B. E. STECHBART

3050

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXX | JANUARY, 1938 | Number 1

CONTENTS

JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

Subscription to non-members, $8.00 per annum; to members, $5.00 per annum, included in their annual membership dues; single copies, $1.00. A discount on subscriptions or single copies of 15 per cent is allowed to accredited agencies. Order from the Society of Motion Picture Engineers, Inc., 20th and Northampton Sts., Easton, Pa., or Hotel Pennsylvania, New York, N. Y.

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

Publication Office, 20th & Northampton Sts., Easton, Pa.

General and Editorial Office, Hotel Pennsylvania, New York, N. Y.

West-Coast Office, Suite 226, Equitable Bldg., Hollywood, Calif.

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

MODULATED HIGH-FREQUENCY RECORDING AS A MEANS OF DETERMINING CONDITIONS FOR OPTIMAL PROCESSING*

J. O. BAKER AND D. H. ROBINSON**

Summary.—*The quality of variable-width sound records depends to a great extent upon image definition. The requirements for a perfect sound-track are complete transparency in the clear portion, complete opacity in the dark portions, an extremely sharp boundary between the clear and dark portions, and exact duplication of the wave traced upon the track by the galvanometer.*

Distortion is introduced by any change in average transmission in recording high-frequency waves. At high densities the average transmission is reduced, and at very low densities is increased by the presence of the high-frequency waves. The average transmission is compared to the transmission through the film for a 50 per cent exposed track without signal.

It is possible to find a density at which there is little, if any, change in average transmission, and this density corresponds to most nearly perfect image definition and least distortion. On an original or negative recording, with present commercial recording stocks, this density is extremely low, of the order of 0.6 to 0.8. For least ground-noise, the negative must be recorded at much higher density. A change in average transmission of the negative can be tolerated, since by proper choice of print density, minimum distortion in the positive track can be attained.

A modulated high-frequency recording affords an extremely accurate means of determining correct negative and print densities for given conditions of laboratory processing. An oscillator, designed for several carrier frequencies, is provided with a 400-cycle modulator for recording. The modulated carrier is recorded for several values of lamp current and processed to several negative densities. Prints are then processed to various values of density, and the 400-cycle output measured on suitable reproducing equipment. The combination of negative and print densities that gives least 400-cycle output indicates the condition for best image definition and least distortion.

Care must be exercised in the design and construction of the oscillator to maintain the 400-cycle output at a minimum.

The quality of variable-width sound records will depend upon how closely the requirements for perfect wave-form, low ground-noise, and freedom from volume distortion are met. Papers have been published in the JOURNAL† from time to time dealing with one or the

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received October 11, 1937.

** RCA Manufacturing Company, Camden, N. J.

† See Glossary.

other of these requirements. Kellogg[1] in 1935 discussed all three in a rather comprehensive manner. It is the purpose of this paper to consider the problem of wave-form in detail, and to describe a method for determining the conditions for optimal processing.

In 1927, Hardy,[2] treating the general subject theoretically, stated "... the quality of sound reproduced by the variable-width type of record does not depend upon the conditions of exposure or development of either the negative or positive." This is essentially true of the variable-width system, in contrast to the variable-density system, and is quite true for the low frequencies up to those of the order of 4000 cps., provided the exposure or development are not too radically different from the correct values. The higher the frequencies recorded, the greater the necessity for correct exposure and development.

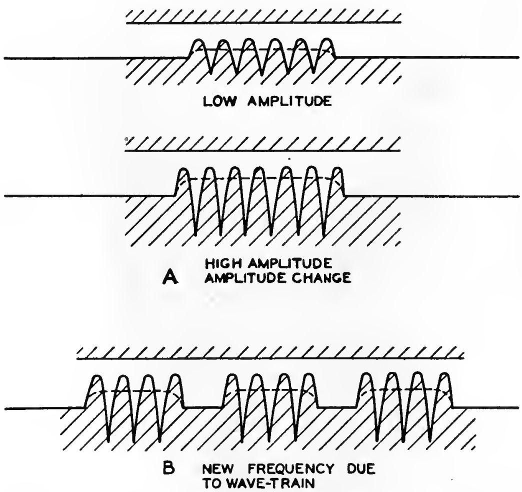


FIG. 1(*A*). Increase of distortion with volume; (*B*) introduction of new frequency due to wave-train.

Jones and Sandvik[3] in 1930 mentioned certain factors affecting the structure of the photographic image, with which this discussion is primarily interested: namely, image contraction, image growth, and the mutual action of adjacent images. For high-quality reproduction at 4000 cps. and above, these factors become of considerable importance.

Maurer,[4] in setting values for the sound negative and positive densities, based his consideration upon resolving power and contrast. While these factors are necessary in variable-width records for frequency and volume range, the structure of the photographic image must also be considered when high frequencies are recorded. Dimmick[5] in 1931 admirably treated the subject of negative and print densities for maximum output at the higher frequencies. Imperfection of the wave-form introduces not only harmonics and volume distortion at high frequencies, but also extraneous sounds, commonly known as "raspiness" or "hash." This distortion bears no frequency relation to the recorded frequency, but is dependent upon the change

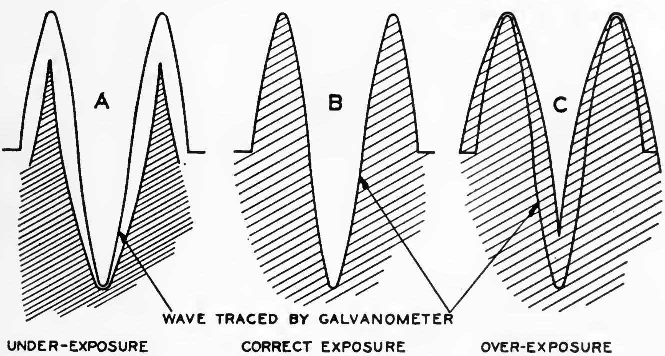


FIG. 2. Showing how the structure of the image is affected by image contraction, image growth, and mutual action of adjacent images.

of amplitude and the recurrence of the recorded high frequency. Fig. 1 illustrates this statement. *A* shows how the distortion increases with increase of volume. *B* illustrates the introduction of a new frequency due to the repetition of the normal build-up and decay of a high-frequency wave-train. Since speech and music are made up of wave-trains of such type, it can be seen that the distortion continuously changes in frequency and amplitude. A mathematical treatment of wave-form distortion was given by Cook[6] in 1930 and by Foster[7] in 1931, and need not be repeated here. This paper will be limited to an illustrative discussion and explanation of experimental data for showing how the distortion occurs in processing, and how it can be minimized.

Mees[8] in 1935 stated quite concisely the condition for minimum distortion: namely, "The point of minimum distortion occurs when the lack of sharpness, due to light scattered by the optical system and by the photographic emulsion in the recording process, is compensated for by a corresponding spreading of the image in the printing process."

Dimmick suggested the use of a modulated high-frequency recording for the practical determination of the distortion introduced by spreading of the photographic image. E. P. Schultz designed and built the first modulated high-frequency oscillator and Dimmick was the first to use it to practical advantage, in the early part of 1936. Since then, improvements have been made in the design and construction of the oscillator and much information has been obtained on the behavior of image-spread for various emulsions, different types

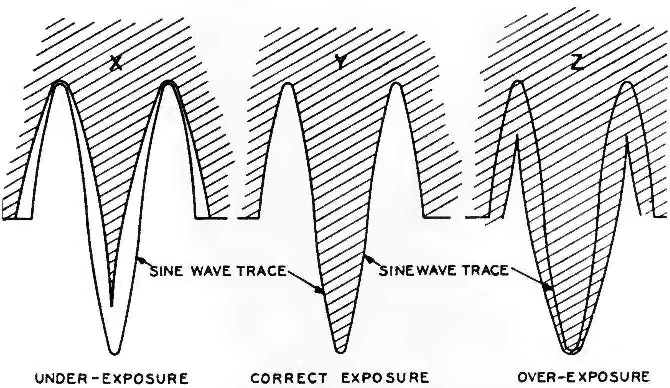


Fig. 3. Effect of exposure upon positive.

of developer, and printers. Without a doubt, this oscillator is the most powerful tool found to date, and is useful not only for studying the processing conditions of photographic sound records, but also for checking other sources of distortion such as found in amplifiers, loud speakers, printers, *etc.*

The purpose of this paper is to show only its use for photographic sound records. A description and explanation of its operation will be given later for the benefit of those who wish to take advantage of this method.

Image Definition.—In order to understand fully the problem involved, it will be desirable to consider the image definition and the factors affecting it, together with the requirements for a perfect sound-track of the variable-width type. A perfect sound-track would be one having complete transparency in the clear portions, complete opacity in the exposed or dense portions, an extremely sharp boundary between the clear and dense portions, and an exact duplication of the wave traced upon the track by the galvanometer.

The transparency of the clear portion depends upon the inherent properties of the photographic material and fog: the opacity of the dense portion depends upon the exposure and development; and the

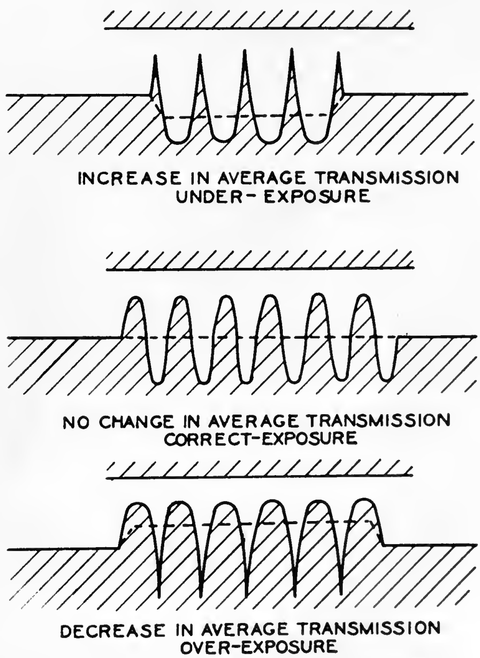


FIG. 4. Effect of exposure upon average transmisssion.

sharpness of the boundary upon the characteristics of the photographic emulsion and development, assuming the edge in recording to be of perfect sharpness.

The exact duplication of the wave traced by the galvanometer depends upon the image definition in both the negative and print. As stated previously, the structure of the image is affected by three factors, image contraction, image growth or spread, and mutual action of adjacent images. All emulsions exhibit these three factors depending upon the exposure and development. Fig. 2 helps to visualize this a little more clearly. *B* is the sine wave as traced by the galvanometer. *A* is the condition for underexposure, which shows image contraction, and *C* is the condition for overexposure, which shows image growth. An exposure can be found where neither contraction nor growth of the image occurs. For convenience, we shall hereafter refer to the density at which this occurs as the "balance-density." At first thought, this would seem to be the proper exposure to use. However, with present available emulsions for variable-width sound recording, this balance occurs at too low a

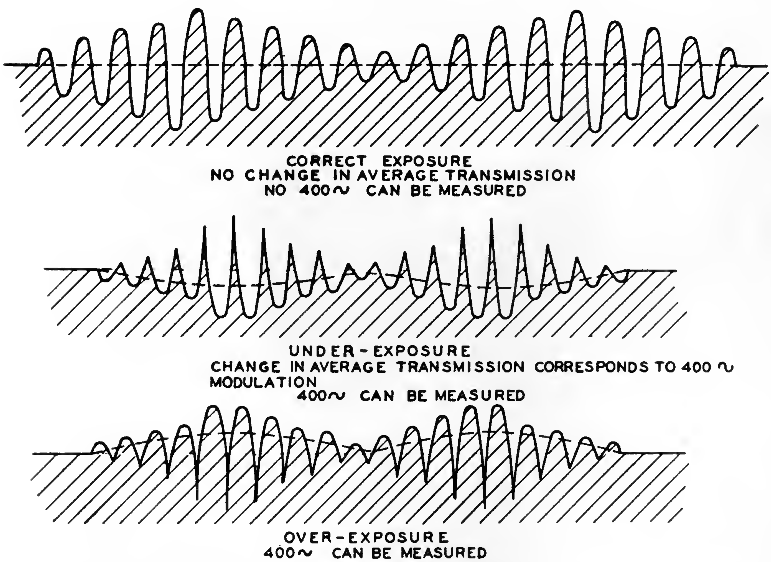


FIG. 5(*A*). Effect of exposure upon transmission of modulated high-frequency recording.

density, and, therefore, does not meet the requirement for a perfect sound record. Another factor is the present method of making prints from a recorded negative. Due to the image characteristics of the positive emulsion and printer slippage, the balance-density of the print track made from a recorded track of balance-density would be extremely low, probably of the order of 0.4 to 0.5, introducing considerable noise and having very low output.

Therefore, of necessity, image-spread must be introduced in the recorded track and then balanced out by the image-spread in the printed track.

Under- and overexposure have the same effect upon the printed positive as upon the negative. Fig. 3 illustrates these conditions. X and Y would be obtained from Fig. 2 (B). Y, from Fig. 2 (B), would give perfect image definition, but would be too low in density for best noise-reduction and maximum output. Z would be obtained from Fig. 2 (A). Y satisfies the requirements and is obtained from Fig. 2 (C).

Average Transmission.—Referring to Fig. 4, and translating image definition into light transmission, image contraction results in an increase of average transmission, where the average transmission is taken for unmodulated half-track, and image-growth results in a decrease in average transmission Perfect image definition for the condition of balance-density does not change the average transmission. Image definition can be determined in a number of ways utilizing this fact of its effect upon the average transmission. One method would be to record a half-track and a high frequency, and measure the change of average transmission on a microdensitometer. This is not a practicable method. The method of measuring the d-c. change of photocell current when the recording is played on a reproducer requires either a d-c. amplifier or a sensitive galvanometer.

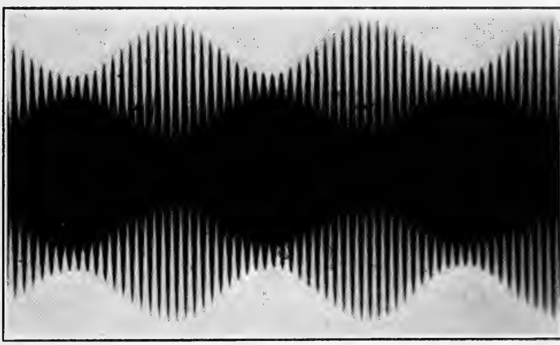


FIG. 5(B). Modulated high frequency, 9000 cycles with 400 cycles.

The modulated high-frequency recording provides means for measuring the change of average transmission in terms of alternating current which can be amplified conveniently and measured on suitable reproducing equipment.

Modulated High Frequency.—When the image definition is not perfect, the change in average transmission of a high-frequency recording depends upon the amplitude and recurrence of the high frequency. If, therefore, a high-frequency note is modulated with a comparatively low-frequency note the average transmission of the high frequency will vary in accordance with the low frequency.

In Fig. 5 (*A*) the modulated high-frequency recording is shown for the three conditions of under-, correct, and overexposure. For underexposure, the average transmission is increased proportionally to the amplitude of the high-frequency note and varies between maximum and minimum in accordance with the low frequency. A similar phenomenon takes place with overexposure, except in this case the

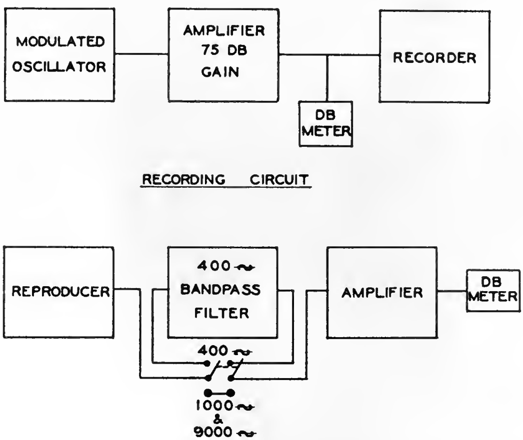


FIG. 6. Measuring circuit, modulated oscillator.

average transmission is decreased. With correct exposure and balance-density, the average transmission is unchanged. Fig. 5 (*B*) is a microphotograph of a modulated 9000-cycle track.

Any change of average transmission is indicated by playing the modulated track on a distortion-free reproducer and measuring the low-frequency output through a band-pass filter that attenuates all frequencies except the modulating frequency. The output will give positive readings for all conditions of under- and overexposure, and will read a minimum for the condition of correct exposure. Hence, the differentiation between over- and underexposure can be determined only by curves plotted from a number of readings.

Graphic Interpretation.—For better understanding and uniform interpretation, the following method of plotting the results has been adopted. Recordings are made of 1000- and 9000-cycle notes, and a 9000-cycle note modulated 75 per cent by a 400-cycle note, of equal amplitudes for several values of exposure or recording lamp current, with a few inches of unmodulated track at the end of each recording for density measurements, and processed in accordance with standard practice for variable-width sound negatives. A series of prints is then made from each negative and given the standard release print

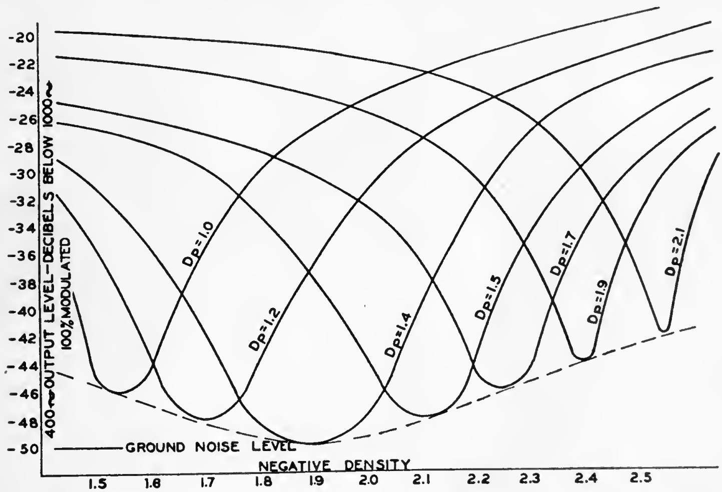


FIG. 7. Variable-width sound record image definition characteristics; 400-cycle output measured through a 400-cycle band-pass filter.

processing. The prints when measured on a reproducer, using a 400-cycle band-pass filter for the modulating frequency only, will give readings for a number of combinations of negative and print densities.

The circuits for recording and measuring are shown in Fig. 6. It is desirable when recording each frequency, first to adjust the input to the recorder for 100 per cent swing of the galvanometer and to note the reading of the decibel meter. The input is then reduced by 1 decibel to avoid the possibility of overshooting. This method of setting the input insures uniform amplitude of the recordings.

In the measuring circuit, the 400-cycle band-pass filter is located between the reproducer and the amplifier; otherwise, the output of the amplifier would saturate the filter and give incorrect readings. A switching arrangement is provided for removing the filter from the circuit when the 1000- and 9000-cycle notes are being measured.

In order to provide a uniform method for comparison purposes, the output readings must be corrected for all losses appearing in the measuring circuit, such as filter attenuation, amplifier response, and scanning slit loss. The 400-cycle output must also be referred to 100 per cent modulation, which, in the case of 75 per cent modulation, is the addition of +2.5 decibels. The corrected output readings are then all referred to the maximum output at 1000 cycles, as the reference level in the decibel system.

The results are plotted in Fig. 7, with relative levels as ordinates and negative densities as abscissas, giving a comparatively smooth curve for any one print density. For the condition of optimal processing, the 400-cycle output will be a minimum while the 1000- and 9000-cycle outputs will be at their maxima.

The 9000-cycle carrier-frequency was chosen in this case merely to indicate the method. While preliminary tests indicate that the negative and print densities remain the same at any high frequency, it is suggested that when the method is used in commercial practice, the cut-off frequency of the particular studio equipment under test be chosen as the high frequency to be modulated. The lower the cut-off frequency, the broader the processing tolerances become.

The method has been in use for more than a year and a half on both the East and West Coasts, and has proved of inestimable value in determining the optimal processing conditions for variable-width sound recordings.

In general, the conditions for the optimal processing of ultraviolet recordings are a negative density of 1.9–2.1 and a print density of 1.4–1.6. It must be emphasized that the exact value of negative and print density will depend upon the particular processing laboratory and the type and condition of developer used. Experience with commercial laboratories has shown that variations of print density from 1.4 to 1.8 occur for the same negative density of 1.9.

The Modulated Oscillator.—Since considerable interest has been shown in the method and since certain precautions must be observed in the construction of a suitable oscillator, it was deemed advisable to include here the design of an oscillator that has proved satisfactory. Unless the oscillator has a very low 400-cycle output from the modulated high-frequency source, a satisfactory 400-cycle minimum can not be obtained from the recorded sound-track. The design given here has a 400-cycle output from the modulated high-frequency of −52 decibels below that of the high-frequency output. This level is near that of the ground-noise.

