens systems. Junior designers or engineers will be considered. Write fully giving education, experience, and other qualifications to Director of Personnel, Bell and Howell Company, 7100 McCormick Road, Chicago 45, Ill.

Motion picture studio in Bombay, India, has positions open for professional motion picture camerman with studio and location experience; sound recording engineer experienced in installation, maintenance and operation of recording equipment; motion picture processing laboratory supervisor; and professional make-up artist. Five-year contracts at favorable terms are offered to those qualified. Write or cable direct to Personnel Manager, Dawlat Corporation Ltd., Patel Chambers, French Bridge, Bombay 7, India, giving experience, etc., in detail.

New film production unit to be located at Athens, Georgia, needs film editor-writer and film director. Experience in 16-mm as well as 35-mm production desirable. Southern background or interest in South preferred but not essential. Write giving full details of experience, etc., to Nicholas Read, The National Film Board, Ottawa, Canada.

POSITIONS WANTED

Projectionist-newsreel editor with 15 years' experience just released from service. Willing to locate anywhere. Write P. O. Box 152, Hampden Station, Baltimore 11, Maryland.

Honorably discharged veteran with 10 years' experience in projection and installation of projection and sound equipment, both for booth and back-stage. Prefer to locate in California, Oregon or Nevada. For additional details write F.A.N., Box 113, Holley, Oregon.

Cameraman, honorably discharged Army veteran, desires re-enter industrial, educational production with independent producer or studio. Experienced in 35- and 16-mm color and black-and-white. References and complete record of experience available. Write, wire or telephone T. J. Maloney, 406 Oak St., Ishpeming, Mich. Telephone 930.

We are grieved to announce the death of Robert E. Hopkins, Associate member of the Society, on June 9, 1946, in Pasadena, Calif.; LeRoy P. Langford, Associate member of the Society, on June 12, 1945, in Lakewood, Ohio; and Irving Samuels, Associate member of the Society, on February 27, 1946, in Allentown, Pa.

¶ **The Society of Motion Picture Engineers** was organized in 1916 by a small group of engineers with 3 objects in view, namely: (1) the advancement of motion picture engineering and the allied arts and sciences, (2) the standardization of the mechanisms and practices employed in the motion picture industry, and (3) the dissemination of scientific knowledge by publication.

● ● ●

¶ **The SMPE now has over 2000 members** of diversified interests and qualifications including cinematographers, laboratory and studio technicians, sound engineers, projectionists, physicists and photographic chemists, exhibitors, equipment dealers, film manufacturers, armed forces representatives, and many others.

● ● ●

¶ **Committees of the Society** are studying projects which will affect the motion picture industry in the post-war period, reports of which will appear in the JOURNAL, mailed to all members, and nonmember subscribers.

● ● ●

¶ **Membership in the SMPE** is open to anyone interested in the motion picture art. For application form and other details turn to the back of the JOURNAL, or write to General Office of the Society, Hotel Pennsylvania, New York 1, N. Y.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

AUTHOR INDEX, VOLUME 46

JANUARY-JUNE, 1946

536

CLASSIFIED INDEX, VOLUME 46

JANUARY–JUNE, 1946

Acoustics

A Discussion of the Acoustical Properties of Fiberglas, W. M. Rees and R. B. Taylor, No. 1 (Jan.), p. 52.

Air Conditioning

The Measurement and Control of Dirt in Motion Picture Processing Laboratories, N. L. Simmons and A. C. Robertson, No. 3 (Mar.), p. 185.

American Standards Association

American Standards on Motion Pictures, No. 4 (Apr.), p. 284.
American Standard 16-Mm Test Films, No. 6 (June), p. 511.
Standardization and the Antitrust Laws, J. D. Hayes, No. 6 (June), p. 516.

Amplifiers

An Analysis of the Comparison of Beam Power and Triode Tubes Used in Power Amplifiers for Driving Loudspeakers, J. K. Hilliard, No. 1 (Jan.), p. 30.