The modulated oscillator to be described was designed to fulfill the following requirements:

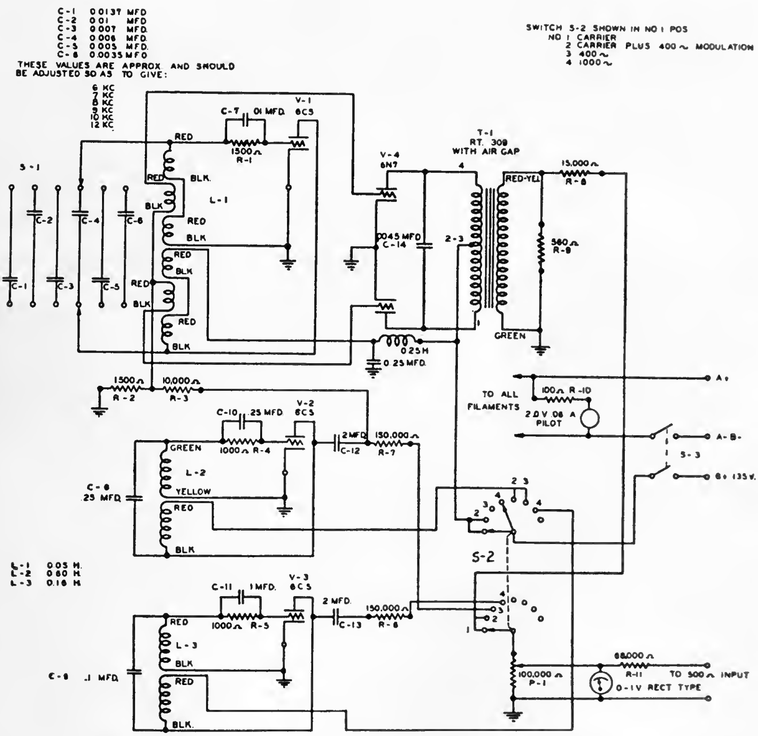


FIG. 8. Modulated carrier oscillator for film measurements.

(*1*) Provide high-percentage modulation with minimum distortion.

(*2*) Provide means for excluding the 400-cycle modulating component from the output circuit.

(*3*) Provide several carrier-frequencies.

(*4*) Be battery-operated for stability of operation, freedom from hum, and for portability.

The first and second requirements were fulfilled by utilizing a carrier oscillator (6000 to 12,000 cps.), a low-distortion, 400-cycle, modulating oscillator, and a balanced modulator. The use of a balanced modulator made elaborate filtering unnecessary in the output and provided linear modulation up to 75 per cent, at which value it was used. In order to provide for the several carrier frequencies, a switch has been included to alter the capacity across the carrier oscillator tank circuit.

The complete circuit diagram with its component parts is shown in Fig. 8. The carrier oscillator coil, *L-1*, is of particular importance, and has been so designed as to enable an optimal *LC* ratio to be maintained for the various carrier frequencies from 6000 to 12,000 cps., and provides a balanced input to the modulator tube.

L-2 is the tank inductance for the 400-cycle oscillator, and *L-3* is the tank inductance for the 1000-cycle oscillator.

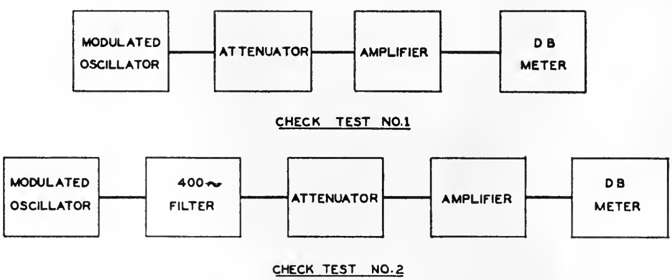


FIG. 9. System for measuring distortion from oscillator.

A switch, *S-1*, has been provided for selecting the carrier frequency. Switch *S-2* is the output selector switch, and is provided with four positions: (*1*) carrier output, (*2*) modulated carrier output, (*3*) 400-cycle, and (*4*) 1000-cycle output. The 1000-cycle output is to be used as reference frequency. Switch *S-3* is the "on-off" switch. Potentiometer *P-1* is for varying the output of the frequency selected.

It will be necessary to use an amplifier having a gain of approximately 85 decibels, with a calibrated attenuator reading in decibels and providing a flat frequency characteristic to 12,000 cps. The output of the oscillator has been adjusted to give approximately −50-db. output (0.0125 watt reference level). This output could have been increased probably to zero level, but an indicating instrument would then be required that could read −50, since the range required is greater than 50 decibels. A 400-cycle band-pass filter is also required, such as the General Radio Co. type *530-A*. With the value of *R-11* given in Fig. 8, a half-scale reading on the voltmeter gives an output into a 500-ohm load of approximately −55 decibels (0.0125 watt reference level).

In order to measure the distortion from the oscillator, the following procedure is recommended, as shown in Fig. 9.

(*1*) Connect the oscillator to the amplifier with a suitable output meter. Set the oscillator on carrier (No. 1 position). Set the amplifier attenuator to give an output meter reading of approximately 10 decibels. Note the amplifier attenuator setting required and the output meter reading for this condition.

(*2*) Set the oscillator for modulated carrier (No. 2 position) and connect to the 400-cycle band-pass filter, the filter output to be connected to the amplifier. If the values of *R-6*, *R-7*, and *R-8* were adjusted properly, no change in oscillator potentiometer setting should be required to give the same oscillator meter reading. Increase the gain of the amplifier by adjusting the attenuator so that the amplifier output meter reads the same as in the first check. The change in attenuator setting, plus the filter attenuation in decibels, is the attenuation of the 400-cycle component to the carrier. This should be down approximately −50 decibels on all carrier frequencies.

Conclusion.—Image definition is one of the factors governing the quality of variable-width sound records. The control of image definition in processing becomes of increasing importance as the frequency range is extended.

Image definition can best be determined in terms of the average transmission. Of the several methods for determining average transmission, the modulated high-frequency recording is the most practicable. The density of the exposed track, for best image definition and minimum output of the modulating frequency, is referred to as the "balance-density."

The design of a modulated oscillator and a method of using it are suggested for general use as an aid in determining the optimal processing conditions for variable-width sound records.

The importance of care in the design and construction of the modulated oscillator can not be overemphasized.

Frequent use of the modulated high-frequency recording by a number of processing laboratories during the past eighteen months has demonstrated the practicability of this method for determining conditions for optimal processing.

The writers wish to express their gratitude to E. W. Kellogg and A. C. Blaney for their helpful suggestions and kindly criticisms in the preparation of this paper.

REFERENCES

[1] KELLOGG, E. W.: "A Comparison of Variable-Density and Variable-Width Systems," *J. Soc. Mot. Pict. Eng.*, **XXV** (Sept., 1935), No. 3, p. 203.

[2] HARDY, A. C.: "The Rendering of Tone Values in the Photographic Recording of Sound," *Trans. Soc. Mot. Pict. Eng.*, **XI** (Sept., 1927), No. 31, p. 475.

[3] JONES, L. A. AND SANDIVIK, O.: "Photographic Characteristics of Sound Recording Film," *J. Soc. Mot. Pict. Eng.*, **XIV** (Feb., 1930), No. 2, p. 180.

[4] MAURER, J. A.: "The Photographic Treatment of Variable-Area Sound Films," *J. Soc. Mot. Pict. Eng.*, **XIV** (June, 1930), No. 6, p. 636.

[5] DIMMICK, G. L.: "High-Frequency Response from Variable-Width Records as Affected by Exposure and Development," *J. Soc. Mot. Pict. Eng.*, **XVII** (Nov., 1931), No. 5, p. 766.

[6] COOK, E. D.: "The Aperture Effect," *J. Soc. Mot. Pict. Eng.*, **XIV** (June, 1930), No. 6, p. 650.

[7] FOSTER, D.: "The Effect of Exposure and Development on the Quality of Variable-Width Photographic Sound Recording," *J. Soc. Mot. Pict. Eng.*, **XVII** (Nov., 1931), No. 5, p. 749.

[8] MEES, C. E. K.: "Some Photographic Aspects of Sound Recording," *J. Soc. Mot. Pict. Eng.*, **XXIV** (April, 1935), No. 4, p. 285.

GLOSSARY

SANDVIK, O.: "A Study of Ground-Noise in the Reproduction of Sound by Photographic Methods," *Trans. Soc. Mot. Pict. Eng.*, **XII** (Sept., 1928), No. 35, p. 790.

STEINBERG, J.: "The Quality of Speech and Music," *Trans. Soc. Mot. Pict. Eng.*, **XII** (Sept., 1928), No. 35, p. 633.

MILLER, D. C.: "The Physical Properties of Music and Speech," *Trans. Soc. Mot. Pict. Eng.*, **XII** (Sept., 1928), No. 35, p. 647.

BIELICKE, W. P.: "The Processing of Variable-Width Sound Records in the Film Laboratory," *J. Soc. Mot. Pict. Eng.*, **XVII** (Nov., 1931), No. 5, p. 778.

SANDVIK, O., HALL, V. C., AND GRIMWOOD, W. K.: "Further Investigations of Ground-Noise in Photographic Sound Records," *J. Soc. Mot. Pict. Eng.*, **XXII** (Feb., 1937), No. 2, p. 83.

DIMMICK, G. L., AND BELAR, H.: "Extension of the Frequency Range of Film Recording and Reproduction," *J. Soc. Mot. Pict. Eng.*, **XIX** (Nov., 1932), No. 5, p. 401.

DISCUSSION

MR. EDWARDS: How does the scanning slit loss affect the result?

MR. BAKER: The scanning slit loss reduces the output at the higher frequencies, the loss depending upon the width of the slit. Of course, the amplifier attenuates some of the higher frequencies, too. For a 1-mil slit, say, the slit loss at 9000 cps. is 4 decibels compared with the 1000-cycle output. The loss increases at the higher frequencies.

MR. NICHOLSON: The family of curves you showed gave the optimal conditions, but laboratories are generally interested in limits. How do you pick limits from the curves? What determines the point beyond which you may not go?

MR. BAKER: We like to see the optimal fulfilled, but I am not sure of the limits. Present indications are that the modulating frequency should not be greater than about −40 db. Our experience in a number of laboratories has been that the sharpness of the two sides of one of the family of curves coming down to a minimum varies. In some laboratories the spread between the two sides is rather large, in other laboratories rather close.

MR. KELLOGG: Mr. Edwards brought up the question of reproducer slit loss. Theoretically a 1-mil slit will give about 65 per cent response, I believe, at 9000 cps. Of course, in measurements we make allowance for that, which I believe is permissible. The calculated slit loss is for a sine wave.

RECORDING TESTS ON SOME RECENT HIGH-RESOLUTION EXPERIMENTAL EMULSIONS*

J. O. BAKER**

Summary.—*In another paper[1] it is shown that present commercial sound-recording emulsions have least distortion at very low density, accompanied by an undesirable amount of ground-noise if used as a positive.*

A new experimental emulsion, E.K. 0-7461-1, differs from present emulsions in having extremely high resolution and minimum distortion at a density of approximately 1.5. Its speed is less than that of regular recording stocks, but since it is used with white light and no filter is required, sufficient densities are readily attained with present optical systems. These characteristics offer possibilities heretofore not attainable.

The high resolution, low image spread, and low film-hiss of this emulsion make possible recording a positive sound-track that can be played directly, eliminating the distortion usually introduced in printing and the ground-noise contributed by the negative.

The advantage of direct playback will be realized whether the recording is standard, Class A push-pull or Class B push-pull. The perfection of image definition in the new emulsion means increased processing tolerances in adjusting the Class B system for perfect cross-over between the negative and positive half-waves.

It is not at present feasible to use this emulsion as a negative for making prints on positive stock. For special sound-films without pictures, it may be used for a printed positive, using a negative made on the same stock, provided printer losses are not excessive.

It has been shown in an earlier paper[1] how image definition in variable-width sound records could be determined by means of modulated high-frequency recording. For best noise-reduction and maximum output, the print density should not be less than 1.3. For minimum image distortion this requires a negative exposure that will give a negative density of 1.8 to 2.2.

The photographic problems with which we are confronted in variable-width sound recording are noise, image definition, and volume distortion at high frequencies.

---

* Presented at the Fall, 1937, Meeting at New York, N. Y., received October 11, 1937.

** RCA Manufacturing Co., Camden, N. J.

Sandvik[2] shows that the inherent noise of a sound-recording emulsion is quite low, but increases considerably during the process of developing, fixing, washing, drying, and handling. Whatever noise

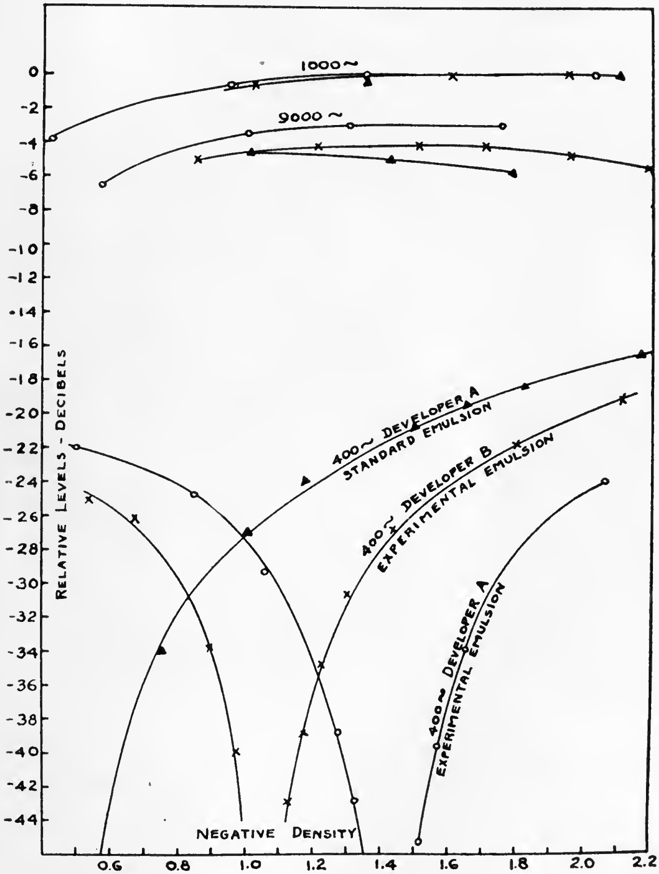


FIG. 1. Image definition characteristics.
○ Experimental emulsion: $13^{1}/_{2}$ min., 65°F., developer *A*.
× Experimental emulsion: $13^{1}/_{2}$ min., 65°F., developer *B*.
▲ Standard emulsion: 10 min., 65°F., developer *A*.
White light exposure for experimental emulsion.
Ultraviolet exposure for standard emulsion.

exists in the negative is carried over into the print, adding to that which results from the imperfections of printing and processing. The image definition and high-frequency losses are dependent upon the contrast and resolution of the emulsion. An aid to the reduction of these imperfections would be an emulsion that could be reproduced directly as a positive without the necessity of making a print, and having high contrast and high resolution, with sufficient speed for use in present recording systems. The film manufacturers have long recognized the need for such an emulsion. Jones and Sandvik[3] in 1930 described an experimental emulsion with these characteristics,

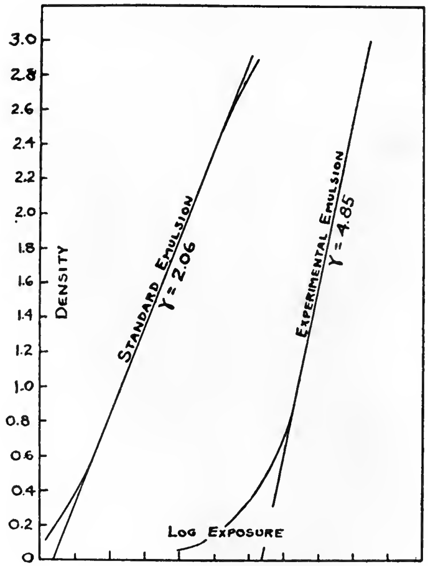


FIG. 2. Sensitometric characteristics; experimental emulsion, 13$^1/_2$ min.; standard emulsion, 10 min. Developer *A*, 65°F. Positive lamp filter.

but concluded that further experimental work was necessary before its utility and practical value could be determined.

In the early part of this year samples of an emulsion were supplied by the Eastman Kodak Company having a fog value of 0.02, extremely free from noise, and having high contrast and high resolution together with a high degree of sharpness. The H&D speed of the emulsion is relatively low compared with that of present recording stocks, but since it was designed for white-light exposure, sufficient density can be attained with the present recorder optical systems. Its greatest sensitivity lies in the region of 5500 Å and hence the only change required in the optical system is the removal of the ultraviolet filter. This emulsion for the first time offers the possibility of recording a positive sound-track for direct reproduction.

In Fig. 1 two sets of image-definition characteristics are shown for two slightly different developers, developer *A* being the one found best suited for variable-width recording and developer *B* having a lower concentration of bromide, resulting in a higher speed. The development time was $13^1/_2$ minutes in both cases. Developer *A* gave maximum image definition at a density of 1.45 at a minimum 400-cycle level of approximately 50 db. The 9000-cycle level is also a maximum, being only 3 db. below that of the 1000-cycle. The density range over which the 400-cycle level is more than −40 db. is from 1.27 to 1.57 or 0.3

Developer *B* gave the maximum image definition at a density of about 1.05, and the minimum 400-cycle level is again approximately −50 db., but the density range at −40 db. is only about 0.2.

The formula for developer *A* is as follows:

Elon	0.9 gram
Sodium sulfite	62.8 grams
Hydroquinone	15.7 grams
Sodium carbonate (monohydrate)	23.5 grams
Potassium bromide	2.1 grams
Water	1 liter

The replenisher is the same with the bromide omitted.

Developer *B* was mixed the same as *A* but using only one gram per liter of bromide.

The sensitometric curve of this emulsion developed for $13^1/_2$ minutes in developer *A* is shown in Fig. 2, and the recorder exposure-density characteristic in Fig. 3.

Fig. 4 is a microphotograph comparing the image spread of this emulsion with standard recording stock.

The principal advantage of this emulsion is for direct playback when the sound-track is recorded as a positive, and will be realized whether the recording is standard, Class *A* push-pull, or Class *B* push-pull. The inherent perfection of image definition provides increased processing tolerances in adjusting the Class *B* system for perfect cross-over between the negative and positive half-waves. Recording a positive track requires a mask in the recorder optical system that is exactly the inverse of the present negative mask.

The optical requirements for recording a positive track have been worked out for the three types mentioned. The advantage of this procedure of using a recorded positive for direct playback or re-recording is the improvement in sound quality due to the elimination of the printing operation, which has been found to introduce a loss of image definition even when done under ideal conditions. A substantial reduction in ground-noise is also achieved, since the printing process always introduces noise at low densities due to pin holes or dirt in the negative emulsion and to the graininess along the boundaries of the recorded track.

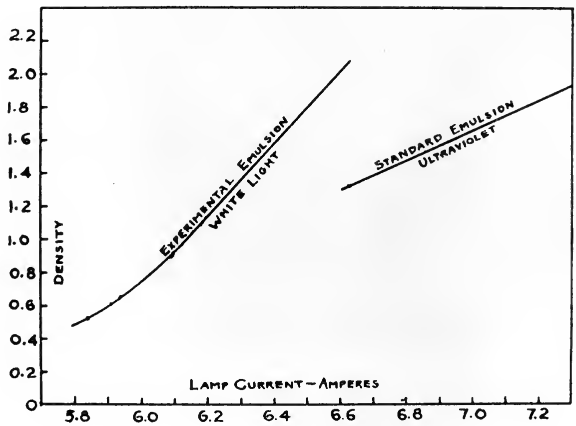


FIG. 3. Exposure characteristics

Since the inherent film noise of this emulsion is extremely low, ground-noise reduction in the original recording is not essential. When used for re-recording to standard emulsions, the ground-noise reduction can be applied there. A particular advantage of this method would be the ability to anticipate a sudden increase in the amplitude of the sound by means of an auxiliary scanning beam ahead of the scanning point, which would avoid cutting off the peaks of the recorded sound.

Since the image definition of this emulsion is superior to that of the commercial stocks, it is not possible to use it as a negative unless the recorded density is made of the order of 2.6 to 2.8, requiring a lamp current of approximately 7.2 amperes. Further investigations are necessary before the feasibility of this procedure can be determined.

In the few tests made using this emulsion for the recorded negative and printed positive, it was found that the image definition is materially impaired in the printing. More work is required before any definite conclusion can be drawn, and the results of the investigation will be made the subject of a future paper.

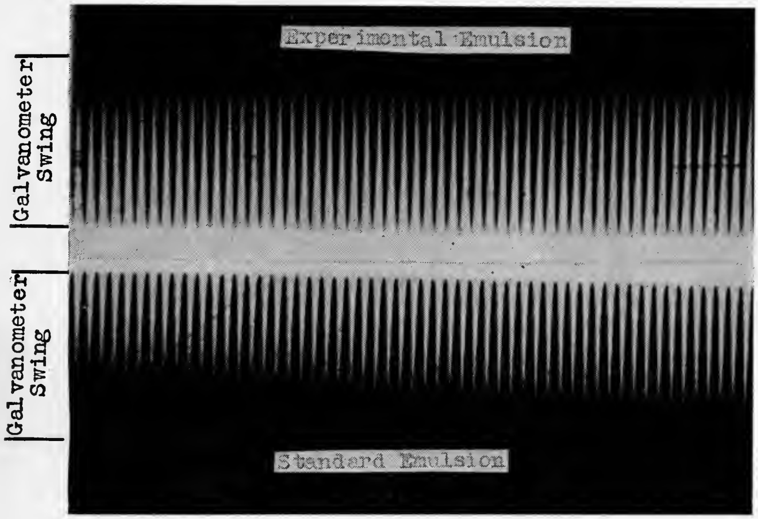


FIG. 4. Microphotographic comparison of image spread.

From this discussion, it is seen that the availability of the new emulsion provides a definite advance in the improvement of variable-width sound recording, and for the first time permits making a recorded positive free of image distortion at usable densities.

REFERENCES

[1] 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** (Jan., 1928), No. 1, p. 3.

[2] SANDVIK, O.: "A Study of Ground-Noise in the Reproduction of Sound by Photographic Methods," *Trans. Soc. Mot. Pict. Eng.*, **XII** (1928), No. 35, p. 790.

[3] JONES, L. A., AND SANDVIK, O.: "Photographic Characteristics of Sound-Recording Film," *J. Soc. Mot. Pict. Eng.*, **XIV** (Feb., 1930), No. 2, p. 180.

DISCUSSION

MR. FARNHAM: Was the 9000-cycle record on standard emulsion made with ultraviolet light, and the other with white light?

MR. BAKER: Yes.

MR. CRABTREE: It would have been interesting if Mr. Baker could have brought along some recordings comparing the method of printing from the negative with re-recording from the negative direct. Do I understand that this would replace the ultraviolet method of recording?

MR. BAKER: No, but it is quite useful for special work. We can not print from this emulsion to the standard positive emulsion, because the image definition is so much better that in order to compensate for the image spread in the negative by the image spread in the positive, we have to record the negative at a density that is quite high, of the order of 3, to get a print density of 1.4 to 1.5, and we begin to lose the higher frequencies at such high negative densities. As we see it now, the principal advantage of this emulsion lies in its use in original recording of a positive track in the studio, then laying it aside until decision has been made as to what is wanted for the final releases; then cutting the negative, running it through the film phonograph with the re-recording system, and making the final release negatives.

MR. KELLOGG: How do you account for the disappearance of peaks in the experimental emulsion? Why do they not come up as near the top of the swing as they do in the standard emulsion? The line of the peaks of the standard emulsion is a straight line; while apparently, due to excessive contrast or something, all the peaks are ragged in the experimental emulsion.

MR. BAKER: The peaks grow somewhat in height due to image spread in the standard emulsion. In the experimental emulsion, they do not grow quite as much. If we could see here on the screen the recorded negatives themselves, I think they would look much better than this does.

MR. KELLOGG: The question has been raised as to whether the optical system was equally favorable to both emulsions. Our optical systems are corrected for ultraviolet and green. This should be favorable for both films, since in making a standard recording we are using exclusively ultraviolet; and in recording on the experimental emulsion, the exposure is produced principally by green light.

FILM PERFORATION AND 96-CYCLE FREQUENCY MODULATION IN SOUND-FILM RECORDS*

J. CRABTREE AND W. HERRIOTT**

Summary.—*When motion picture film is flexed around a cylinder the film in the region of the sprocket holes does not follow a smooth curve. In a sound record this leads to frequency distortion of perforation frequency.*

If a length of motion picture film is bent into an arc of short radius, it is apparent from visual inspection that the film surface departs from a smooth curve in the region of the sprocket holes and assumes a polygonal profile with the angles of the polygon situated at the sprocket holes. This tendency to a polygonal profile of a curved perforated film exists even where the arc is of large radius, and is readily apparent when suitable methods of observation are used.

Fig. 1 shows the image of a parallel-line screen reflected from the emulsion surface of a length of 35-mm. sound-recording film, curved around a cylindrical form of 2-inch radius. Distortion of the line images results from distortion of the reflecting surface, the degree of distortion indicating the order of departure from the average condition. From an examination of Fig. 1 it is evident that distortion of the film extends well into the sound-track area, although the picture area in general conforms well to the radius. The widening of the line-screen pattern shown between sprocket holes in Fig. 1 is evidence of a lengthening of the radius of curvature or flattening of the film in this area. Distortion of the opposite sign, *i. e.*, shortening of the radius of curvature, is shown adjacent to the sides of the perforation that are parallel to the direction of film travel.

That the degree of distortion increases as the radius of curvature of form decreases is seen in Fig. 2, where are shown reflected images of a series of parallel lines from film surfaces curved over cylindrical forms of different radii. It is to be noted that in some cases the distortions extend well across the sound-track areas.

---

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received October 14, 1937.

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

Figs. 1 and 2 were made by means of the arrangement shown in Fig. 3. For Fig. 1 the axis of the film support was parallel to the optical axis of the camera, and for Fig. 2 the axes of the various cylindrical forms were at right angles to the camera axis.

These effects can readily be observed visually by taking a short length of motion picture film and viewing the reflected images of the

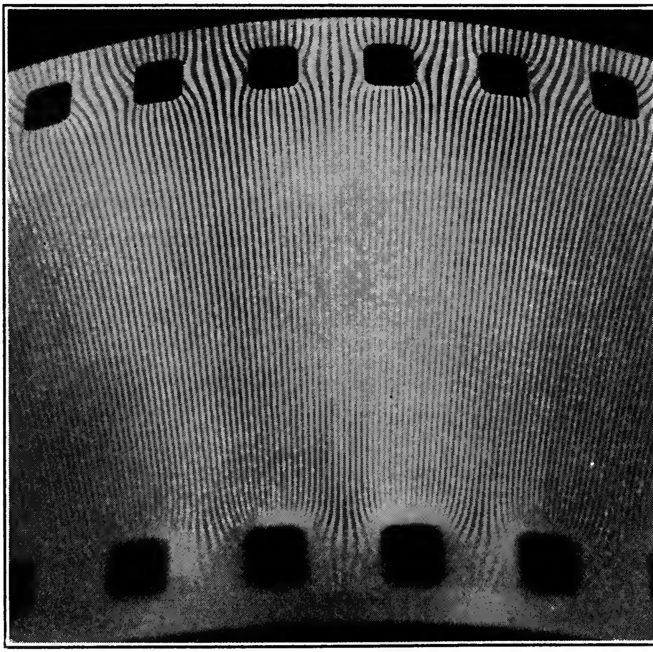


FIG. 1. Image of parallel-line screen reflected from emulsion surface of film.

edges or bars of a window from its surface. A trace of oil rubbed over the emulsion surface will make it more reflective.

These figures are evidence that motion picture film curved over a sprocket or drum assumes in the region of the perforations a shape similar to that shown in Fig. 4.

If a constant frequency is recorded on a straight length of film, in the usual location adjacent to perforations, bending the film over a drum or sprocket will change the spacing of the striations of the record due to the stretching of the outer, and compression of the inner layers. The change of spacing increases as the radius of the drum or sprocket decreases. Since differences in curvature exist in the region of each perforation, differences in spatial relationship of the sound striations (frequency modulation) will exist at perforation frequency. Ninety-six cycle frequency "flutter" will therefore be present when such a record is reproduced by any means that introduces curvature of the film at the point of translation.

From these observations the following conclusions are reached:

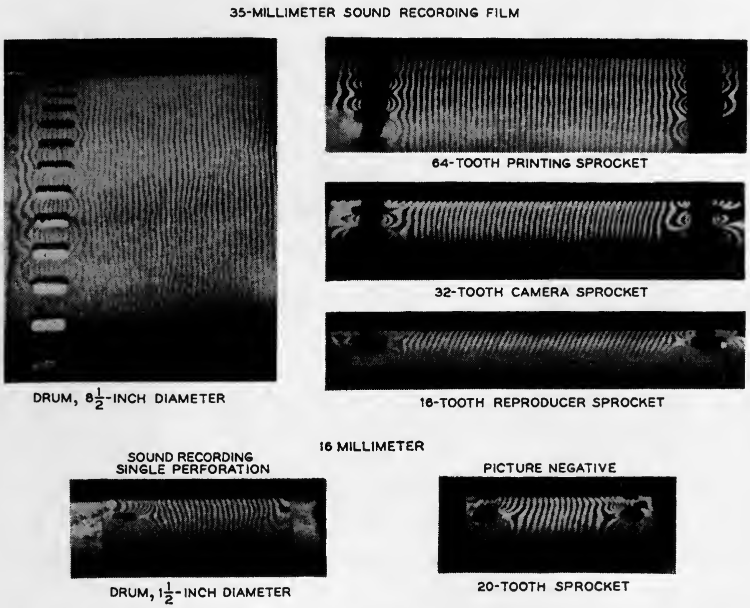


FIG. 2. Degree of distortion with respect to radius of curvature of film.

(*1*) The act of flexing a sound-film record introduces 96-cycle flutter if the record is reproduced in the flexed condition. This effect is due solely to the film distortion near the perforations resulting from flexure, and is not to be confused with effects attributed to the presence of the teeth on the drive sprockets.

(*2*) No increase in 96-cycle frequency flutter should result from the printing operation when conducted in a contact printer, such as the Bell & Howell, so long as the pitches of negative and positive are such that no slippage occurs. This follows because, in this operation, negative and positive are curved together over the same sprocket and so are similarly distorted. Image transfer will therefore be effected correctly as far as spatial relationship of the striations is concerned. Frayne and Pagliarulo[1] recently reported that the printing operation leads to negligible increase in 96-cycle frequency modulation.

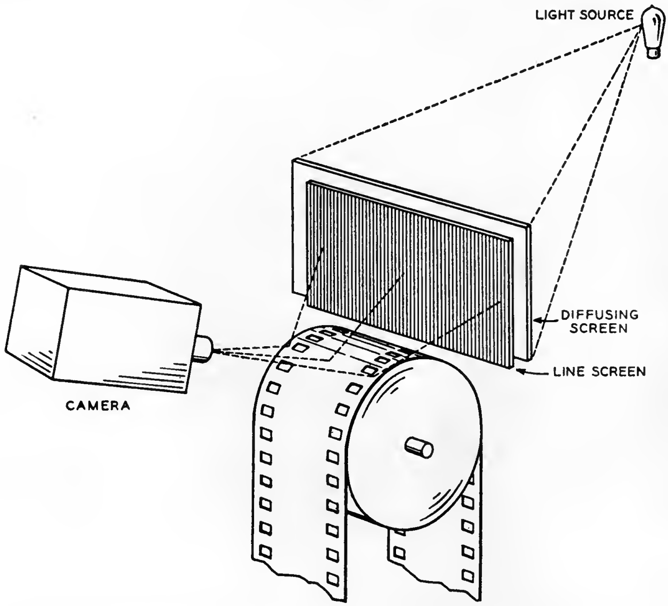


FIG. 3. Arrangement for photographing reflections of parallel-line screen on film.

Where pitch mismatching occurs in the printing operation the contours of negative and positive will not match and an increase in frequency modulation would be expected, probably at some other than

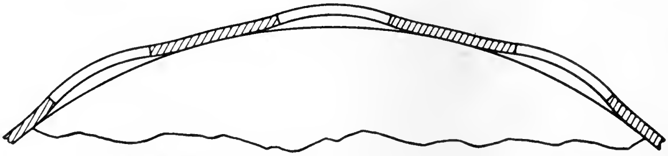


FIG. 4. Shape of film curved over a drum, at region of perforations.

perforation frequency, depending upon the manner of slippage and the degree of mismatching.

(3) Moving the sound-track away from the sprocket holes should largely remove this source of frequency modulation.[1]

REFERENCE

[1] FRAYNE, J. G., AND PAGLIARULO, V.: "The Influence of Sprocket Holes upon the Development of Adjacent Sound-Track Areas," *J. Soc. Mot. Pict. Eng.*, **XXVIII** (March, 1937), No. 3, p. 235.

DISCUSSION

MR. PALMER: Fig. 2 seems to show a lot of distortion in the 16-mm. film on the side opposite the perforations. How would you account for that?

MR. CRABTREE: We have observed distortions at the side of the film opposite the perforations but we have not considered them to be related to 96-cycle frequency modulation with which this paper is concerned.

MR. FISHER: What is the quantitative relation between the variation in the lines on your figures and the actual amount of variation from a true surface? This is an extremely sensitive indicating system, I believe.

MR. CRABTREE: We have not determined the relation between movements of the line pattern and the departures of the film surface from a true plane.

MR. SACHTLEBEN: Is not such distortion evident even in a flat piece of film that has not been distorted by the sprocket holes?

MR. CRABTREE: General distortions of the film surface are readily apparent but are not to be confused with localized distortion around perforations.

MR. ROBERTS: You stated that printing did not introduce any of this 96-cycle flutter. Is it not conceivable, in non-slip printing, that this flutter will occur because often the two films are fed in at unequal angles and the point at which the printing is done is unsupported? At that point we are engaging, or rather contacting, a series of flat surfaces, so in that type of printing why should not the effect be serious?

MR. CRABTREE: That would seem reasonable.

MR. CARVER: Is it not true that these reflections from surfaces of small curvature, or large radii of curvature, exaggerate the spaces between the lines very greatly, and that the whole effect is one that you can see at any time in film that has dried out a little? When the emulsion is shrunken, areas between the perforations are always curved. If the film is dried out to, say, 40 or 50 per cent relative humidity, the curvature would be even much greater than you showed. I think the effect is very much exaggerated.

MR. CRABTREE: We are not considering effects due to shrinkage. The appearance of shrunken film around perforations is well known. We are concerned with fresh film used in recording, and the effect upon frequency of flexing the film around a cylinder. To illustrate graphically the nature of these local distortions, photographs were made using a parallel-line screen.

MR. CARVER: You do not need the lines to see the distortion. You can see it by merely looking at the film.

MR. CRABTREE: The local distortions are perhaps best revealed by the use of straight parallel lines.

MR. CARVER: Those are reflections of lines that are very much exaggerated, and have nothing to do with frequency.

MR. CRABTREE: The use of a line-screen does not "exaggerate" the nature of these distortions. It gives an undistorted although enlarged view of these localized effects. It was the purpose of this paper to associate these effects with 96-cycle frequency modulation.

HIGH-SPEED MOTION PICTURE PHOTOGRAPHY APPLIED TO DESIGN OF TELEPHONE APPARATUS*

W. HERRIOTT**

Summary.—*High-speed motion pictures are employed at Bell Telephone Laboratories as a visual aid in the study of problems associated with the design, manufacture, and testing of telephone apparatus. A new high-speed camera of the optical compensator type operating at 4000 pictures per second is described, and its application to the study of problems associated with telephone apparatus is discussed.*

High-speed motion picture photography offers to the engineer means of analyzing mechanical movements otherwise too rapid to be normally perceived. It involves taking a series of pictures on motion picture film at high speed and projecting them at a much slower rate, such as at the normal viewing rate for motion pictures of sixteen or twenty-four pictures per second. In this manner a time-delay factor is introduced which is the ratio of the taking frequency to the viewing frequency. Pictures taken at the rate of 4000 per second will, when projected and viewed at the rate of 20 pictures per second, offer a time-delay factor of 200, and a rapid mechanical movement may thus appear to take place during a substantially longer period of time and so permit a detailed study of the motions involved.

Photographic records of this type have particular value in that space-time relationships of the movements of parts involved may be directly determined by measurements either of projected images of individual pictures or of enlarged paper prints. The time-interval between successive pictures is determined either directly from a clock-face photographed at the side of each picture area or from a knowledge of the taking rate.

Another method of analyzing rapid mechanical movement involves photographically scanning a small section of the silhouetted image of closely adjacent parts of a mechanism that are in relative motion.

---

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received October 10, 1937.

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

This results in a shadowgraph type of record on sensitized paper or motion picture film, from which the space-time relationships can be determined. This method, however, imposes severe limitations upon the size and the useful area of mechanisms that can be studied, and producing silhouetted images of important parts is frequently impossible due to structural conditions.

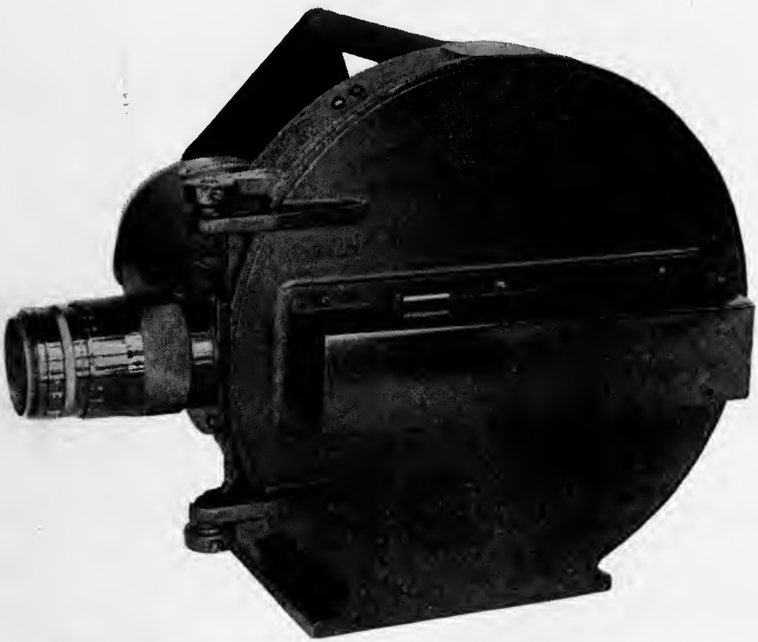


FIG. 1. High-speed camera, operating at 4000 pictures a second.

High-speed photography is finding extensive application in automotive and aeronautical engineering, in the study of problems associated with combustion of fuels and vibration in motors, air-flow around structures and in propeller design and performance. It is used extensively in the study of ballistics and in timing athletic events. It is coming into use in the fields of biology and medicine, in the study of nervous and muscular reactions under controlled conditions. Its widest use is in industry, where it is applied to "motion analysis" of a wide variety of manufacturing operations and of problems associated with the design and performance of machinery.

Bell Telephone Laboratories has for several years made use of high-speed photography as a visual aid in studying problems associated with the design, manufacture, and performance of telephone apparatus. It has been applied to studies related to dials, relays, switches, ringers, and to many other similar devices. It has found use in a study of stress, impact, and noise conditions associated with a variety of mechanical or electromechanical units. It has been of particular value in the study of transient movement of mechanical elements in telephone apparatus.

Apparatus used at Bell Telephone Laboratories in taking high-speed motion pictures includes a specially designed camera, shown in

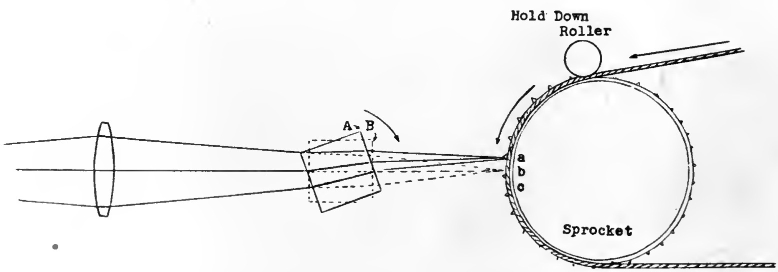


FIG. 2. Schematic arrangement of high-speed camera.

Fig. 1, which is usually operated at the taking speed of 4000 pictures per second.

The camera is of the optical compensator type having a small cube of optical glass rotating at high speed between the camera lens and the film, and serves to render the image of the object being photographed stationary relative to the rapidly and continuously moving film.