Apparatus

A Film Noise Spotter, J. P. Corcoran, No. 2 (Feb.), p. 124.
Westrex Standard Sound Film Reproducer, G. S. Appelgate and J. C. Davidson, No. 4 (Apr.), p. 272.
Westrex Master Sound Film Reproducer, G. S. Appelgate and J. C. Davidson, No. 4 (Apr.), p. 278.
Electronic Shutter Testers, R. F. Redemske, No. 5 (May), p. 409.
An Improved Film Drive Filter Mechanism, C. C. Davis, No. 6 (June), p. 454.

Arcs

Carbon Arcs for Motion Picture and Television Studio Lighting, F. T. Bowditch, M. R. Null, and R. J. Zavesky, No. 6 (June), p. 441.

Atlantic Coast Section (See *SMPE Activities and Announcements*)

Book Reviews

Television: The Eyes of Tomorrow, W. C. Eddy, No. 5 (May), p. 424.
Television Show Business, J. Dupuy, No. 5 (May), p. 424.
Report of Conference on Unification of Engineering Standards, No. 5 (May), p. 425.

Cameras

Technical News, No. 1 (Jan.), p. 80.

A Wide Angle 35-Mm High-Speed Motion Picture Camera, J. H. Waddell, No. 2 (Feb.), p. 87.

Specialized Photography Applied to Engineering in the Army Air Forces, P. M. Thomas and C. H. Coles, No. 3 (Mar.), p. 220.

Electronic Shutter Testers, R. F. Redemske, No. 5 (May), p. 409.

Cinematography

The Illusion of Depth in Motion Pictures, H. T. Souther, No. 4 (Apr.), p. 245.

The Theory and Practice of Lighting for the Camera, H. T. Souther, No. 4 (Apr.), p. 254.

Cinematography, High-Speed

A Wide Angle 35-Mm High-Speed Motion Picture Camera, J. H. Waddell, No. 2 (Feb.), p. 87.

Specialized Photography Applied to Engineering in the Army Air Forces, P. M. Thomas and C. H. Coles, No. 3 (Mar.), p. 220.

Color

Ansco Color for Professional Motion Pictures, H. H. Duerr and H. C. Harsh, No. 5 (May), p. 357.

Sensitometric Evaluation of Reversible Color Film, R. H. Bingham, No. 5 (May), p. 368.

A Phototube for Dye Image Sound Track, A. M. Glover and A. R. Moore, No. 5 (May), p. 379.

Preliminary Sound Recording Tests with Variable-Area Dye Tracks, R. O. Drew and S. W. Johnson, No. 5 (May), p. 387.

Behavior of a New Blue-Sensitive Phototube in Theater Sound Equipment, J. D. Phyfe, No. 5 (May), p. 405.

Committee Activities and Reports

Membership and Subscription Committee: (Review of recent activities), No. 4 (Apr.), p. 310.

Nominating Committee: (Nominations open for annual Fall elections), No. 4 (Apr.), p. 337.

Personnel of Society Committees, No. 4 (Apr.), p. 312.

Current Literature

No. 2 (Feb.), p. 157; No. 3 (Mar.), p. 237; No. 5 (May), p. 426; No. 6 (June), p. 526.

Distribution

Army Film Distribution and Exhibition, R. A. Kissack, Jr., No. 1 (Jan.), p. 26.