The compensator cube has four polished faces, each parallel to its axis of rotation which is, in turn, parallel to the axis of the sprocket. The film passes from the supply spool under a hold-down roller, shown in Fig. 2, and is held in contact over half the circumference of the sprocket from which it passes to the take-up reel. One picture is taken for each quarter revolution of the compensator, and, if blurring is to be avoided, the film and the image must move at the same rate. The index of refraction of the glass and the dimensions of the cube are chosen to cause the correct movement of the image as the film is continuously advanced past the exposure area. The downward image movement results from rotation of the cube and the consequent change in refraction of the light-rays at opposite faces of the cube. Rays from a point in the object to the left of the lens are converged by the lens and become incident upon the front face of the cube in the position at A, at which they are refracted to the opposite face and thence pass to form an image of the object point upon the film at a. When the film has reached a point b on the lens axis, the compensator has rotated to the position B. Displacement of the image is zero at this point, but further rotation of the prism causes further downward displacement of the image toward the point C, thus allowing the exposure of an elemental area of the film to continue during a substantial part of the exposure cycle. The duration of each exposure is con-

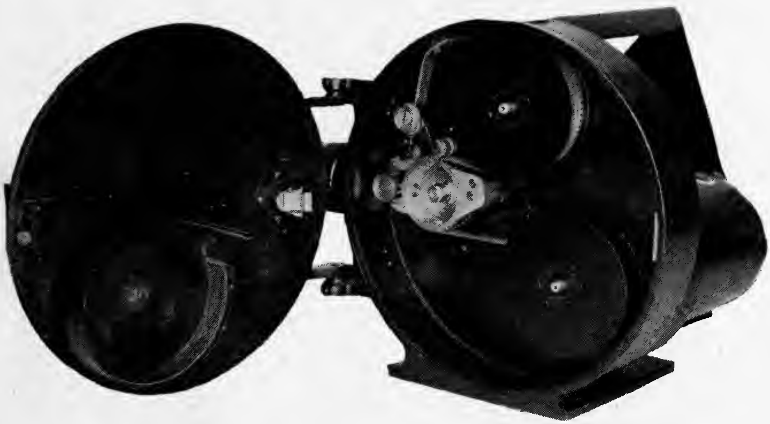


FIG. 3. Interior of the camera.

trolled both by the speed of rotation of the compensator and by the angular height of an aperture in front of each of the four faces of the cube.

The cube rotates on a ball-bearinged shaft at 60,000 rpm. for a taking speed of 4000 pictures per second, and is driven by spur-gears from a main shaft directly connected to a $^1/_5$-hp. motor. A toothed sprocket drives a 100-ft. length of 16-mm. supersensitive panchromatic film having twice the usual number of perforations, for better distribution of stresses in the film during acceleration. The sprocket is directly attached to the main drive-shaft of the motor and rotates at 12,000 rpm. for a taking speed of 4000 pictures per second. The loaded film spool is placed upon the upper spindle as shown in Fig. 3, and the film is threaded under a guide roller onto the main sprocket and to a take-up spool driven by a separate motor. A finder is provided which permits viewing the image on the film as seen upon a hooded ground-glass screen mounted upon the hinged door of the camera. Lenses of various focal lengths are interchangeable upon the front of the camera. The camera is mounted upon a substantial tripod and is readily portable.

FIG. 4. Portable lighting units used for high-speed work.

The effective duration of exposure for each picture is of the order of $^1/_{10,000}$ second or less. It is obvious that intense light-sources must be used to illuminate the subject adequately. Portable lighting units of the types shown in Fig. 4 have been developed at Bell Telephone Laboratories. These employ both carbon arcs and tungsten lamps, and offer intensities of illumination of the order of 10,000 to 500,000 foot-candles as desired. Liquid filters are used for absorbing excess heat radiated by the light-sources.

Facilities for high-speed photography of the type described are used as an aid to numerous kinds of development work in the Laboratories

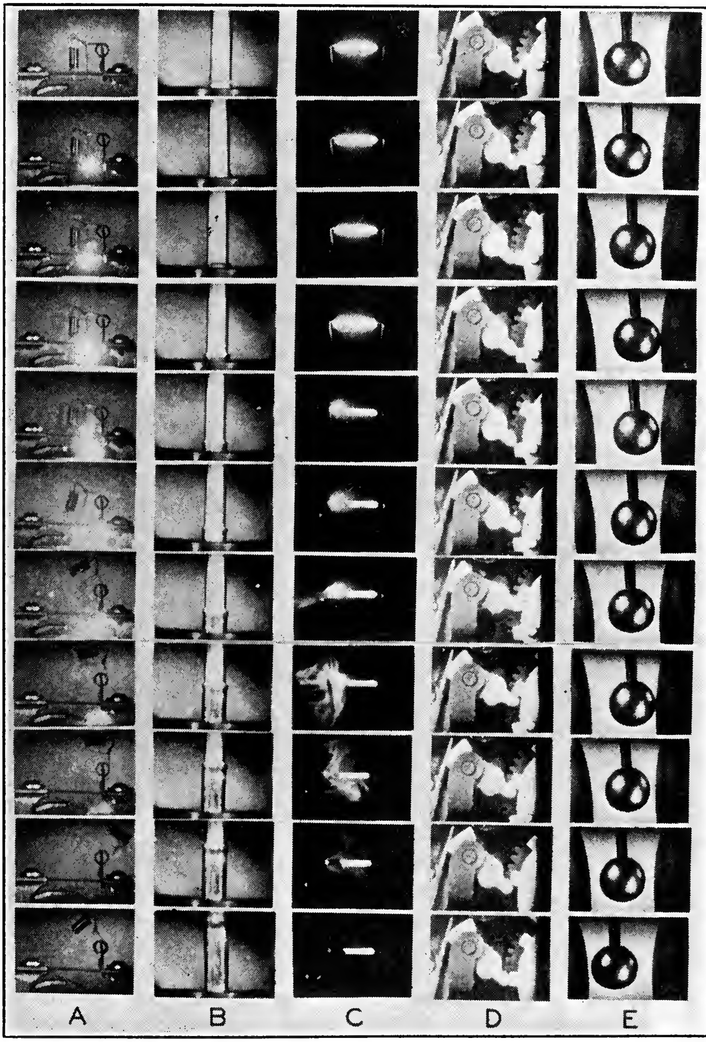


FIG. 5. Frames from films taken at high speed.

and are made generally available for this purpose. About 2000 films have been made to date, which indicates the extent to which the device is finding application to telephone apparatus problems. The high degree of portability that has been achieved in both the camera and lighting equipment lends itself well to extensive application to a wide variety of problems.

In Fig. 5 are shown series of selected frames from films that are representative of the application of high-speed photography to telephone apparatus problems.

At *A* is shown the action of the *35A* alarm fuse when burn-out occurs.

At *B* is a study of condenser-can extrusion in a punch-press. Valuable information relating to punch and die adjustment and to the flow of metal during the punching operation was derived from a series of such pictures.

At *C* is shown the burn-out of an experimental exciter lamp from which information relating to the influence of variation in coil pitch upon lamp life was obtained.

At *D* is a series of pictures illustrating the action of the impulse wheel, pawl, and snubbing spring in the Type *5* dial.

At *E* is shown the action of the clapper striking one gong of an experimental 20-cycle ringer. A peculiar acoustical effect was explained by this picture which revealed more strokes of the clapper per cycle than were desired.

DISCUSSION

MR. TOWNSLEY: How do you get your camera up to speed to avoid wasting too much film?

MR. HERRIOTT: We rely upon the power of the motor to accelerate the sprocket rapidly. No speed-regulating or clutch devices are used. We use a high-torque motor.

MR. CRABTREE: Have you done any work with 35-mm. cameras?

MR. HERRIOTT: Our developments to date have been concerned only with 16-mm. cameras.

MR. HARRIS: What lens aperture are you using?

MR. HERRIOTT: In general, most of our exposures are made at *f*/5 to *f*/8. We have gone as low as *f*/20 on certain subjects. Seldom do we go above *f*/4 or *f*/5.

MR. CRABTREE: Why is it necessary to use two motors?

MR. HERRIOTT: Our experience has indicated that power applied to the sprocket, gearing, compensator, and the supply reel through the film from the take-up reel resulted in film breakage and uneven film movement.

MR. CRABTREE: Could you not connect the take-up by a friction drive?

MR. HERRIOTT: Our experience has been that a friction drive leads to irregular film movement. The take-up motor runs almost without load, and serves only to take up slack in the film that has been accurately paid out by the sprocket and its drive motor. We experienced considerable trouble in film breakage at the take-up reel after the 100 feet of film had passed through the camera. This amounted to as much as several yards of film, but has been reduced to a matter of an inch or less by the use of a suitable guard around the take-up reel.

MR. WALKER: How many feet of film are wasted before the film comes up to speed?

MR. HERRIOTT: This camera will get up to 90 per cent of its speed in about 30 to 35 feet of film. Then there is a rather slow rise to maximum at the end. We are operating at 4000 frames per second and use 100-ft. rolls of film.

MR. CRABTREE: Are the perforations damaged at all?

MR. HERRIOTT: No.

MR. CRABTREE: Perhaps humidifying the film would prevent it from breaking, and permit higher speeds.

MR. HERRIOTT: That is doubtless true. We like to hold the film rather close to the pitch of the sprocket, and find that it will ride off the teeth and trouble will develop if the pitch is not reasonably close to that of the sprocket.

MR. RICHARDSON: What is now regarded as the highest maximum taking speed?

MR. HERRIOTT: Pictures have been made at 60,000 frames a second by spark motion picture photography, which should not be confused with this kind of high-speed photography. Special cameras have been built wherein short lengths of film can be whirled on a drum. We can not study transient phenomena with such a camera, and that is what interests us most. It would be extremely difficult to use cameras of such high speed because of the difficulty of synchronizing exposure with transient phenomena. Such cameras have, however, found a great deal of use in aeronautical studies where steady-state conditions apply.

MR. CRABTREE: What is the practical limit with your type of camera?

MR. HERRIOTT: In present practice we are operating at 4000 frames per second. We are hopeful of going higher. Perhaps 6000 is the next step. The strength of materials employed in the construction of the camera and the strength of the film certainly establish an upper limit. Just where that limit lies we can not say. We are interested in making pictures at much higher speeds than these as we have many applications for the use of higher speeds if they can be proved fairly practicable in routine use.

MR. CRABTREE: Does the limit lie in the strength of the film or the mechanism or both?

MR. HERRIOTT: We have had little or no trouble with our mechanism at 4000 frames per second. We have, however, had trouble with film breakage and film shrinkage.

VACUUM-TUBE ENGINEERING FOR MOTION PICTURES*

L. C. HOLLANDS AND A. M. GLOVER**

Summary.—*Manufacturing and developmental technics of vacuum tubes are described with particular reference to their use in motion picture equipment. A brief discussion of how application requirements affect the choice of materials, structural design, and electrical characteristics of phototubes and amplifiers of both power and voltage types is included. How tubes are designed to meet specific needs is illustrated by reference to recent tube developments. Work on producing tubes having low-hum, low-microphonic, and low-noise characteristics is described as of special interest to the motion picture engineer. The paper closes with recommendations as to how to use vacuum tubes to best advantage.*

The problems of vacuum tube engineering as applied to motion pictures are primarily those of recognizing the special requirements that must be solved for the recording and reproduction of sound motion pictures. In a few words, these requirements consist of the faithful reproduction in the theater of sounds created before the microphone when the picture was originally recorded. They are not unlike the requirements encountered in the design of public address systems and the audio amplifiers of modern radio sets. The main differences are of degree rather than as representing basically new problems. The problems of the phototube designer will be dealt with in another section of this paper.

Let us now look at some of the problems facing the tube design engineer. One of the major problems is that of reducing the random noise that appears in the grid circuit of the first amplifier tube. Since this noise is due to discrete changes of electrical potential of the grid of the tube and since the function of the tube is to amplify such changes of potential, if becomes the problem of the design engineer to keep these changes as low as possible in order to realize the maximum of gain from any given tube structure. There are several sources of this noise and it is with each of these that the tube engineer

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received October 12, 1937.

** Radiotron Division, RCA Manufacturing Co., Inc., Harrison, N. J.

is concerned. First is thermal agitation, or the noise resulting from the flow of current in the elements of the input circuit of the tube as well as within the grid material. Thermal agitation is a function of the conductivities of the various metals employed in the tube and the tube circuits. For example, since the grid side-rods conduct heat away from the grid wires, the materials used for the grid-support side-rods must have good conductivity. Also, the engineer must balance improved performance against increased difficulties in manufacturing technic. He can not choose a grid wire material that will be so soft or so hard that it can not be used in manufacture of the finished product because, if he does, the cost of manufacture may be out of all proportion to the improvement from the noise-generation standpoint. In other words, some compromise in performance must be made in order to produce a tube that will economically justify itself. The amount of thermal-agitation noise depends also upon the width of the frequency band passed by the amplifier. With the advent of high-fidelity recording and reproduction, new lower limits of noise must be met.

A second source of noise within the tube results from the fact that the stream of electrons flowing from the cathode to the plate is made up of a series of particles rather than a continuous fluid. The electron flow to the plate is somewhat irregular, resembling the fall of hailstones. This irregularity gives rise to irregularities in the plate current of the vacuum tube, and hence causes noise in the amplifier. Fortunately, it happens that the more electrons available from the cathode, the less irregular is the electron flow to the plate. It is therefore very important that the electron emission from the cathode be ample if the noise is to be kept low. As a result, the need for low-noise tubes has added another reason for improved cathode emission.

In addition to the causes of noise mentioned above are others such as noise arising in the plate curcuit as a result of irregularities in secondary emission from the plate, and noise produced by disturbances of the space-charge around the cathode due to ionization. The first of these can be controlled by choice of materials used in the plate structure and also by coating the plates with materials (such as carbon) that have low secondary-emission properties. The second can be reduced in manufacture by making the residual gas content of the tube exceedingly low by using a very active getter and by accurately controlling the heating of the tube electrodes during exhaustion. Both these factors are under the control of the design engineer, but he must exercise his judgment and experience to attain the desired results by the least costly methods.

A fourth source of noise is the small leakage that takes place across the parts used to support the various electrodes of the tube structure and for spacing the electrodes so as to produce the desired electrical characteristics. These parts of the tube are the glass supports for the lead wires and the mica supports for the grid side-rods, the cathode, the plate side-rods, and the screen side-rods. Each of these parts must be treated in a different manner. For instance, it has been determined that some kinds of glass are not as good insulators as others. Therefore, glass of only certain compositions should be used for supporting the various tube electrodes. On the other hand, the glass must be capable of being handled in the manufacturing processes with a certain ease and rapidity in order that production will not be overly difficult or slow. In the case of mica, it has been found that supplies from different parts of the world vary greatly in insulating qualities. Also, these qualities may change due to the temperatures to which they are subjected during the exhaust process. Again, the mica must not give off excess moisture during the exhaustion process as this tends to affect both the emission from the cathode and the amount of residual gas, and hence the extent of ionization that may occur in the tube under operating conditions.

Another problem confronting the tube design engineer is reduction of microphonics. Microphonics are the result of physical movement of one or more of the electrodes within the tube structure. As a result, the designer is faced with the problem of making the electrodes of the tube as non-resonant as possible. The most immediate solution of this problem would seem to be to make the tube electrodes as large and heavy as possible. This, however, is not always practicable because we must at the same time obtain the desired electrical characteristics. This requirement may limit the size of the control grid wire, the diameter of the control grid, and the size and shape of the plate. Furthermore, it is necessary to provide clearance in insulators in order to compensate for expansion as the tube parts become warm in service. If tube electrodes are supported too rigidly they may buckle or bow out of line and cause changes in the electrical characteristics. The buckling may actually go so far as to cause a direct short-circuit under operating conditions. It has been demonstrated in the laboratory that looseness of the heater in the cathode causes microphonic noise. As a result of this discovery, it has been found necessary to make the heater a force-fit in the cathode, which is a difficult problem from the manufacturing standpoint.

Still another problem that confronts the design engineer is that of reducing hum produced by the alternating current used to heat the filament of the tube. The hum may be produced by electromagnetic effects, or by direct emission from the heater to some element within the tube structure, or by leakage between the heater and the cathode. Taking the causes one at a time and analyzing them, we can determine the method of solution as applied in modern practice. In the case of electromagnetic effects, the double-helix method of winding the heater is very effective. One leg of the heater is wound in the form of a helix for the proper length for a given size of cathode, and then the wire is doubled back upon itself to form a bifilar helical type of winding. It can readily be seen that in this type of winding any electromagnetic field produced in one leg of the winding will be cancelled by the electromagnetic field of the adjacent wire. After the ends of the heater leave the cathode to go to the support wires in the stem they separate. As a result of this separation, the fields sur-

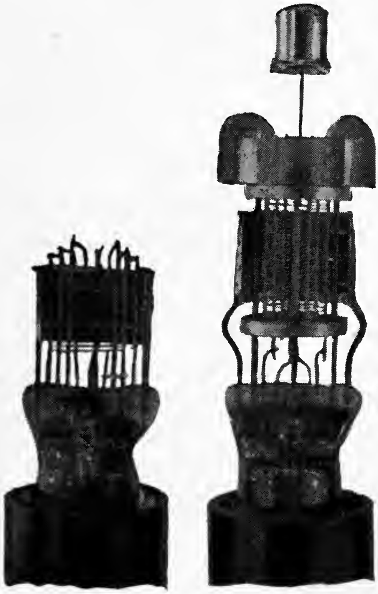


FIG. 1. Type *1603* tube.

rounding these wires no longer cancel. Now if, for example, a control-grid support or lead-wire is placed in the stem press close to this heater lead, there is always the possibility of introducing alternating current into the grid of the tube as a result of the latter's proximity to the heater leads. Again, it is advisable to isolate the plate and other electrode leads from the heater leads to prevent electromagnetic, electrostatic, and direct-emission effects.

Furthermore, if the heater-cathode insulation is not very high and if there is impedance between the cathode circuit and ground, voltage at hum frequency will be introduced across this impedance into either the grid circuit or the plate circuit of the tube. This condition is made worse by the fact that it is common practice in amplifier designs to have a biasing resistor common to both grid circuit and plate circuit.

To show how these various factors are taken into account in current designs of vacuum tubes, the type *RCA-1603* tube, illustrated in Fig. 1, may be taken as a typical example. From the standpoint of thermal agitation noise, regular vacuum tube design practice is such that no particular precautions have to be observed. Most common practice is to use either nickel or some alloy of nickel for both grid wires and side-rod supports. The choice of these materials is due to the high electrical conductivity of nickel and the fact that both are relatively easy to fabricate.

From the standpoint of shot-effect noise, the cathode structure and heater are designed so that adequate emission will be obtained for all conditions of operation. The cathode has a capacity of electron emission several hundred times that ordinarily required for operation. A laboratory test for hiss is made of the tubes in a regular amplifier, and strict limits are maintained. In order to get low gas pressure and preclude any effects of ionization the temperature of the electrodes during the exhaustion process is controlled within very close limits. Micas in the tube that support and space the various electrodes are sprayed with an insulating compound that is chemically inactive even at high temperatures. This process not only reduces the likelihood of electrical charges building up on the mica, but also reduces the electrical leakage between electrodes. At some points in the micas, openings have been cut between the various supports to increase the leakage path. A still further precaution to reduce secondary-emission effects is to coat the inside of the glass envelope of the tube with carbon. This reduces the possibility of unequal charges on the inner surface of the glass container. These unequal charges in trying to reach a state of equilibrium give rise to noise effects. Another precaution is to place the getter in such position that when it flashes none of the deposits will reach the stem press. The reason is that the material used in the getter, if allowed to deposit upon the stem between the lead wires, would form a leakage path of variable resistance that would tend to make the tube noisy in operation.

From the microphonic-response standpoint, certain structural features are incorporated. First of these is the use of nickel side-rod supports of large diameter, for rigidity and mechanical strength. The supporting micas are also made double the thickness used in conventional designs. In order further to reduce the possibility of electrode movement in the micas the diameter of the holes into which the grid and plate support rods are placed is from 0.0005 to 0.001 inch smaller than the diameter of the wires themselves. This insures a tightness and rigidity of mount that must be attained even at some expense in manufacturing ease and speed. The micas are then rigidly clamped in metal collars to strengthen the entire structure further. To center the entire mount within the tube envelope, four butterfly micas are used instead of the two customarily found in vacuum-tube practice. As pointed out previously, extra-heavy plate-support rods are used; these are also suspended at three points of support instead of the customary two. Further to preclude mechanical movement of the heater within the cathode, the heater outside diameter, including the insulating coating, is held within 0.0005 inch of a specified diameter. This close tolerance results in a force-fit of the heater into the cathode and again illustrates a condition where performance is more important than convenience of manufacture.

In order to reduce the hum to low orders of magnitude a double-helix type of heater winding is used. To insure that the heater-to-cathode leakage will be extremely small, very careful chemical control is maintained over the ceramics used for spraying the heaters. Minute particles of iron, alkali, and other impurities may mean the difference between a usable product and one that is wholly unsuitable. In order to avoid any possible emission from the ends of the heater, centering the heater within the cathode sleeve is carefully supervised. To insure further that the heater is as nearly chemically pure as possible, the wire is very carefully cleaned even before spraying it with insulating material. The cathode sleeve is also subjected to this same process for the same reason. Some control of the hum in the final product can also be gained by specially aging the tube after exhaustion. Hum is also dependent to a large extent upon cathode temperature; the lower the operating temperature, the less the hum. Again, the design engineer, from experience, must balance between a low temperature and low hum, and a high temperature and low "shot" noise. Since the effects are complicated they can not readily be calculated mathematically and must be arrived at by cut-and-try methods. This brief analysis gives some idea of the problems confronting the tube engineer on special applications of vacuum tubes.

Another typical example of special tube design is the type *RCA-1609* tube, shown in Fig. 1, which is a filamentary type of sharp cut-off pentode. This tube finds its widest use in portable equipment at points remote from power lines, which must of necessity be operated on either dry batteries or storage batteries. In this tube extra-heavy mount supports are used to insure rigidity from the microphonic standpoint and also to withstand the rough handling to which portable equipment is likely to be subjected. The grids of the tube are supported and spaced by glass beads instead of by mica, because it has been determined that glass beads are better suited mechanically to tubes for portable service. The filament is made of ribbon, in a short inverted *V*, for the same reason. Again, as in the *1603*, the getter flash is directed in such a way that there is no tendency for deposits to form upon the stem press. The tube has a high emission limit for factory testing to insure freedom from shot effect. In order to insure low microphonic response, the tension of the filament during mounting is closely controlled.

One of the newer tubes of this special group is the type *RCA-1612*. Its construction is similar to the standard type *6L7* tube in that it has two control grids separated from each other by a screen grid. The control grid nearest the plate is separated from the plate by another screen grid and a suppressor grid. Its electrical characteristics are similar to those of the standard *6L7*. At the present time, its widest application is in a new amplifier design allowing remote control of volume without the usual difficulties experienced with circuits of this kind. Since the transconductance, and hence the gain, of the tube can be controlled by means of a d-c. bias applied to the control grid next to the cathode, the gain of a signal applied to the control grid nearer the plate may be controlled by the control grid nearer the cathode without the necessity of bringing the audio-frequency signal to the remote control point. It is thus possible to dispense with the elaborate shielding usually necessary for such an amplifier circuit. This opens up vast new possibilities for the motion picture engineer due to the extreme flexibility of the system. Other possibilities and design features will undoubtedly result from the availability of this tube.

Let us now consider phototubes and their applications in the field of motion pictures. The phototube is an essential part of modern motion picture projection equipment; by it the photographic record of music or speech is transferred back into audible sound. The design of a phototube is quite simple compared to that of a receiving tube, yet the procedure involved in producing the sensitive photo surface is complex and still not completely understood.

The usual type of phototube contains a semicylindrical silver surface treated in such fashion as to become sensitive to light. The sensitizing process consists, in the main, in producing a layer of silver oxide upon which is deposited caesium; a reaction is then brought about, the final product being a mixture of caesium and silver and their oxides. This surface is the cathode or negative electrode of the phototube. Upon exposure to light of suitable color or wavelength, electrons are given off from the cathode in numbers proportional to the intensity of the light. If the output of a phototube is not linearly responsive to the light-intensity, the cause of the departure from linearity is to be found in some effect occurring subsequently to the emission of the electron current.

The anode or positive electrode is a wire placed concentrically along the axis of the cathode, and may be made of any metal photoelectrically insensitive to light in the spectral region for which the phototube is designed. The modern caesium cell is particularly suitable for use with incandescent light-sources because the major portion of its sensitivity lies in the red and infrared regions of the spectrum. The position of the anode serves to create a radial electrical field between it and the cathode. This is important if the tube contains an inert gas that may be ionized and thus contribute to the photoelectric current that flows when the sensitive cathode is illuminated. The degree of ionization and consequent amplification is dependent upon the number of collisions between the photoelectrons and the molecules of the gas during the transit of the electron from cathode to anode.

The photoelectric tube is thus a diode, and possesses the rectification properties associated with such tubes. Current flows only when the anode is positive; thus, either a direct voltage or alternating voltage may be used for the anode, but in the latter case current will flow during half the cycle only. This fact may be useful in controlling the action of the tube in its associated circuits. It is important to consider the magnitude of the current that may flow under practical conditions. The most sensitive caesium surface will emit only 30 to 50 microamperes per lumen of visible light (light-source at 2870°K). When gas is used to amplify this primary current, the current is multiplied by a factor of five to ten, but at some sacrifice of performance which will be discussed later. The illumination available will probably not exceed one lumen at best—in sound equipment a few hundredths of a lumen is commonly used, so that the output current is to be measured in microamperes.

The applications of phototubes may be divided roughly into two main classes: one in which the tube serves merely to trigger some mechanism such as a counter—in this use there is no question of the nature of the photocurrent response other than that it be relatively instantaneous and positive; and another in which the phototube is used to translate a rapidly varying photographic record into an accurate reproduction of the original sound. This record may contain fundamentals and harmonics of a complicated pattern. The tube is required to respond to frequencies in the neighborhood of 10,000 cps. and upward, and a flat frequency response is, therefore, desirable. Furthermore, the tube is part of equipment that must undergo considerable physical vibration, which would appear as "noise" in the sound output were the phototube not especially resistant to such causes of microphonics. An optimal lower limit to microphonic noise is reached only when the level of the noise is reduced below that of the noise introduced by the photographic film, which may be caused by the nature of the emulsion and its film base, and by noise inherent in the recording apparatus. By and large, the noise present for a given output of the so-called "gas-type phototube" is greater than that present in the output of a vacuum phototube; *i. e.*, the signal-to-noise ratio is higher in the latter case. On the basis of this consideration alone, the vacuum type of phototube is to be preferred for sound use. However, with the improvement in sensitivity, a factor of five is customary, and the low output impedance of the gaseous type of tube has made its use popular in the motion picture industry.

In this connection it is interesting to note that the use of a high impedance with a gas phototube reduces its effective voltage-sensitivity to a level more nearly comparable to that of the vacuum type. For applications permitting the use of a high impedance, the vacuum type is preferable because of its high-fidelity frequency response and its improved signal-to-noise ratio.

The effect of load impedance upon the voltage sensitivity of a gas phototube is shown in Fig. 2, which gives the plate families of curves for a gas and a vacuum phototube. Let us first consider the sensi-

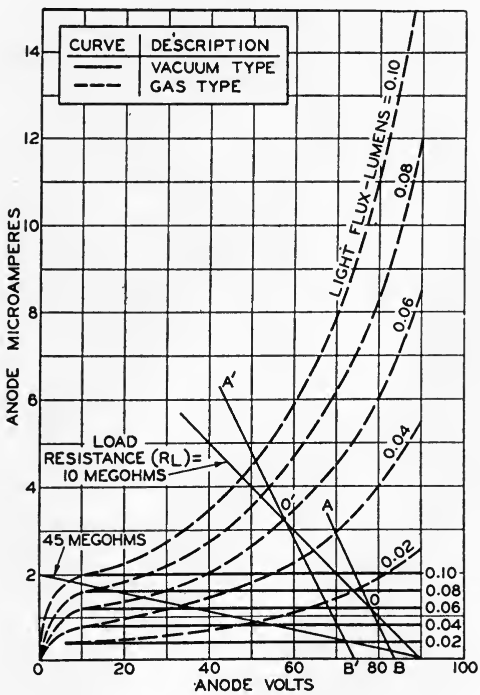


FIG. 2. Phototube anode characteristics.

tivity of a phototube when used to actuate a relay; under such circumstances the current that will flow, for a given amount of light, defines the static sensitivity $S = I/L$. When the tube is used to respond to modulated light, the sensitivity must be expressed as $S_d = dI/dL$, a quantity that is akin to the transconductance of an amplifier tube. The phototube is usually used with a voltage amplifier so that a voltage sensitivity $S_v = dV/dL = S_d\,(R_pR_L)/(R_p + R_L)$ is defined, again analogous to that of an amplifier tube. For a vacuum tube in which R_p is large, the voltage sensitivity reduces to $S_v = S_d R_L$ so that S_v can be increased by increasing R_L as long as the approximation holds. In Fig. 3 is shown the effective voltage obtained for a given light, from both gas and vacuum tubes, as a function of the load used.

The radio tube owes many of its physical characteristics to its predecessor the electric lamp: the glass bulb and the nature of the stem press by which the electrical connections to the interior elements are made are but two of these inherited traits. For a tube as simple electrically as the phototube the cumbersome stem press is unnecessary;

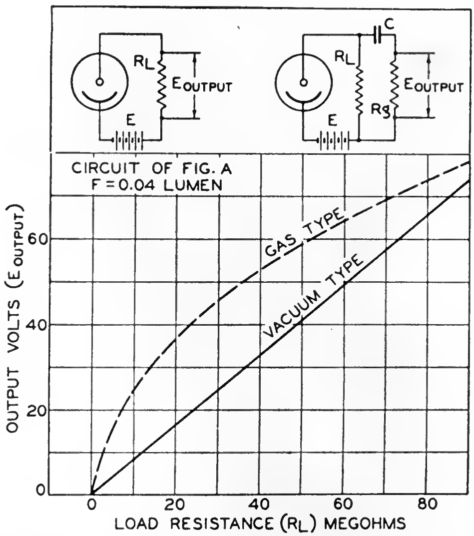


FIG. 3. Phototube operating characteristics.

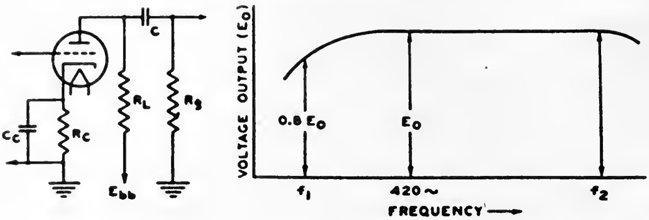
furthermore a considerable part of the electrical capacity present, which may limit the response of the tube at high frequencies, is to be found between the lead wires of the stem press. Hence it was decided to introduce a line of phototubes mounted in glass tubing and analogous to the *Lum-i-line* lamp in construction. These tubes are the *RCA-921* and *RCA-922*. The cathode and anode are mounted independently of each other at opposite ends on chrome-iron caps insulated from each other by a length of glass tubing—indeed, in the vacuum-type tube of this construction one of the metal caps serves as the anode, the concentric wire being found unnecessary when an ionizing gas is omitted. By this construction the electrical capacity has been reduced to 1.1 $\mu\mu$f and 0.6 $\mu\mu$f, for the gas and vacuum types, respectively, as compared with 2.4 $\mu\mu$f and 2.2 $\mu\mu$f for the corresponding bulb types. The smaller cathode is of course responsible for part of this reduction. The tubes have been designed with the point in mind that the user may wish to make direct connection from one contact of the phototube to the grid of the first amplifier tube, for which purpose an amplifier with grid top connection is desirable. The phototube may be supported on one end, by a simple contact as compared with the customary tube socket. To orient the tube with respect to the direction of the light-beam, a square metal clip has been added which serves also to protect the exhaust tubing. The compact construction thus resulting should prove particularly adapted for use with 16-mm. equipment where economy of space is a desirable feature. The *RCA-922* (the *RCA-921* is similar structurally) is shown in Fig. 4. Its height is about 2 inches over all.

FIG. 4. *RCA-922* tube.

The sensitive surface of a phototube may change considerably during the life of the tube. When a surface is first prepared, a high sensitivity is obtained which gradually decreases with use until a steady value is reached. The aging schedule adopted for the production of phototubes is based upon this initial decrease of sensitivity. It is found that a large fraction of the drop may be covered during the aging schedule, so that only a small further decrease may be expected during use. When a tube stands for any length of time, the sensitivity may increase temporarily to a value close to the original high sensitivity; for that reason it is recommended that a phototube that is in use only intermittently be operated for some length of time before being put into service.

The drop with use is much more pronounced in gas tubes than in vacuum tubes. Little attention need be paid to a vacuum tube; its characteristics remain unchanged over long periods of time.

In summing up the applications of the phototube to sound pictures mention may be made of the electron multiplier, which consists of a photosensitive surface and a number of secondary emitting surfaces so arranged that the primary photoelectron current may be amplified by large factors depending upon the number of secondary



(*A*) Condensers *C* and C_c have been chosen to give output voltages equal to 0.8 E_o for f_1 of 100 cycles. For any other value of f_1, multiply values of *C* and C_c by $100/f_1$.

In the case of condenser C_c, the values shown are for an amplifier with d-c. heater excitation. When a-c. is used, depending upon the character of the associated circuits, the gain, and the value of f_1, it may be necessary to increase the value of C_c to minimize hum disturbances. It may also be desirable to have a d-c. potential difference of approximately 10 volts between heater and cathode.

(*B*) f_2 = frequency at which high-frequency response begins to fall off.

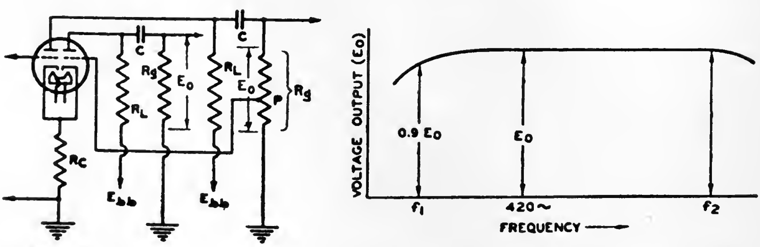
(*C*) The voltage output at f_1 for *n* like stages equals $(0.8\ E_o)^n$.

(*D*) Decoupling filters are not necessary for two stages or less.

(*E*) For an amplifier of typical construction, the value of f_2 is well above the audio-frequency range for any value of R_L.

(*F*) Always use highest permissible value of R_g.

(*G*) A variation of $\pm 10\%$ in values of resistors and condensers has only a slight effect upon performance.



The diagram given above is for Phase-Inverter Service. The signal input is supplied to the grid of the left-hand triode unit. The grid of the right-hand unit obtains its signal from a tap *P* on the grid resistor R_g in the output circuit of the left-hand triode unit. The tap *P* is chosen so as to make the voltage output of the right-hand unit equal to that of the left-hand unit. Its location is determined from the voltage gain values. For example, if the voltage gain is 20, *P* is chosen so as to supply $^1/_{20}$ of the voltage across R_g to the grid of the right-hand triode.

For phase-inverter service, the cathode resistor R_c should not be by-passed by a condenser. Omission of the condenser in this service assists in balancing the output voltages. The value of R_c is specified on the basis that both units are operating simultaneously at the same values of plate load and plate voltage.

FIG. 5 (*Upper*). Single-stage resistance-coupled triode amplifier.
(*Lower*). Resistance-coupled twin-triode amplifier.

surfaces used. If gains of 3.5 or 4 are obtained at each surface the overall gain for various numbers of stages is as shown in Table I.

The electron multiplier is a current amplifier; the power output is limited by the nature of the secondary-emission surfaces. The output characteristic is quite similar to that of a vacuum phototube; however, the plate voltage is measured with respect to the last secondary-emission surface which itself may be several hundred volts above the photocathode. At least one hundred volts per stage of secondary emission is required to obtain a sufficient ratio of secondary to primary current. These tubes should not be used in commercial designs since they are developmental tubes and the characteristics are still undergoing changes of a design nature.

TABLE I

Gains for Various Numbers of Stages in Electron Multiplier

Stages	Gain
1	3.5– 4
2	12.2– 16
3	43 – 64
4	150 – 256
5	530 – 1,024
6	1,850 – 4,096
7	6,500 –16,384
8	20,000 –65,536

Fig. 5 contains data that will be data of assistance to engineers in the motion picture field who are interested in designing resistance-coupled amplifiers.

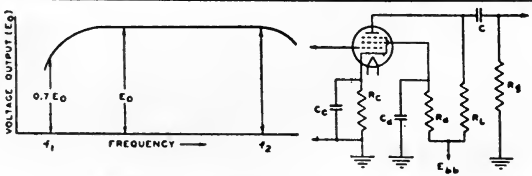
It is well to remind the design engineer at this point that, in general, conservative design produces the most economical apparatus from the standpoint of life. This is particularly true of vacuum-tube apparatus where long life and uninterrupted service are prime considerations. In such applications, it is very essential to design so that tubes are operated under moderate voltage and load conditions.

Difficulties from low-frequency oscillation (motorboating) are often experienced when a high-gain multistage audio amplifier of conventional design obtains its *B* voltage from a single power-supply unit. These difficulties are usually due to interstage coupling through a common impedance in the power unit. Customary expedients to prevent motorboating include the use of very large filter condensers and several power-supply units. However, by suitable design, the

PLATE-SUPPLY VOLTAGE (Ebb) – Volts [1]	90									180								
PLATE RESISTOR (RL) – Megohms	0.1			0.25			0.5			0.1			0.25			0.5		
GRID RESISTOR (Rg) – Megohms [2]	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2
SCREEN RESISTOR (Rd) – Megohms	0.37	0.44	0.44	1.1	1.18	1.4	2.18	2.6	2.7	0.44	0.5	0.5	1.1	1.18	1.4	2.45	2.9	2.7
CATHODE RESISTOR (Rc) – Ohms	1200	1100	1300	2400	2600	3600	4700	5500	5500	1000	750	800	1200	1600	2000	2600	3100	3500
SCREEN BY-PASS CONDENSER (Cd) – µf	0.05	0.05	0.05	0.03	0.03	0.025	0.02	0.05	0.02	0.05	0.05	0.05	0.04	0.04	0.04	0.03	0.025	0.02
CATHODE BY-PASS CONDENSER (Cc) – µf	5.2	5.3	4.8	3.7	3.2	2.5	2.3	2	2	6.5	6.7	6.7	5.2	4.3	3.8	3.2	2.5	2.8
BLOCKING CONDENSER (C) – µf	0.02	0.01	0.006	0.008	0.005	0.003	0.005	0.0025	0.0015	0.02	0.01	0.006	0.008	0.005	0.0035	0.005	0.0025	0.0015
VOLTAGE OUTPUT (Eo) – Peak Volts [3]	17	22	33	23	32	33	28	29	27	42	52	59	41	60	60	45	56	60
VOLTAGE GAIN [4]	41	55	66	70	85	92	93	120	140	51	69	83	93	118	140	135	165	165

PENTODE TYPES: 6C6, 6J7, 57

PLATE-SUPPLY VOLTAGE (Ebb) – Volts [1]	300									600 (max.)								
PLATE RESISTOR (RL) – Megohms	0.1			0.25			0.5			0.1			0.25			0.5		
GRID RESISTOR (Rg) – Megohms [2]	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2
SCREEN RESISTOR (Rd) – Megohms	0.44	0.5	0.53	1.18	1.18	1.45	2.45	2.9	2.95	0.48	0.53	0.53	1.18	1.18	1.45	2.5	2.94	3
CATHODE RESISTOR (Rc) – Ohms	500	450	600	1100	1200	1300	1700	2200	2300	200	250	300	500	800	800	1050	1400	1500
SCREEN BY-PASS CONDENSER (Cd) – µf	0.07	0.07	0.06	0.04	0.04	0.05	0.04	0.04	0.04	0.09	0.08	0.08	0.05	0.05	0.05	0.05	0.05	0.05
CATHODE BY-PASS CONDENSER (Cc) – µf	8.5	8.3	8	5.5	5.4	5.8	4.2	4.1	4	11.5	11.1	10.5	8.2	7.2	7	5.7	5.6	4.5
BLOCKING CONDENSER (C) – µf	0.02	0.01	0.006	0.008	0.005	0.005	0.005	0.003	0.0025	0.02	0.01	0.006	0.008	0.005	0.005	0.005	0.003	0.002
VOLTAGE OUTPUT (Eo) – Peak Volts [3]	55	81	96	81	104	110	75	97	100	90	140	150	125	200	180	140	185	165
VOLTAGE GAIN [4]	61	82	94	104	140	185	161	350	240	77	100	112	136	171	210	198	435	350



(*A*) Condensers C, C_c, and C_d have been chosen to give output voltages equal to 0.7 E_0 for f_1 of 100 cycles. For any other value of f_1, multiply values of C, C_c, and C_d by $100/f_1$. In the case of condenser C_c, the values shown are for an amplifier with d-c. heater excitation. When a-c. is used, depending on the character of the associated circuits, the gain, and the value of f_1, it may be necessary to increase the value of C_c to minimize hum disturbances. It may also be desirable to have a d-c. potential difference of approximately 10 volts between heater and cathode.