Loudspeakers

Midwest Section (See *SMPE Activities and Announcements*)

Obituary

Optics

Photometry

Phototemplates

Phototubes

Processing

Projection

Sound Reproduction

Sound Waves

Standards

Stock Shots

Studio Lighting (See *Illumination, Studio*)

Technical News

Television
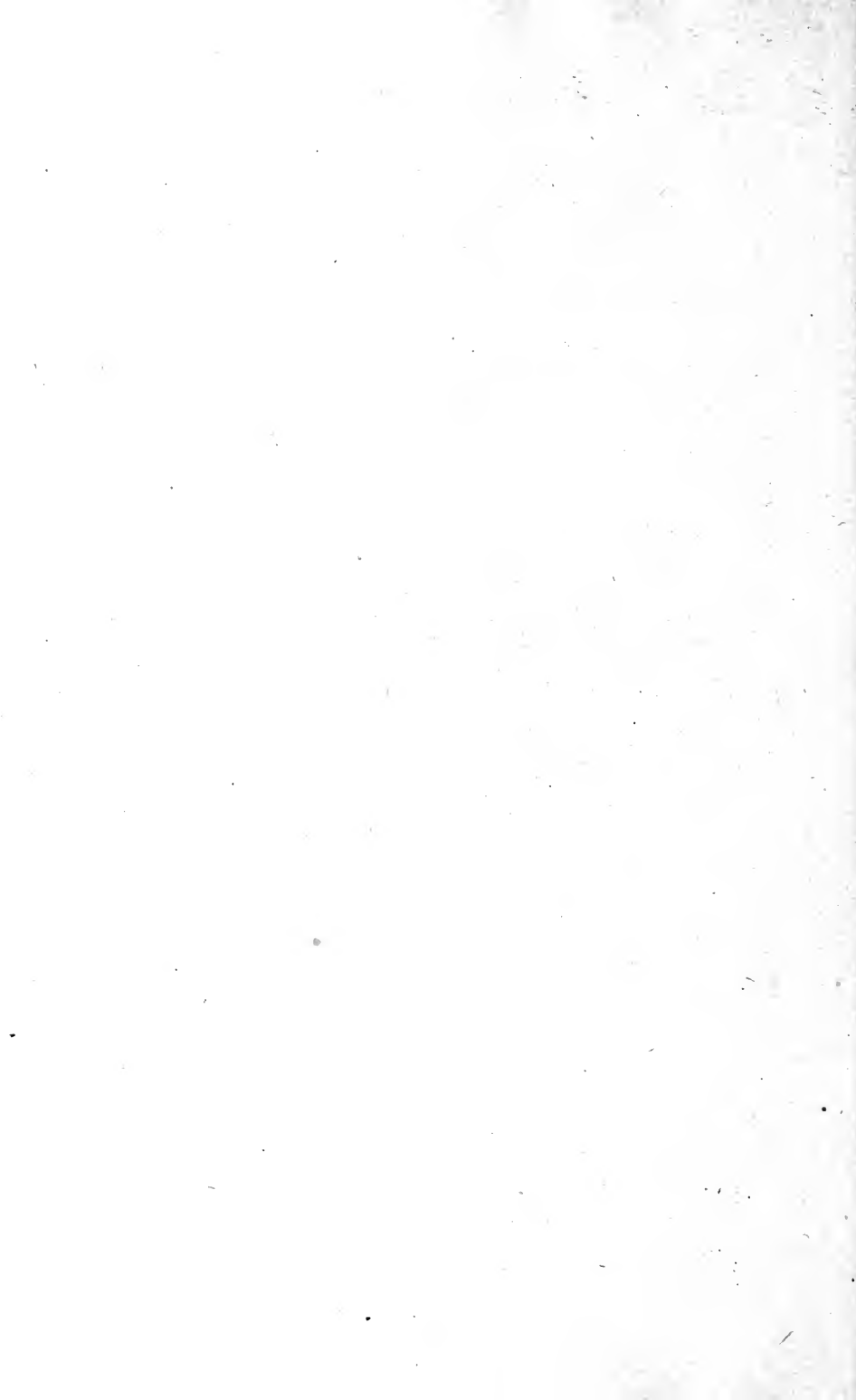
COMMITTEES OF THE SOCIETY

(Correct to June 15, 1946)

❦

ADMISSIONS.—To pass upon all applications for membership, applications for transfer and to review the Student and Associate membership list periodically for possible transfers to the Associate and Active grades, respectively. The duties of each committee are limited to applications and transfers originating in the geographic area covered.

(East Coast)

A. S. DICKINSON, *Chairman*
28 West 44th St.
New York 18, N. Y.

M. R. BOYER   JAMES FRANK, JR.   HARRY RUBIN
F. E. CAHILL, JR.   J. A. MAURER   E. I. SPONABLE

(West Coast)

H. W. REMERSCHEID, *Chairman*
716 N. LaBrea St.
Hollywood, Calif.

C. R. DAILY   PETER MOLE
EMERY HUSE   H. W. MOYSE

BOARD OF EDITORS.—To pass upon the suitability of all material submitted for publication, or for presentation at conventions, and publish the JOURNAL.

A. C. DOWNES, *Chairman*
Box 6087
Cleveland 1, Ohio

J. I. CRABTREE   A. M. GUNDELFINGER   C. R. KEITH
A. N. GOLDSMITH   C. W. HANDLEY   E. W. KELLOGG
                     A. C. HARDY

CINEMATOGRAPHY.—To make recommendations and prepare specifications for the operation, maintenance, and servicing of motion picture cameras, accessory equipment, studio and outdoor set lighting arrangements, camera technique, and the varied uses of motion picture negative films for general photography.

J. W. BOYLE, *Chairman*
1207 N. Mansfield Ave.
Hollywood, Calif.

C. G. CLARKE   *ARTHUR MILLER   ARTHUR REEVES
KARL FREUND   JOSEPH RUTTENBERG

COLOR.—To make recommendations and prepare specifications for the operation, maintenance, and servicing of color motion picture processes, accessory equipment, studio lighting selection of studio set colors, color cameras, color motion picture films, and general color photography.

J. A. BALL, *Chairman*
12720 Highwood St.
Los Angeles 24, Calif.

M. R. BOYER   R. O. DREW   A. M. GUNDELFINGER
O. O. CECCARINI   R. M. EVANS   A. C. HARDY
G. A. CHAMBERS   J. L. FORREST   L. L. RYDER
L. E. CLARK   J. G. FRAYNE   J. G. WHITE
                    L. T. GOLDSMITH

---

* Advisory Member.

CONVENTION.—To assist the Convention Vice-President in the responsibilities pertaining to arrangements and details of the Society's technical conventions.

W. C. KUNZMANN, *Chairman*
Box 6087
Cleveland 1, Ohio

*JULIUS HABER	C. R. KEITH	H. W. MOYSE
H. F. HEIDEGGER	R. H. MCCULLOUGH	O. F. NEU

EXCHANGE PRACTICE.—To make recommendations and prepare specifications on the engineering or technical methods and equipment that contribute to efficiency in handling and storage of motion picture prints, so far as can be obtained by proper design, construction, and operation of film handling equipment, air-conditioning systems, and exchange office buildings.

(Under Organization)

FELLOW AWARD.—To consider qualifications of Active members as candidates for elevation to Fellow, and to submit such nominations to the Board of Governors.

HERBERT GRIFFIN, *Chairman*
133 E. Santa Anita Ave.
Burbank, Calif.

M. R. BOYER	D. E. HYNDMAN	H. W. MOYSE
F. E. CAHILL, JR.	C. R. KEITH	L. L. RYDER
A. C. DOWNES	W. C. KUNZMANN	E. I. SPONABLE
	J. A. MAURER	

FILM PROJECTION PRACTICE.—To make recommendations and prepare specifications for the operation, maintenance and servicing of motion picture projection equipment, projection rooms, film storage facilities, stage arrangement, screen dimensions and placement, and maintenance of loudspeakers to improve the quality of reproduced sound and the quality of the projected picture in the theater.