(*B*) f_2 = frequency at which high-frequency response begins to fall off.
(*C*) The voltage output at f_1 for n like stages equals $(0.7\ E_o)_n$.
(*D*) Decoupling filters are not necessary for two stages or less.
(*E*) Approximate values of f_2 for different values of R_L for an amplifier of typical construction are as follows: R_L = 0.1 meg., 20,000 cps.; R_L = 0.25 meg., 10,000 cps.; R_L = 0.5 meg., 5000 cps.
(*F*) Always use highest permissible value of R_g.
(*G*) A variation of ±10% in values of resistors and condensers has only slight effect upon performance.

FIG. 6. Resistance-coupled pentode amplifier chart.

[1] Voltage at plate equals plate-supply voltage minus voltage drop in R_L and R_c. For other supply voltages differing by as much as 50% from those listed, the values of resistors, condensers, and gain are approximately correct. The value of voltage output, however, for any of these other supply voltages equals the listed voltage output multiplied by the new plate-supply voltage divided by the plate-supply voltage corresponding to the listed voltage output. The 600-volt conditions are maximum.

[2] For following stage (see Circuit Diagram).

[3] Voltage across R_g at grid-current point.

[4] At 5 volts (RMS) output. Gain at full output is somewhat less than the listed values.

gain of an audio amplifier of low frequencies can be reduced to such levels that the effects of feed-back through a power unit of conventional design are greatly reduced.

The use of a series screen resistor and a self-bias resistor offers several advantages over fixed-voltage operation: (*1*) the effects of possible tube differences are minimized; (*2*) operation over a wide range of plate-supply voltages without appreciable change of gain is feasible; and (*3*) the low frequency at which the amplifier cuts off is easily changed. Fixed-bias or fixed-screen voltage operation increases the tendency of an amplifier to motorboat and decreases the compensating action of the remaining series resistors. The advantages of an amplifier constructed according to the data presented herewith can be further emphasized by the addition of suitable decoupling resistors and condensers. With a proper decoupling filter in the plate circuit of each stage, three or more amplifier stages can be operated from a single power-supply unit of conventional design without encountering difficulties due to coupling through the power unit; not more than two stages should be operated from a single power-supply unit when decoupling filters are not used.

Detailed information on the operation of the *6C6*, *6J7*, and *57* as resistance-coupled audio-frequency amplifiers is presented in Fig. 6. These data hold for plate-supply voltages from 90 to 600 volts, for plate-resistor values of 0.1, 0.25, and 0.5 megohm, and for a number of grid-resistor values. The combination of resistor and condenser values suggested in the pentode chart causes a 30 per cent drop in output voltage per stage at 100 cps. A similar cut-off characteristic at any other low frequency (f_l) can be obtained by multiplying the capacitance values shown in the chart by $100/f_l$.

Detailed information on the operation of triodes as resistance-coupled audio-frequency amplifiers is presented in Fig. 7. The combination of condenser and resistor values suggested in this chart causes a 20 per cent drop in output voltage per stage at 100 cps. A similar cut-off characteristic at any other low frequency (f_l) can be obtained by multiplying the capacitance values shown by $100/f_l$. As with pentodes, the use of self-bias reduces the effects of possible tube differences and permits operation over a wide range of plate-supply voltages without appreciable change of gain. The regulating action of a self-biased triode amplifier is not as good as that of a pentode amplifier having series screen and self-biasing resistors, because the regulating action of a screen is not available in a triode.

C = BLOCKING CONDENSER (μf) Cd = SCREEN BY-PASS CONDENSER (μf) Eo = VOLTAGE OUTPUT (Peak Volts) Rd = SCREEN RESISTOR (Megohms) RL = PLATE RESISTOR (Megohms)
Cc = CATHODE BY-PASS CONDENSER (μf) Ebb = PLATE-SUPPLY VOLTAGE (Volts) Rc = CATHODE RESISTOR (Ohms) Rg = GRID RESISTOR (Megohms) V.G. = VOLTAGE GAIN

TYPES: 6C5 (TRIODE), AND 6C6, 6J7, 57 (AS TRIODES)

Ebb [1]	90									180									300									Ebb [1]
RL	0.05			0.1			0.25			0.05			0.1			0.25			0.05			0.1			0.25			RL
Rg [2]	0.05	0.1	0.25	0.1	0.25	0.5	0.25	0.5	1	0.05	0.1	0.25	0.1	0.25	0.5	0.25	0.5	1	0.05	0.1	0.25	0.1	0.25	0.5	0.25	0.5	1	Rg [2]
Rc	2800	3400	3800	4800	6400	7500	11400	14500	17300	2200	2700	3100	3900	5300	6200	9500	12300	14700	2100	2600	3100	3800	5300	6000	9600	12300	14000	Rc
Cc	2	1.62	1.3	1.12	0.84	0.66	0.52	0.4	0.33	2.2	2.1	1.85	1.7	1.25	1.2	0.74	0.55	0.47	3.16	2.3	2.2	1.7	1.3	1.17	0.9	0.59	0.37	Cc
C	0.05	0.025	0.01	0.025	0.01	0.005	0.01	0.006	0.004	0.055	0.03	0.015	0.035	0.015	0.008	0.015	0.008	0.004	0.075	0.04	0.015	0.035	0.015	0.008	0.015	0.008	0.003	C
Eo [3]	14	17	20	16	22	23	18	23	26	34	45	54	41	54	55	44	52	59	57	70	83	65	84	88	73	85	97	Eo [3]
V.G. [4]	9	9	10	10	11	12	12	12	13	10	11	11	12	12	13	13	13	13	11	11	12	12	13	13	13	14	14	V.G. [4]

TRIODE TYPE 6F5

Ebb [1]	90									180									300									Ebb [1]
RL	0.1			0.25			0.5			0.1			0.25			0.5			0.1			0.25			0.5			RL
Rg [2]	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	Rg [2]
Rc	4400	4800	5000	8000	8800	9000	12200	13500	14700	1800	2000	2200	3500	4100	4500	6100	6900	7700	1300	1600	1700	2600	3200	3500	4500	5400	6100	Rc
Cc	2.5	2.1	1.8	1.33	1.18	0.9	0.76	0.67	0.58	4.4	3.3	2.9	2.3	1.8	1.7	1.3	0.9	0.83	5	3.7	3.2	2.5	2.1	2	1.5	1.2	0.93	Cc
C	0.02	0.01	0.005	0.01	0.005	0.003	0.005	0.003	0.0015	0.025	0.015	0.006	0.01	0.006	0.004	0.006	0.003	0.0015	0.025	0.01	0.006	0.01	0.007	0.004	0.006	0.004	0.002	C
Eo [3]	4	5	6	6	7	10	8	10	12	16	23	25	21	26	32	24	33	37	33	45	48	41	54	65	50	62	70	Eo [3]
V.G. [4]	28 [d]	34 [b]	35 [c]	39 [b]	43 [c]	44	43	46	48	37	44	46	48	53	57	53	63	66	42	49	52	56	63	67	65	70	70	V.G. [4]

TWIN-TRIODE TYPES: 6A6, 6N7, 53 (ONE TRIODE UNIT)

Ebb [1]	90									180									300									Ebb [1]
RL	0.1			0.25			0.5			0.1			0.25			0.5			0.1			0.25			0.5			RL
Rg [2]	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	Rg [2]
Rc *	1900	2250	2500	4050	4950	5400	7000	8500	9650	1300	1700	1950	2950	3800	4300	5250	6600	7650	1150	1500	1750	2650	3400	4000	4850	6100	7150	Rc
C	0.025	0.01	0.006	0.01	0.006	0.003	0.006	0.003	0.0015	0.03	0.015	0.007	0.015	0.007	0.0035	0.007	0.0035	0.002	0.03	0.015	0.007	0.015	0.0055	0.003	0.0055	0.003	0.0015	C
Eo [3]	13	19	20	16	20	24	18	23	26	35	46	50	40	50	57	44	54	61	60	83	86	75	87	100	76	94	104	Eo [3]
V.G. [4]	16	19	20	20	22	23	22	23	23	19	21	22	23	24	24	24	25	25	20	22	23	23	24	24	23	24	24	V.G. [4]

TWIN-TRIODE TYPE 79 (ONE TRIODE UNIT)

Ebb [1]	90									180									300									Ebb [3]
RL	0.1			0.25			0.5			0.1			0.25			0.5			0.1			0.25			0.5			RL
Rg [2]	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	0.1	0.25	0.5	0.25	0.5	1	0.5	1	2	Rg [2]
Rc *	2050	2200	2350	4000	4250	4650	6150	6850	7500	1050	1250	1350	2050	2450	2750	3450	4100	4650	800	1000	1100	1650	2050	2350	2850	3600	4450	Rc
C	0.04	0.015	0.009	0.015	0.006	0.004	0.006	0.004	0.002	0.04	0.02	0.009	0.02	0.01	0.005	0.009	0.0035	0.002	0.025	0.01	0.006	0.01	0.0055	0.003	0.0055	0.003	0.0015	C
Eo [3]	5.8	8.4	9.5	7.1	9.7	12	8.8	12	15	21	27	31	26	34	40	30	39	44	40	57	60	56	66	77	61	75	82	Eo [3]
V.G. [4]	23 [b]	29 [c]	29	31 [c]	33	35	34	38	40	27	31	34	37	41	42	42	44	45	29	34	36	39	42	43	44	46	46	V.G. [4]

TRIODE TYPES: 56, 76

Ebb [1]	90									180									300									Ebb [1]
RL	0.05			0.1			0.25			0.05			0.1			0.25			0.05			0.1			0.25			RL
Rg [2]	0.05	0.1	0.25	0.1	0.25	0.5	0.25	0.5	1	0.05	0.1	0.25	0.1	0.25	0.5	0.25	0.5	1	0.05	0.1	0.25	0.1	0.25	0.5	0.25	0.5	1	Rg [2]
Rc	2500	3200	3800	4500	6500	7500	11100	15100	18300	2400	3000	3700	4500	6500	7600	10700	14700	17700	2400	3100	3800	4500	6400	7500	11100	15200	18300	Rc
Cc	2	1.6	1.25	1.05	0.82	0.68	0.48	0.36	0.32	2.5	1.9	1.65	1.45	0.97	0.8	0.6	0.45	0.4	2.8	2.2	1.8	1.6	1.2	0.98	0.69	0.5	0.4	Cc
C	0.06	0.03	0.015	0.03	0.015	0.007	0.015	0.007	0.0035	0.06	0.035	0.015	0.035	0.015	0.008	0.015	0.007	0.0045	0.08	0.045	0.02	0.04	0.02	0.009	0.02	0.009	0.005	C
Eo [3]	16	21	23	19	23	25	21	24	28	36	48	55	45	55	57	49	59	64	65	80	95	74	95	104	82	96	108	Eo [3]
V.G. [4]	7	7.7	8.1	8.1	8.9	9.5	9.4	9.7	9.8	7.7	8.2	9	9.3	9.5	9.8	9.7	10	10	8.3	8.9	9.4	9.5	10	10	10	10	10	V.G. [4]

FIG. 7. Resistance-coupled triode amplifier chart.

When a number of high-mu triode amplifier stages are cascaded, the high-frequency response may be severely curtailed, because the high effective input capacitance of a triode shunts the load of the previous tube. When good high-frequency response from a triode amplifier is desired, therefore, low-mu tubes and low values of plate and grid resistors should be used.

On the charts, the values of C_c are given for an amplifier with d-c. heater excitation. When alternating current is used, depending upon the character of the associated circuits, the gain, and the value of f_l, it may be necessary to increase the value of C_c to minimize hum disturbances. It may also be desirable to have a d-c. potential difference of approximately 10 volts between heater and cathode.

DISCUSSION

MR. CRABTREE: What metals other than nickel are used in vacuum tubes?

MR. HOLLANDS: Molybdenum, copper, some iron; practically all metals normally known to ordinary manufacturing technic. The plates and side-rods of the tubes shown here are of nickel and the grids are of molybdenum nickel, or what we call "moly nickel." The filament is thoriated tungsten in some cases; in most receiving tubes, oxide-coated nickel wire or cathodes are used. Not much tantalum is used in receiving tubes, but more in transmitting tubes.

MR. TUPPER: Is there any difference in materials between a regular RCA tube and a tube licensed by RCA?

MR. HOLLANDS: I can not answer that question, because our licensees use any metals they find desirable in the construction of tubes. Ordinarily they use about the same materials that we do.

MR. CRABTREE: Does RCA insist that the manufacturers of tubes under its licenses maintain the standards set by RCA?

MR. HOLLANDS: No. However, progress is being made in standardizing the electrical characteristics of receiving tubes by the Radio Manufacturing Association. The physical structure or the materials used in the tubes are entirely up to the licensees.

MR. PALMER: Can the sounds from a photocell be heard through a pair of head-phones without amplification? If not, how many stages are needed?

MR. HOLLANDS: The output of the phototube is measured in microamperes, so it would be necessary to use one or two stages of amplification.

MR. FARNHAM: I have heard designers of high-grade amplifiers, particularly those used for picture transmission, say that the conventional tubes supplied for broadcast receivers are not of sufficiently high quality, and that special tubes were desirable. Are there two grades of tubes?

MR. HOLLANDS: Yes; we make a special line of tubes called the *1600* series, in which we go to extreme lengths to assure mechanical rigidity, perfect spacing, and other important features. Those tubes are more expensive, because their manufacture is very much slower and they require considerably closer supervision in production. They also go through several tests that are not given to regular amplifier tubes. For instance, they are tested directly under actual voltage amplification conditions.

MR. FARNHAM: Does the sensitivity of a phototube depend upon the width of the spectral band impinging upon it?

MR. GLOVER: The caesium tube, which has a high microampere-per-lumen sensitivity, is very sensitive to the red and infrared so that if used with a monochromatic light-source in the blue, it will show a much lower sensitivity. In the blue region a potassium surface would be much more sensitive.

MR. FARNHAM: And if all the illumination were concentrated in the blue or blue-green?

MR. GLOVER: Then the caesium tube would be much less sensitive than the potassium tube.

MR. KELLOGG: In our sound reproducing optical system no measures have been taken to exclude the infrared light. Is it likely that the infrared is contributing very largely to the response? What per cent of the light will an infrared filter exclude?

MR. GLOVER: Quite a large fraction. The maximum sensitivity of a caesium tube occurs between 7000 and 8000 Å, which is at the very edge of the visible spectrum. The sensitivity extends to 12,000 Å, and over that range the emission from a tungsten lamp rises rapidly, so that the response of the tube in that range is, roughly, perhaps 60 per cent of the overall response.

MR. MALMUTH: I understand that these tubes are mounted directly on the first-stage amplifier tube.

MR. HOLLANDS: Not directly upon it. They can be mounted very close to it, so that the small cap is at the top and relatively close to the grid-cap of the amplifier tube. The grid-cap of the amplifier tube is round, not square, like the chrome cap of the phototube. The reason for making the latter square was to permit orienting the tube with regard to the light-beam.

MR. PALMER: It is customary to rate exciter lamps in volts and amperes, say, 4 volts, 0.75 ampere. Would we have as much photoelectric effect if we operated them at 2 volts? The life would be much longer.

MR. GLOVER: As the voltage of an incandescent lamp is raised, a greater and greater fraction of the light emitted falls within the visible spectrum. At very low voltages only heat is given off, which means that the energy radiated is in the far infrared, which is beyond the sensitivity of the tube.

MR. PALMER: I did not mean to go that far. I meant some compromise between the rated voltage and the voltage necessary to activate the photocell.

MR. GLOVER: You will find a considerable decrease if you attempt to cut the voltage to any extent.

MR. FARNHAM: Reproducer optical systems pick up only a small area of the light-source, and if you reduce the brightness or the color-temperature of the exciter lamp, then the light that is available is less, and more amplification must be used. As a result, other troubles may enter due to, say, ground-noise; whereas, if the lamp is operated at a high order of brightness, a great deal more light will pass through the optical system. It is a little different from using a lamp without an optical system; if the entire luminous output of the filament were available you could substitute wattage for brightness and get the same effect and thus longer life.

MR. WEISS: How do the *922* and *921* tubes compare in characteristics with the present phototubes, for instance, the *868?*

MR. GLOVER: The *922* is electrically identical to the *917*. The gas type is very nearly the same as the *918*. The *921* and the *918* have higher sensitivity than the *868*.

MR. KELLOGG: Photoelectric tubes operate saturated, and there is no appreciable space-charge effect. Do not practically all microphonic effects disappear under such conditions?

MR. HOLLANDS: No. There are several microphonic effects that are rather difficult to trace, but we have found that the microphonic troubles we have at the present time are due almost entirely to physical movement of the elements within the tube. That is easily demonstrated with a Strobotac, by vibrating the tube and using any two elements of it as a condenser microphone, "stopping" the movement of the two elements with the Strobotac, and watching the amplitudes of the output amplifier. Relatively few microphonics are due to electrical characteristics of the tube.

MR. KELLOGG: I do not believe I made the question clear. Assuming there is movement of the electrodes with respect to each other, it is hard to imagine that that will alter the current through the device except through the agency of space-charge.

MR. HOLLANDS: That is right.

MR. KELLOGG: Working so close to the saturation point, then, would there be enough space-charge effect to cause microphonic noise in the circuit? Our experience has been that photocells are relatively immune from microphonic tendencies.

MR. GLOVER: There is very little trace of microphonics in a vacuum phototube. We have recently measured the microphonics in the gas type of tube, and find that they rise rapidly with increase of voltage and increase of gas amplification. Apparently the cause lies in the gas, although at present we can give no explanation for it.

MR. CRABTREE: Is the geometry of the tube arrived at by trial-and-error, or do you apply a mixture of trial-and-error and mathematical methods?

MR. HOLLANDS: The tube design engineer has an idea of the characteristics for which he is striving. From curves and mathematical data that we have, we can derive a pretty close first approximation by calculation. The factory then fabricates the tubes, and minor changes are made to produce the desired characteristics. Briefly, we arrive at the first approximation mathematically, and then by cut-and-try methods we trim the characteristics.

RECENT DEVELOPMENTS IN GASEOUS DISCHARGE LAMPS*

S. DUSHMAN**

Summary.—*The luminous and electrical characteristics of a number of vapor discharge lamps that have attained practical importance in recent years are described. These include the sodium vapor lamp, the high-intensity mercury vapor lamp, and the high-pressure quartz capillary lamp. The fundamental physical phenomena and the manner in which these affect the light output and efficiency are discussed briefly. The effect of variations in gas pressure and current density upon the distribution of intensity in the spectrum is dealt with, and also the accompanying changes in intrinsic brilliancy and color of light emitted.*

The latter part of the paper contains a discussion of recent developments in the utilization of fluorescent materials in gaseous discharge lamps. These lamps offer interesting possibilities from the point of view of general illumination and special color effects.

During the past few years there has been considerable development in the utilization of electric discharges in gases and vapors for the production of light at higher efficiencies than those obtainable with incandescent lamps of similar wattage. It is the object of the following remarks to describe some of these new light-sources from the point of view of the engineer who is interested in their application.

As a result of the knowledge that has been gained during the past two decades on the nature of the emission spectra of different elements and compounds, we find that the only discharges that are of practical interest as light-sources are those in neon, mercury vapor, and sodium vapor. Logically, we should include under the same general heading arcs between carbon or impregnated carbon electrodes in air at ordinary pressure. However, since the phenomena in such arcs are different in certain respects from those observed with discharges in the monatomic vapor, they will not be discussed in the present connection.

---

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received October 6, 1937. (A summary, with slight additional material, of a paper published in *J. Opt. Soc. Amer.*, **27** (Jan., 1937), No. 1, p. 1, where a comprehensive bibliography is given.)

** Research Laboratory, General Electric Co., Schenectady, N. Y.

Luminous Efficiency.—In any consideration of light-sources, it is first of all necessary to take into account the characteristics of the human eye as a detector of radiation. What is usually designated as "light" is actually a rather narrow region in the extremely wide range of electromagnetic radiations that have been observed, and are shown in Table I.

TABLE I

Radiation	Lower Range of Wavelength in Ångstrom Units	Corresponding Electron Volts
Gamma Rays	0.1	123,360
X-rays	1.0	12,336
Far Ultraviolet	1000	12.34
Near Ultraviolet	3000	4.11
Visible	4100	3.01
Infrared	7200	1.71
Shortest Hertzian Waves	10^7 = 0.1 cm.	10^{-3}
"Radio" Waves	1 meter	10^{-6}
	1 kilometer	10^{-9}

The second column gives the value in Ångstrom units (1 Å = 10^{-8} cm.) of approximately the shortest wavelength in the particular region. Since there are no sharp dividing lines between these regions, these values are to be regarded as rough indicators of the extent of each type of radiation. The third column gives the voltage through which an electron would have to be accelerated to cause the emission of the given wavelength. As will be pointed out subsequently, there is a definite relation between the two magnitudes, which is expressed by the relation

$$\lambda = \frac{V}{12{,}336}$$

where λ is the wavelength in Ångstrom units, and V is measured in volts.