G. T. LORANCE, *Chairman*
63 Bedford Road
Pleasantville, N. Y.

HENRY ANDERSON	L. W. DAVEE	C. F. HORSTMAN
*C. J. BACHMAN	A. S. DICKINSON	L. B. ISAAC
T. C. BARROWS	J. K. ELDERKIN	E. R. MORIN
H. D. BEHR	JAMES FRANK, JR.	M. D. O'BRIEN
H. J. BENHAM	R. R. FRENCH	HARRY RUBIN
M. F. BENNETT	G. GAGLIARDI	J. J. SEFING
KARL BRENKERT	E. R. GEIB	R. O. WALKER
F. E. CAHILL, JR.	ADOLPH GOODMAN	V. A. WELMAN
D. W. COLLINS	HERBERT GRIFFIN	H. E. WHITE
C. C. DASH	SYLVAN HARRIS	A. T. WILLIAMS
	J. J. HOPKINS	

HISTORICAL AND MUSEUM.—To collect facts and assemble data relating to the historical development of the motion picture industry, to encourage pioneers to place their work on record in the form of papers for publication in the JOURNAL, and to place in suitable depositories equipment pertaining to the industry.

J. E. ABBOTT, *Chairman*
11 West 53d St.
New York 19, N. Y.

O. B. DEPUE	RICHARD GRIFFITH	TERRY RAMSAYE

HONORARY MEMBERSHIP.—To diligently search for candidates who through their basic inventions or outstanding accomplishments have contributed to the advancement of the motion picture industry and are thus worthy of becoming Honorary members of the Society.

EMERY HUSE, *Chairman*
6706 Santa Monica Blvd.
Hollywood 38, Calif.

NATHAN LEVINSON	L. L. RYDER
A. J. MILLER	E. I. SPONABLE

* Advisory Member.

JOURNAL AWARD.—To recommend to the Board of Governors the author or authors of the most outstanding paper originally published in the JOURNAL during the preceding calendar year to receive the Society's Journal Award.

F. E. CARLSON, *Chairman*
Nela Park
Cleveland 12, Ohio

C. R. DAILY　　　　　　　　　　G. E. MATTHEWS
P. J. LARSEN　　　　　　　　　　W. V. WOLFE

LABORATORY PRACTICE.—To make recommendations and prepare specifications for the operation, maintenance, and servicing of motion picture printers, processing machines, inspection projectors, splicing machines, film cleaning and treating equipment, rewinding equipment, any type of film handling accessories, methods, and processes which offer increased efficiency and improvement in the photographic quality of the final print.

H. E. WHITE, *Temporary Chairman*
Room 813
350 Madison Ave.
New York 17, N. Y.

J. R. ALBURGER　　　　F. L. EICH　　　　　　J. M. NICKOLAUS
A. C. BLANEY　　　　　G. H. GIBSON　　　　　N. F. OAKLEY
L. A. BONN　　　　　　EMERY HUSE　　　　　W. H. OFFENHAUSER, JR.
A. W. COOK　　　　　　T. M. INGMAN　　　　　W. L. PRAGER
O. B. DEPUE　　　　　　C. L. LOOTENS　　　　V. C. SHANER
R. O. DREW　　　　　　A. J. MILLER　　　　　J. H. SPRAY

MEMBERSHIP AND SUBSCRIPTION.—To solicit new members, obtain nonmember subscriptions for the JOURNAL, and to arouse general interest in the activities of the Society and its publications.

(East Coast)

JAMES FRANK, JR., *Chairman*
356 West 44th St.
New York 18, N. Y.

T. C. BARROWS　　　　SYVAN HARRIS　　　　G. E. MATTHEWS
J. G. BRADLEY　　　　L. B. ISAAC　　　　　G. C. MISENER
KARL BRENKERT　　　W. C. KUNZMANN　　　H. B. SANTEE
G. A. CHAMBERS　　　S. A. LUKES　　　　　E. O. WILSCHKE
E. R. GEIB　　　　　　　　　　　　　　　　C. R. WOOD, SR.

(West Coast)

H. W. REMERSCHEID, *Chairman*
716 N. LaBrea St.
Hollywood, Calif.

L. W. CHASE, JR.　　　HERBERT GRIFFIN　　W. A. MUELLER
J. P. CORCORAN　　　　EMERY HUSE　　　　L. L. RYDER
C. R. DAILY　　　　　　K. F. MORGAN　　　　G. E. SAWYER
J. G. FRAYNE　　　　　H. W. MOYSE　　　　W. L. THAYER
L. T. GOLDSMITH　　　　　　　　　　　　　W. V. WOLFE

NOMINATIONS.—To recommend nominations to the Board of Governors for annual election of officers and governors.

E. M. HONAN, *Chairman*
6601 Romaine St.
Hollywood 38, Calif.

E. A. BERTRAM　　　　EMERY HUSE　　　　W. C. MILLER
M. R. BOYER　　　　　D. B. JOY　　　　　PETER MOLE
HERBERT GRIFFIN　　　J. A. MAURER　　　　E. A. WILLIFORD

PAPERS.—To solicit papers, and provide the program for semi-annual conventions, and make available to local sections for their meetings papers presented at national conventions.

C. R. DAILY, *Chairman*
5451 Marathon St.
Hollywood 38, Calif.

BARTON KREUZER, *Vice-Chairman*
RCA Victor Division
Radio Corp. of America
Camden, N. J.

A. R. DAVIS
F. L. EICH
JAMES FRANK, JR.
J. G. FRAYNE

L. T. GOLDSMITH
C. R. KEITH
E. W. KELLOGG
G. E. MATTHEWS
P. A. McGUIRE

H. W. MOYSE
V. C. SHANER
S. P. SOLOW
W. V. WOLFE

PRESERVATION OF FILM.—To make recommendations and prepare specifications on methods of treating and storage of motion picture film for active, archival, and permanent record purposes, so far as can be prepared within both the economic and historical value of the films.

J. G. BRADLEY, *Chairman*
The Library of Congress
Washington 25, D. C.

J. E. ABBOTT
*H. T. COWLING
J. I. CRABTREE
A. S. DICKINSON

J. L. FORREST
*J. E. GIBSON
*ORVILLE GOLDNER
C. L. GREGORY

*C. A. LINDSTROM
G. S. MITCHELL
TERRY RAMSAYE
V. B. SEASE

PROCESS PHOTOGRAPHY.—To make recommendations and prepare specifications on motion picture optical printers, process projectors (background process), matte processes, special process lighting technique, special processing machines, miniature set requirements, special effects devices, and the like, that will lead to improvement in this phase of the production art.

(Under Organization)

PROGRESS.—To prepare an annual report on progress in the motion picture industry.

W. V. WOLFE, *Chairman*
1016 N. Sycamore Ave.
Hollywood 38, Calif.

(Under Organization)

PROGRESS MEDAL AWARD.—To recommend to the Board of Governors a candidate who by his inventions, research, or development has contributed in a significant manner to the advancement of motion picture technology, and is deemed worthy of receiving the Progress Medal Award of the Society.

E. A. WILLIFORD, *Chairman*
230 Park Ave.
New York 17, N. Y.

M. R. BOYER
F. E. CARLSON

NATHAN LEVINSON
G. F. RACKETT

PUBLICITY.—To assist the Convention Vice-President in the release of publicity material concerning the Society's semi-annual technical conventions.

*HAROLD DESFOR, *Chairman*
RCA Victor Division
Radio Corp. of America
Camden, N. J.

*LEONARD BIDWELL
*E. O. BLACKBURN

C. R. DAILY
BARTON KREUZER

P. A. McGUIRE
HARRY SHERMAN

SCREEN BRIGHTNESS.—To make recommendations, prepare specifications, and test methods for determining and standardizing the brightness of the motion picture screen image at various parts of the screen, and for special means or devices in the projection room adapted to the control or improvement of screen brightness.