Fig. 1 shows the average visibility curve for the eye. For all practical purposes the visibility V_λ may be taken as zero for all wavelengths outside the region included between λ_1 = 4100 Å and λ_2 = 7200 Å, and has a maximum value for the radiation in the green which has a wavelength λ = 5550 Å. A source of light emitting radiation of this wavelength exclusively would have an efficiency of 621 lumens per watt. On the other hand, the most that we could expect from a source emitting only the characteristic yellow radiation of sodium vapor (λ = 5890, 5896) is 475 lumens per watt, and for red or blue the optimum efficiency would be much less.

While a tungsten filament lamp or other incandescent solid emits radiations of which the wavelengths vary *continuously* from the ultra-violet into the infrared, the radiation from a monatomic gas or vapor such as neon or mercury, when examined by a spectroscope, is found to consist of a number of distinct lines, each corresponding to a definite wavelength. A few typical line spectra are shown at the top

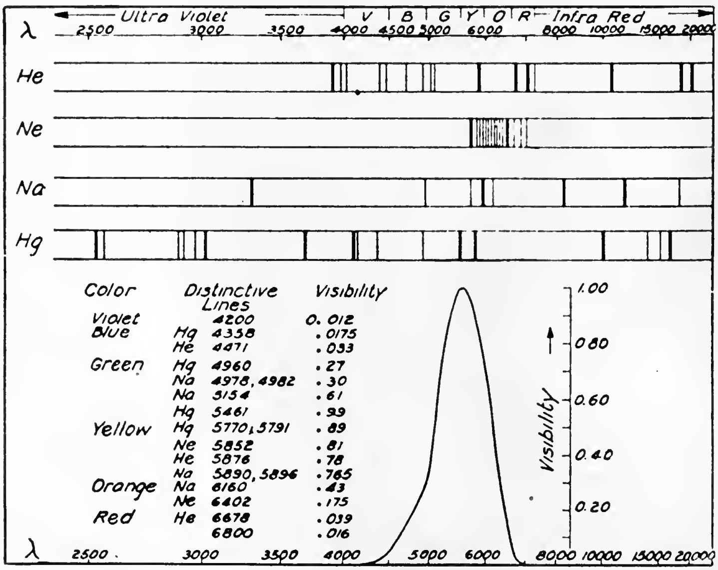


FIG. 1. Some typical line spectra and visibility curve.

of Fig. 1, while the table in the left-hand corner gives the wave-lengths, corresponding colors, and visibilities (in terms of the maximum visibility as 1). It is the predominance in intensity of one or more of these lines that gives rise to the characteristic colors of the light obtained from these gases and vapors.

On the basis of the observed distribution of energy in the spectrum of any light-source and the visibility curve shown in Fig. 1, it is possible to calculate a theoretically optimum efficiency, which we shall designate by L_o. Table II gives values of L_o for different sources and, for comparison, values of efficiency L_s actually obtained on practical lamps. The third column gives the percentage 100η

of the total energy emitted by the source that is in the visible range. This is deduced by means of the relation

$$\eta = L_s/L_o$$

The last column gives the energy utilization ratio ϵ, that is, the ratio between the total watts input and the watts emitted as visible light (which is measured in terms of lumens).

TABLE II[1]

Luminous Efficiencies of Various Sources of Light
(Lumens per Watt)

Source	L_o	L_s	100	100ϵ
Black Body at $T = 6500$	218	86.3	39.5	13.9
Sun	250	100	40	16.1
Tungsten (Gas-Filled)	143	15–30	10 –20	2.5– 5.0
Flaming Arc	220	45–75	20 –34	7.2–12.1
Sodium Vapor	475	50–75	10 –15	8 –12
Mercury Vapor				
Low-Pressure	248	15–20	6 –8	2.5– 3.2
1 Atm. (Type H)	298	30–35	10 –12	4.8– 5.6
Higher Pressures	298	40–50	13 –17	6.4– 8.0
Neon	198	15–40	7.5–20	2.5– 6.4
Helium		4–10		
Carbon Dioxide		2– 4		
Cadmium		0.5– 1		
Green Fluorescent (L. P. Mercury)	475	60–80	12.6–16.9	9.6–12.9

Physical Phenomena in a Gaseous Discharge Lamp.—In an incandescent solid the light is produced as a result of the high temperature to which the conductor is raised by the passage of the current. The light output increases with the temperature, and tungsten has become the metal for use in incandescent lamps because it has a higher melting point than any other metal.

On the other hand, the mechanism by which light is produced in a gaseous discharge is quite different, and we must therefore consider briefly the nature of this mechanism. This may be discussed under two headings: (*1*) the fundamental processes by which an atom or molecule of any gas or vapor may be made to emit radiation, and (*2*) the processes of electrical conduction in a gas or vapor. Primarily, a gaseous discharge lamp is a conductor of current, and the essential characteristics of the conduction phenomena are the same whether the gas used is argon or neon. But in the case of the former there is very little visible light, since most of the lines in the spectrum of argon occur in the ultraviolet and infrared regions, while in the case of neon, as evidenced by its practical utilization, the spectrum is rich in lines in the red end.

Our present views on the origin of spectral lines are based upon a theory that was first postulated by N. Bohr in 1913, and has since then been found to be in excellent agreement with observations by a large number of investigators who have worked in this field during the past twenty-four years. These views may be understood best by describing briefly an experiment that was carried out by two German physicists, J. Franck and G. Hertz, in 1915, in order to test certain deductions from Bohr's theory.

It is well known that when a heated tungsten filament is used as a cathode (negative electrode) in a highly evacuated bulb, electrons are emitted. These carry the current to the anode (positive electrode, or "plate"), and the magnitude of the current thus transported by the electrons depends upon both the temperature of the cathode and the plate voltage. The kinetic energy of the electrons is proportional to the anode voltage in accordance with the relation

$$^1/_2 mv^2 = Ve$$

where e = charge on electron,
m = mass of electron,
v = velocity of electron,
V = positive potential on anode.

Such an evacuated device is used as a rectifier in radio sets because the electrons can pass in only one direction, as long as the plate is not at a sufficiently high temperature to emit electrons at any considerable rate. Now, into this bulb we insert a pellet of metallic sodium and increase the temperature of the walls so that the vapor pressure of the sodium reaches a value of about one-millionth of an atmosphere. (This is the order of magnitude of the pressure in a 10,000-lumen sodium vapor lamp.) With the tungsten cathode heated to a temperature at which electrons are emitted in considerable numbers, we gradually increase the anode voltage from zero. At first, as long as this is below 2.1 volts, nothing happens; but at 2.1 volts, or 0.1 volt higher, it is observed that the vapor emits a spectrum consisting of only the two D-lines of wavelengths 5890 and 5896 Å. These are the most prominent lines in the spectrum of sodium, and impart to the light its yellow-orange color.

As the voltage is increased still higher, more lines appear in the spectrum, until, at 5.1 volts or higher, the whole spectrum is emitted. Now, what happened in this experiment is to be interpreted thus:

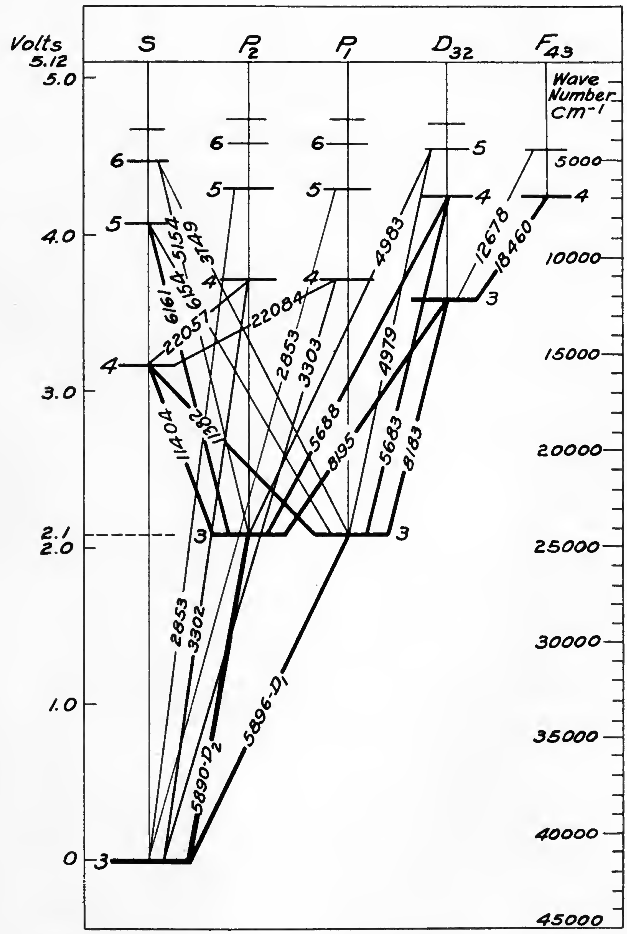


FIG. 2. Energy levels and lines in arc spectrum of sodium.

When an electron possessing the velocity corresponding to an acceleration through 2.1 volts collides with a sodium atom, the latter is excited to a higher-energy state, and when the system passes spontaneously from this higher state to the normal, monochromatic radiation is emitted in accordance with the relation

$$h\nu = Ve,$$

where ν is the frequency of the radiation and h is a universal constant (known as the *quantum constant*). The corresponding wavelength is given by the relation

$$\nu = c/\lambda$$

where c is the velocity of light.

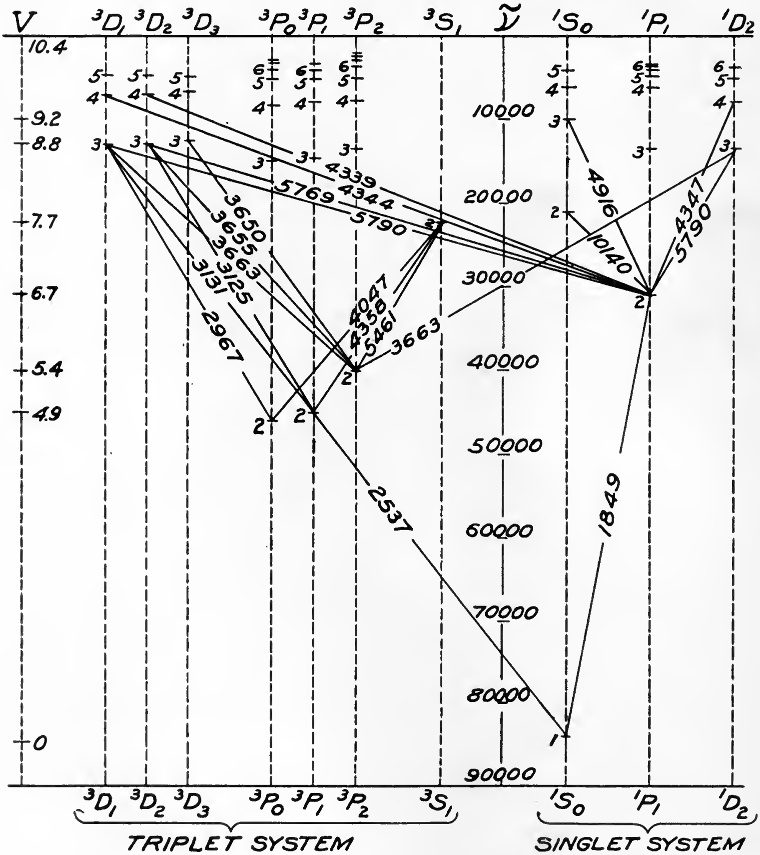


FIG. 3. Energy levels and lines in arc spectrum of mercury.

Each line in the spectrum of sodium corresponds to a similar transition between a higher- and lower-energy state of the sodium atom, and each of these states requires a definite electron energy (corresponding to a so-called critical potential) for its excitation. Fig. 2

shows these so-called "energy-levels" in the spectrum of sodium, and some of the lines that are observed spectroscopically. Fig. 3 is a similar energy-level diagram for mercury. It will be observed that while in the case of sodium the first excited state occurs at 2.1 volts, the lowest excited state for mercury occurs at 4.9 volts. Consequently, the corresponding transition in the latter case gives rise to a line of shorter wavelength (λ = 2537 Å), which is in the ultraviolet. Lines, such as the latter, corresponding to transitions between the first excited state and the normal state of an atom are known as resonance lines, since the atoms also absorb these radiations. Furthermore, the

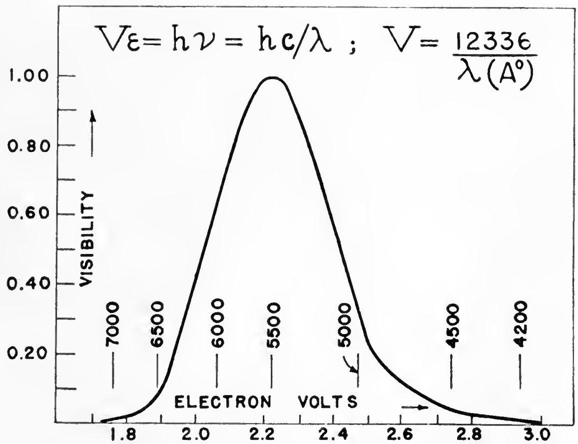


FIG. 4. Visibility as function of electron volts.

excited state from which a transition can occur with emission of resonance radiation is designated a resonance state (or level). In order to obtain visible light from mercury it is necessary to excite the mercury atom to about 6.7 volts or higher, and the whole spectrum appears only when the electron velocities exceed that corresponding to 10.4 volts.

Similarly, in the case of other spectra, the production of any line requires that the electron shall acquire a minimum value of the kinetic energy. Obviously, the most efficient light is obtained when the kinetic energy of the electron can be converted completely into visible radiation. Now, the visible radiation, as stated previously, extends from about 4000 to 7000 Å. To produce these radiations the minimum values of the electronic energy must lie between about 1.8

and 3.0 volts. Fig. 4 shows the visibility curve plotted against electron volts instead of against wavelength, as in Fig. 1. The maximum visibility is obtained by collisions of atoms with electrons of about 2.25 volts.

When we examine the energy-level diagrams of the three elements, sodium, mercury, and neon, it is seen that only in the case of sodium is it possible to convert the energy of 2.1-volt electrons into light. On the other hand, in the case of the other two elements, the lowest excited levels are so high that the only radiation that can arise as a result of transitions from these levels to the normal lies in the ultraviolet. To obtain visible light the atoms have to be excited to above 6.7 volts in the case of mercury and to above 19 volts in that of neon. Thus it would appear that at the maximum we could not expect an efficiency of light production from neon greater than about 2.2/19 = 1/9 of the optimum; and in the case of mercury similar considerations lead to the expectation that the maximum efficiency would be only about 2/8 of the optimum.

Actually, as Table II shows, the values of L_s, the specific luminous efficiencies observed for neon and mercury, are greater than predicted by this simple argument. While it is not practical in the present discussion to consider in detail the reasons for these observations, some of these may be mentioned briefly.

First, even when the electrons possess the requisite energy to excite an atom by collision, this does not take place at every such collision. There exists a definite probability of excitation, which varies with the nature of the atom and the speed of the electron.

Second, at higher pressures and higher current-densities an excited atom may suffer a collision with either another electron or another atom before a transition can occur that is accompanied by emission of light.

Third, in order that the electrons may be able to pass freely from the cathode to the anode of the discharge, it is necessary to have present a minimum concentration of positive ions to neutralize the negative space-charge otherwise produced by electrons. In order to produce these ions the electrons have to acquire a velocity corresponding to the ionization potential, and in a gas discharge this gives rise to a voltage drop at the cathode that is considerably greater than the voltage required for the excitation of visible light.

The magnitude of this cathode drop depends upon the electron emissivity of the cathode, and is lower the higher the electron emissivity. At a cold cathode, such as those used in ordinary Geissler tubes, the electrons are pulled out, as it were, from the cathode by the intense electric field produced there by a high concentration of positive ions. As a result, the cathode drop may vary from slightly less than 100 to 300 volts or higher, depending upon the nature of both the cathode and the gas.

On the other hand, in the case of a thermionic cathode such as an oxide-coated nickel electrode, which emits electrons in virtue of its high temperature, the cathode fall ordinarily does not greatly exceed the ionization potential of the gas. Since this has the value of 25.5 volts for helium, 21.5 volts for neon, 10.4 volts for mercury, and 5.1 volts for sodium, and a fraction of a volt in excess of the ionization potential is required to produce all the ions necessary for conduction of the electrons through the gas, the use of hot cathodes in gaseous discharges has made it possible to operate such discharges at much lower voltages and higher currents than in the case of Geissler discharges.

Summarizing the foregoing remarks, it is important to recognize that any gaseous discharge lamp is fundamentally a conductor in which more than 99 per cent of the current is carried by electrons passing from the cathode to the anode, and the small residual current is carried by positive ions moving in the opposite direction. The light emitted is merely a by-product of the electrical phenomena in the discharge. The fundamental processes consist in the collision of electrons with the atoms of the gas or vapor. These collisions result in the formation of excited atoms and ions. The latter serve to eliminate electron space-charge at the cathode, and thus make it possible for the discharge to operate at appreciable current-densities. The nature of the atoms governs the type of spectrum emitted, and therefore affects the intensity and color of the light emitted, as well as the efficiency of light production.

In recent years many investigators in different laboratories, both in this country and abroad, have studied these phenomena of conduction and light production in gases, and as a result there have been developed a number of gaseous discharge lamps that have found considerable commercial application. Not only are most of these light-sources more efficient than gas-filled tungsten lamps of similar wattage, but they possess other characteristics that should be of advantage in many special applications. In the following paragraphs some of these gaseous discharge lamps will be described briefly, and mention will be made of those characteristics that may be of interest in the present connection.

Types of Gaseous Discharge Lamp.—Since in the following discussion we shall consider only discharge lamps in which hot cathodes are used, the classification suggested by C. G. Found[2] will be adopted. Found classifies them, according to the *geometry* of the containing vessel, into two types: (*1*) *cathodic*, (*2*) *positive column;* and defines these as follows:

"A cathodic discharge is defined as one that is more or less bulbular in shape and in which the distance between cathode and anode is comparable with the smallest dimension of the bulb.

"A positive column is an elongated tube in which the distance between cathode and anode is several times the diameter."

In general, it may be stated that a cathodic type of discharge operates with a voltage drop that is approximately equal to the ionization potential of the gas, and may be as low as the resonance (lowest critical) potential (owing to successive impacts). A tungar rectifier is an example of such a discharge, and the d-c. low-voltage sodium lamp is another example. Such an arc may be started on a comparatively low-voltage circuit (less than 110 volts) without any auxiliary voltage "kick."

In a positive-column discharge the total voltage drop usually exceeds the ionization potential for the gas, and while the discharge tube may be designed to operate on less than 110 volts, a starting kick or some equivalent device, such as an auxiliary electrode, is necessary. This initial high voltage is needed to overcome the negative charge on the walls tending to prevent the flow of electrons. The low-pressure mercury-vapor lamp with mercury cathode and the hot-cathode high-current neon tubes are examples of this type of discharge. The positive-column sodium-vapor neon lamp and high-lumen output a-c. sodium lamp developed for use on 6.6-ampere constant-current circuits (described in a subsequent section) are other examples. The main distinction between the two forms of discharge is in the fact that in the cathodic type all the energy from the external source of supply is converted into kinetic energy of electrons at the cathode, and, consequently, there is no voltage gradient outside the region of the cathode fall, as in a positive column. In the latter, there is, in addition to the cathode fall, a drop in the rest of the tube that varies with the length, other conditions remaining constant. In a cathodic discharge the extent of the light region is governed by the distance that the electrons traverse before they lose so much energy that they can not excite any atoms by collision. Such electrons are known as "ultimate" electrons in contrast to the "primary" electrons, which have acquired high kinetic energy in passing through the region of cathode fall. The light output in such a discharge is therefore a function of both the gas pressure and the cathode fall, and the latter is in turn governed by the thermionic emissivity of the cathode. As has been emphasized already, the function of the ions is merely that of eliminating space-charge. In consequence, the voltage drop in the arc adjusts itself to such a value for any given arc current that a sufficiently strong field will exist at the cathode both to provide the necessary electron emission and to enable the electrons to acquire sufficient energy to produce the necessary amount of ionization.

In a cathodic discharge in neon-sodium the pressure of neon is about 1 mm., and under conditions of optimum light output the pressure of sodium vapor is about 0.001 mm. The value of the arc drop actually observed in such a discharge is about 18 or 19 volts when optimum light output is obtained, and it is only when the vapor pressure of sodium increases to values above 0.002 mm. that the arc drop decreases to about 8 volts and at the same time the neon lines disappear.