E. R. GEIB, *Chairman*
National Carbon Company, Inc.
Fostoria Works
Fostoria, Ohio

* Advisory Member.

Herbert Barnett	W. F. Little	H. E. White
F. E. Carlson	W. B. Rayton	A. T. Williams
Sylvan Harris	C. M. Tuttle	R. J. Zavesky
	C. R. Underhill	

16-MM AND 8-MM MOTION PICTURES (Formerly Nontheatrical Equipment).—To make recommendations and prepare specifications for 16-mm and 8-mm cameras, 16-mm sound recorders and sound recording practices, 16-mm and 8-mm printers and other film laboratory equipment and practices, 16-mm and 8-mm projectors, splicing machines, screen dimensions and placement, loudspeaker output and placement, preview or theater arrangements, test films, and the like, which will improve the quality of 16-mm and 8-mm motion pictures.

D. F. Lyman, *Chairman*
333 State St.
Rochester 4, N. Y.

E. W. D'Arcy	E. R. Geib	A. Shapiro
William Balch	R. C. Holslag	D. G. Smith
W. C. Bowen	H. J. Hood	Raymond Spottiswoode
F. L. Brethauer	R. Kingslake	*J. B. Streiffert
*F. E. Brooker	L. R. Martin	Harry Strong
F. E. Carlson	W. C. Miller	*A. L. Terlouw
G. A. Chambers	V. J. Nolan	Lloyd Thompson
S. L. Chertok	W. H. Offenhauser, Jr.	M. G. Townsley
John Christie	M. W. Palmer	L. E. Varden
G. W. Colburn	A. G. Petrasek	J. E. Volkmann
R. O. Drew	S. Read, Jr.	R. J. Zavesky
*J. Walter Evans	L. T. Sachtleben	A. G. Zimmerman

SOUND.—To make recommendations and prepare specifications for the operation, maintenance, and servicing of motion picture film, sound recorders, rerecorders, and reproducing equipment, methods of recording sound, sound film processing, and the like, to obtain means of standardizing procedures that will result in the production of better uniform quality sound in the theater.

J. G. Frayne, *Chairman*　　　　C. R. Keith, *Vice-Chairman*
6601 Romaine St.　　　　　　　233 Broadway
Hollywood 38, Calif.　　　　　　New York 7, N. Y.

D. J. Bloomberg	L. B. Isaac	Otto Sandvik
B. B. Brown	J. P. Livadary	G. E. Sawyer
F. E. Cahill, Jr.	G. T. Lorance	S. P. Solow
C. R. Daily	W. C. Miller	E. I. Sponable
R. J. Engler	W. A. Mueller	R. T. VanNiman
L. D. Grignon		J. E. Volkmann

STANDARDS.—To constantly survey all engineering phases of motion picture production, distribution, and exhibition, to make recommendations and prepare specifications that may become proposals for SMPE Recommended Practices and/or American Standards. This Committee should carefully follow the work of all other committees on engineering and may request any committee to investigate and prepare a report on the phase of motion picture engineering to which it is assigned.

F. T. Bowditch, *Chairman*
Box 6087
Cleveland 1, Ohio

J. M. Andreas	Herbert Griffin	W. H. Offenhauser, Jr.
M. F. Bennett	A. C. Hardy	J. D. Phyfe
E. A. Bertram	R. C. Holslag	W. L. Prager
M. R. Boyer	J. K. Hilliard	G. F. Rackett
F. L. Brethauer	D. B. Joy	W. B. Rayton
F. E. Carlson	C. R. Keith	A. C. Robertson
E. K. Carver	W. F. Kelley	L. T. Sachtleben
*J. S. Chandler	R. Kingslake	Otto Sandvik
A. W. Cook	P. J. Larsen	J. A. Scheik
E. D. Cook	C. L. Lootens	R. R. Scoville
L. W. Davee	G. T. Lorance	J. H. Spray
L. T. Goldsmith	D. F. Lyman	Monroe Sweet
Irl Goshaw	H. W. Moyse	Lloyd Thompson

* Advisory Member.

*THOMAS BILLS	T. T. GOLDSMITH	E. I. SPONABLE
F. E. CAHILL, JR.	L. B. ISAAC	C. S. SZEGHO
P. C. GOLDMARK	A. G. JENSEN	V. A. WELMAN
	J. J. KOHLER	H. E. WHITE
	PIERRE MERTZ	*R. S. YEANDLE

TEST FILM QUALITY.—To supervise, inspect, and approve all print quality control of sound and picture test films prepared by any committee on engineering before the prints are released by the Society for general practical use.

F. S. BERMAN, *Chairman*
111–14 76th Ave.
Forest Hills, N. Y.

C. F. HORSTMAN   F. R. WILSON

THEATER ENGINEERING, CONSTRUCTION AND OPERATION.—To make recommendations and prepare specifications on engineering methods and equipment of motion picture theaters in relation to their contribution to the physical comfort and safety of patrons, so far as can be enhanced by correct theater design, construction, and operation of equipment.

HENRY ANDERSON, *Chairman*
1501 Broadway
New York 18, N. Y.

H. J. BENHAM	JAMES FRANK, JR.	J. J. HOPKINS
WILLIAM BORBERG	T. T. GOLDSMITH	C. F. HORSTMAN
F. E. CARLSON	ADOLPH GOODMAN	E. R. MORIN
*W. B. CUTTER		BEN SCHLANGER
*W. L. FLEISHER		J. J. SEFING

SMPE REPRESENTATIVES TO OTHER ORGANIZATIONS

American Documentation Institute....................J. E. ABBOTT
American Standards Association:
  Sectional Committee on Standardization of Letter
    Symbols and Abbreviations for Science and
    Engineering, Z10..............................L. A. JONES
  Sectional Committee on Motion Pictures, Z22..C. R. KEITH, *Chm.*
                                          A. N. GOLDSMITH, *Hon.Chm.*
                                          F. T. BOWDITCH
                                          E. K. CARVER
                                          D. F. LYMAN†

  Sectional Committee on Acoustical Measurements
    and Terminology, Z24.........................J. E. VOLKMANN
  Sectional Committee on Photography, Z38.........J. I. CRABTREE
European Advisory Committee.....................DONALD McMASTER, *Chm.*
Inter-Society Color Council........................R. M. EVANS, *Chm.*
                                          J. A. BALL
                                          RONALD BINGHAM
                                          F. T. BOWDITCH
                                          M. R. BOYER
                                          A. M. GUNDELFINGER
                                          G. F. RACKETT
National Fire Protection Association..............A. S. DICKINSON
Radio Technical Planning Board...................P. J. LARSEN
                                          E. I. SPONABLE†

* Advisory Member;   † Alternate.

SOCIETY of MOTION PICTURE ENGINEERS
HOTEL PENNSYLVANIA • NEW YORK 1, N·Y· • TEL. PENN. 6 0620

APPLICATION FOR MEMBERSHIP

(This page should be completely filled out by applicant in conformity with Qualifications and Requirements given on the opposite page for grade desired. References given should be members or nonmembers who will supply information on applicant's experience and serve as sponsors.)

Name_____Age_____

Address:_____

City_____

Employer_____

Occupation_____

Grade Desired: Associate ☐ ;   Active ☐

Education*_____

_____

_____

Record of Employment* (list companies, years, and positions held)_____

_____

_____

_____

Other Activities*_____

_____

_____

REFERENCES

(Name)	(Address)	(City)
1		
2		
3		

The undersigned certifies that the statements contained in this application are correct, and agrees, if elected to membership, that he will be governed by the Society's Constitution and By-Laws so long as his connection with the Society continues.

Date_____19_____   (Sgd)_____

* If necessary, use additional sheet to give complete record.