Theoretical considerations show that, as a first approximation, the light output should be proportional to the current; and actually it has been observed by Found that for a large range of values of arc current, the light output is 1000 lumens per ampere. At higher currents the ratio decreases, and when the discharge is all sodium, the light output is only about 500 lumens per ampere.

In a cathodic type of discharge, the electrons acquire a high kinetic energy in the cathode fall region and then lose this energy in excitation and ionization of atoms. Thus the kinetic energy decreases with increase in distance from cathode, and finally when the electrons have reached the stage in which their kinetic energy is no longer adequate for excitation (ultimate electrons) the light generation also disappears.

The fact that the light generation is uniform throughout the length of the positive column shows that the electrons must acquire energy for excitation and ionization from some other source than the cathode fall. This energy is supplied, obviously, by the energy input into the column; that is, Gi_a watts per unit length, where G is the voltage gradient and i_a the arc current. The magnitude of G varies with current-density and pressure of gas. Owing to the fact that the gradient in a positive column is constant, the concentrations of elec-

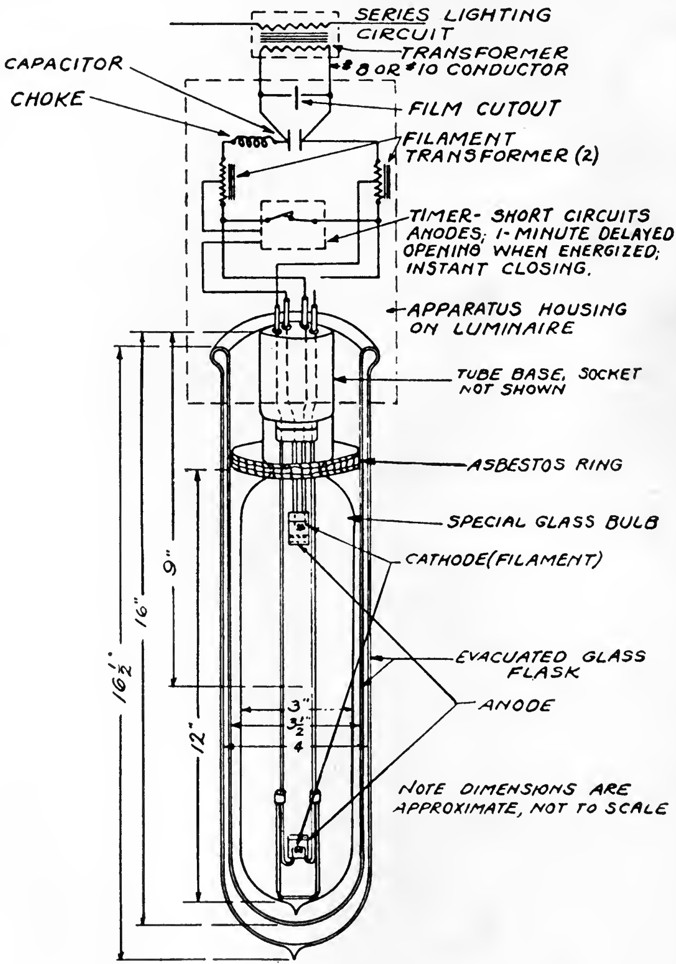
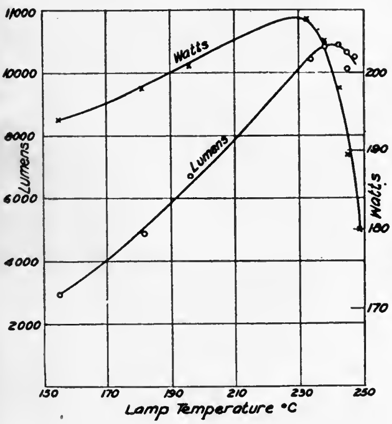


FIG. 5. 10,000-lumen a-c. sodium lamp, showing connections for operation of cathodes in series with arc.

trons and positive ions in the column must be approximately equal. Since the ions and electrons are constantly diffusing to the walls, there must be some mechanism by which fresh ions are generated.

Light Output in Positive-Column Neon-Sodium Vapor Discharge.—In order to obtain considerable light output with appreciable intrinsic brilliancy of source, the positive column is more advantageous than the cathodic type of discharge. Thus, in the case of low-pressure mercury vapor and sodium-neon lamps it has been found that from the point of view of both lumen output and efficiency the best results are obtained with the positive-column type of lamp.

While the mercury-vapor lamp of this type has been a familiar form of illumination for many years, only within the past few years has it been found possible to develop a commercial type of sodium-vapor



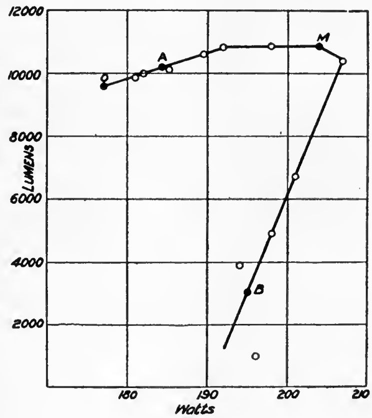


FIG. 6 (*Left*). Characteristics of 10,000-lumen sodium lamp.
FIG. 7 (*Right*). Lumens-watts relation for 10,000-lumen sodium lamp.

positive-column lamp for use on standard alternating-current circuits. Such lamps have been developed by the Osram Company in Germany, and by the Philips' Lamp Company in Holland. A lamp emitting approximately 10,000 lumens at an input of about 190 watts has been described by G. R. Fonda and A. H. Young.[3] Fig. 5 shows the design of this lamp and the connections for series-circuit operation. The electrodes are oxide-coated tungsten spirals enclosed by elliptically shaped anodes, with a distance of about 25 cm. between the latter. The pressure of neon used varies from 1 to 3 mm., and under operating conditions (6.6 amperes' constant current and a drop of 27–30 volts) the pressure of sodium vapor is approximately 0.001 mm.

The glass is covered internally with a sodium-resistant glaze, and the lamp itself is enclosed in a transparent Dewar flask in order to maintain the pressure of sodium vapor at the optimum value (which corresponds to a temperature in the neighborhood of 230°C).

Now let us consider the phenomena of light production in such a lamp. The electrons in a positive-column discharge are distributed throughout the whole volume. Therefore, the excitation, ionization, and light production are each uniformly distributed along the column. At lower pressures of sodium the voltage gradient along the tube is higher than at higher pressures, since the ions are supplied for the most part by ionization of neon. The sodium is excited by collision with electrons that have already lost part of their energy in producing the lower-excited states of neon.

On the other hand, at higher pressures of sodium, the electrons can produce a sufficient number of ions by collision with sodium atoms, and hence the electron velocities are lower and the voltage gradient is decreased. But when this occurs, the wattage input decreases and the lamp cools. Hence, for stable operation the lamp must be operated at such a pressure of sodium as will maintain the higher voltage gradient.

In this laboratory Found has investigated the operation of the lamp as affected by varying the ambient temperature and, consequently, the vapor-pressure of sodium. In Fig. 6, taken from a recent paper,[4] the lumens and watts at 6.6 amperes are plotted as functions of the external temperature of the tube wall. Below about 200°C the light is due to excitation of neon. As the temperature is increased the light output increases as well as the watts input, and both pass through maximum values as shown.

These observations are plotted also in Fig. 7, which shows the light output as a function of watts input. Starting with the cold lamp, the lumens increase linearly with the watts, and then remain practically constant over a range extending from 207 to about 190 watts. This characteristic makes it possible, as has been pointed out by Found, to operate a neon-sodium vapor-discharge lamp over a considerable range of ambient temperature without any appreciable change in light output or efficiency.

The energy distribution for the neon-sodium vapor lamp operating at 200 watts' input has been described by Buttolph.[5] Nearly all the light occurs in a range between 5600 and 6100 Å. It therefore possesses an orange-yellow color.

The average intrinsic brilliancy is about 6 candles per square cm., and the efficiency ranges from 50 to 60 lumens per watt, depending upon the type of circuit used for operation.

High-Pressure Mercury-Vapor Lamps.—In the low-pressure gaseous-discharge lamps the average kinetic energy of the electrons is very much higher than that of the gas molecules. Thus, while the gas in the neon-sodium vapor lamp is at a temperature of about 230°C, the electrons possess a kinetic energy that is the same as that of molecules in a gas at about 6000° to 30,000°C. This is quite different from the state of affairs in the sun or other stars. In the case of the latter, thermal equilibrium exists between electrons, ions, and atoms; that is, all the constituent particles possess the same average kinetic energy. Under these conditions atoms are constantly dissociating into ions and electrons while the latter are recombining to form atoms, and at constant temperatures the rates of the two reactions are equal, so that it is possible to calculate for a given temperature the relative numbers per unit volume of undissociated atoms, electrons, ions, and excited atoms.

In an electrical discharge in a gas, conditions approaching those in a star are more and more nearly approached as the pressure is increased, so that in a discharge in mercury at a pressure of one atmosphere there exists a state of approximate thermal equilibrium, and as the pressure is increased still higher the temperature in the center of the arc-stream gradually increases.

The earliest form of such a discharge was the quartz tubular lamp which has been used mainly as a source of ultraviolet light. By the application of thermionic cathodes it has been found possible to develop designs that are very convenient for practical operation. In these lamps a gas, such as neon or argon at a pressure of a few cms. of mercury, is used to initiate the discharge between the cathodes which are thereby raised to a temperature at which they act as thermionic sources. Owing to the high energy input the mercury becomes vaporized, the pressure increases to one atmosphere or even higher, depending upon the design of lamp and operating conditions, and the spectrum exhibits only those lines that are characteristic of mercury along with a certain amount of continuous radiation.

Measurements of the relative intensities of the lines and of the energy distribution in the spectrum made on discharges in quartz tubes at different pressures show that while the intensity of the resonance line ($\lambda = 2537$ Å) is very high at low currents and low pressures, this line is practically eliminated (owing to absorption) in the discharge at pressures of 1 atmosphere and higher. At the higher pressures the intensities of the lines $\lambda = 3650/3663$, $\lambda = 5461$, and $\lambda = 5769/5790$ are increased. In a very recent publication by W. Elenbaas it is shown that at higher pressures the spectral lines are broadened more and more with increase in pressure, and at higher current-densities the continuous spectrum is enhanced. Also, the fraction of the total energy radiated in the form of near-ultraviolet, visible, and infrared increases with increase of pressure, and this accounts for the observed increase in light efficiency (see subsequent remarks).

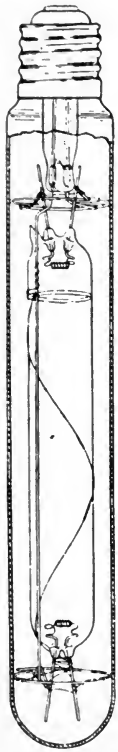


FIG. 8. High-intensity 400-watt mercury-vapor lamp.

The various designs of the high-pressure discharge lamp that have been developed may be divided into two groups: (*1*) those operating at 1 atmosphere and utilizing glass envelopes, and (*2*) those operating at higher pressures and requiring the use of quartz envelopes.

Fig. 8 is a diagram of the 1-atmosphere lamp developed by the General Electric Co., Ltd., Wembley, England, and described by J. W. Ryde.[6] The inner glass tube which carries the arc is enclosed in a heat insulating jacket. The wire along the outside of the discharge tube is for the purpose of easier starting.

The electrical characteristics of this lamp have been described in a paper by J. A. St. Louis[7] and the luminous characteristics by L. J. Buttolph.[5]

The lamp is made in both 400-watt and 250-watt units, and operates on a 220-volt a-c. circuit with series inductance. Argon is used as starting gas, and a *limited* amount of liquid mercury is inserted in the lamp initially. Fig. 9 shows the electrical characteristics of the 400-watt unit between the time of starting and complete vaporization of the mercury. It will be observed that the initial volts and arc watts are low, but that after a slight decrease, both the voltage drop in the arc and the power input increase rapidly. "During this period of rapidly increasing pressure," as St. Louis observes,[7] "the arc constricts. The wattage passes through a maximum but the voltage increases with time as long as any liquid mercury remains in the tube. After about seven minutes all the mercury is vaporized and the electrical characteristics are thereafter constant. If the mercury were not limited in amount, then the course of these characteristic curves would continue as indicated by the dotted lines. It should be emphasized that the shape of these characteristic curves is influenced by the value of the series inductance, by the value of the line voltage, and by the design details of the arc tube."

While it is possible to design the lamp so that equilibrium is attained with liquid mercury at a temperature corresponding to any desired

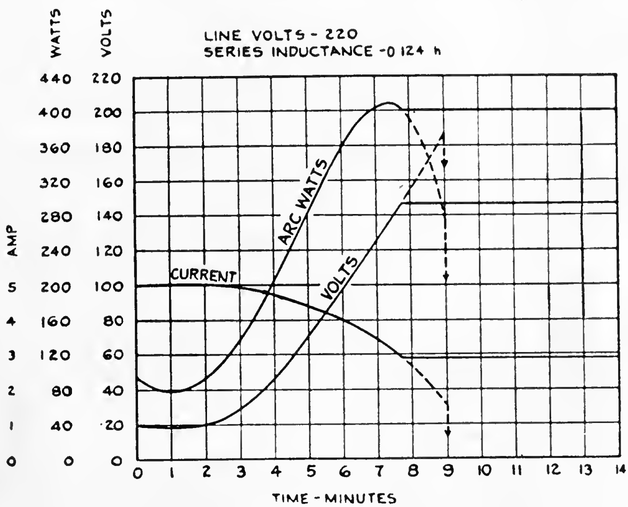


FIG. 9. Electrical characteristics of 400-watt mercury-vapor arc between time of starting and complete vaporization of mercury.

mercury-vapor pressure, the use of a limited amount of mercury has many practical advantages, not the least of these being the fact that under these conditions the lamp is not nearly so sensitive to fluctuations in either line voltage or ambient temperature.

Under operating conditions the temperature of the inner glass wall is about 350°C, the pressure of mercury 1 atmosphere, and the initial efficiency 40 lumens per watt. This efficiency decreases after 1500 hours to about 33 lumens per watt. The average brightness of the light-source itself is about 30 candles per square cm.

The High-Pressure Mercury-Vapor Lamp.—One of the most interesting of the recent developments in the field of illumination is the quartz capillary lamp developed by C. Bol of the Philips' Lamp Co., Eindhoven, Holland. The air-cooled form which operates at 230 volts with a power input of about 85 watts, consists of a quartz capillary 4 mm. in diameter, with a total distance of 18 mm. between the oxide-coated tungsten electrodes. A small drop of mercury is inserted and argon is used as a starting gas. The lamp is operated on a high-reactance transformer having a maximum open-circuit voltage of about 450 volts. The pressure of mercury vapor attained in operation depends for a given size of capillary upon the gradient and the arc current, but is usually greater than 10 atmospheres.

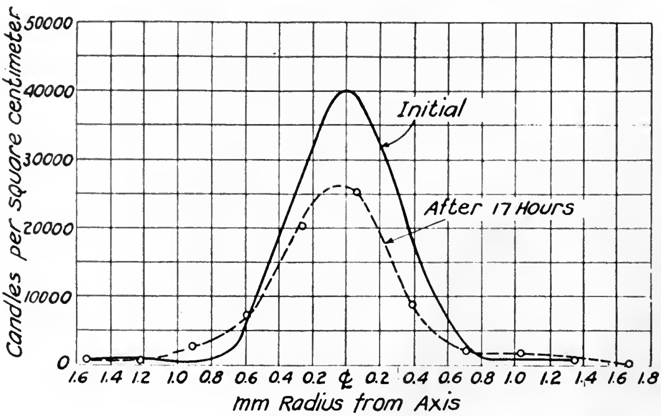


FIG. 10. Brightness distribution along cross-section of tube. Photometric test of water-cooled capillary mercury arc; apparent brilliancy of arc viewed through glass jacket.

By cooling the walls of the quartz capillary in a rapid stream of water, the wattage input may be increased more than five-fold, and while this increases the efficiency from approximately 40 lumens per watt, in the air-cooled, to 60 lumens per watt or even higher, the intrinsic brilliancy and lumen output are increased manifold. In fact, Elenbaas[8] has reported that by increasing the power input in the water-cooled lamp to 1400 watts per cm. in a 1-mm. diameter tube, a brilliancy of 180,000 candles per sq. cm. has been attained. This is greater than that of the sun, as observed from the surface of the earth, which is 165,000 candles per sq. cm.

A very comprehensive study of the characteristics of high-pressure vapor discharges has been made by Elenbaas and a summary of these investigations has been published by G. Heller.[9]

As mentioned previously, the most important difference between these discharges in mercury vapor at 1 atmosphere or higher and those in much lower pressures is that in the former the temperature of the vapor is much higher and thermal equilibrium exists between mercury atoms, electrons, ions, and excited atoms, similar to that which exists in the atmosphere of a star.

The temperature in the arc-stream is about 6000°C or even higher at the axis and decreases as the walls are approached, so that at the latter it is about 800°C. As a result, the light distribution across the arc-stream is like that shown in Fig. 10 which is based upon some observations made in this laboratory by F. Benford and N. T. Gordon.[10]

The pressure of mercury vapor in the lamp increases linearly with voltage gradient G for values of the gradient above about 100 volts per cm., and at 500 volts per cm. the pressure is about 150 atmospheres. This condition of operation can be attained only by use of a very high rate of cooling. The light output L also increases linearly with the watts per cm. of length W, and, as shown by Marden and his associates, the relation between the two quantities is of the form

$$L = 65\ (W - 30)$$

Hence, the maximum attainable efficiency is 65 L/W, and for 500 watts' input the light output is about 30,000 lumens per cm.

Table III is based upon data published by Marden and his associates in the paper mentioned previously, and presents data on the arc characteristics, light output (in candle-power), and average brightness of the light-source.

TABLE III

Lamp	Volts	Amps.	Watts	C. P.	Arc Length, Mm.	Arc Diam., Mm.	C P. per Sq. Cm.
Commercial	150		400	1,560	157	10	100
High-Intensity Glass	70		250	830	100	8	
Commercial Quartz	250	0.4	85	340	18	1	1,900
Water-Cooled	580	2.0	920	5,900	18.5	1.5	21,000
Water-Cooled	840	2.08	1490	10,500	17.5	0.85	70,000

As shown by results obtained in this laboratory by F. Benford and N. T. Gordon, it would seem quite practicable to operate a water-cooled quartz lamp at 500 volts per cm. and 1 ampere, with an average brightness of 20,000 candles per sq. cm.

The color of the light emitted has considerably more red than the low-pressure lamp and thus shows a better color reproduction.

It should be mentioned in this connection that in the case of the water-cooled lamp operated by Elenbaas which gave a brightness of 180,000 candles per sq. cm., the power input was 1400 watts per cm. in a tube 1 mm. in diameter; the gradient was 805 volts per cm.; and the mercury vapor pressure attained was 200 atmospheres; while the temperature at the axis was calculated as 8600°C.

Transformation of Ultraviolet Radiation into Visible Light.—That many materials fluoresce under the action of ultraviolet radiation is a fact that has been known for a long time, and quite a vast literature has accumulated describing both the methods of preparation of various "phosphors" and the relation between the emission spectra and the wavelength of exciting radiation. Some materials, like the sulfides of the elements of Group II in the periodic table (Lenard phosphors), respond to radiation in the range $\lambda = 3000$ Å to $\lambda = 4000$ Å, while others, such as the silicates of zinc and cadmium and some of the tungstates and molybdates, respond better to radiation in the neighborhood of $\lambda = 2537$ Å (the resonance line of mercury). In the case of the sulfides as well as the silicates, the fluorescence is observed only if some "activator," such as bismuth or copper in the first case or manganese in the latter, is present. A list of the more commonly used phosphors, as compiled by Fonda, of this laboratory, is given in Table IV.

TABLE IV

Phosphor	Activator	Exciting Range	Radiation Peak	Emitted Range	Fluorescence Peak
Zinc Silicate	Manganese	2200–3000	2530	4600–6000	5100
Cadmium Silicate	Manganese	2200–3200	2530	5200–6500	5900
Calcium Tungstate	Lead	2200–3000	2500–2800	4300–5150	5200
Magnesium Tungstate	Lead	2200–3300	2500–3000	4300–6500	5400
Zinc Sulfide	Copper	2400–4400	3600–4300	4700–6200	5400
Zinc Cadmium Sulfide	Copper	2400–4400	3600–4300	5100–6700	5800–5900

The second column gives the activator, while the other columns give the wavelengths of exciting and emitted radiations.

Fig. 11 shows observations made by Fonda on the excitation and emission spectrum of the zinc silicate. It will be observed that the two spectra are separated by quite a wide interval, which corresponds to about 1.4 electron volts. On the other hand, in the case of Lenard phosphors the maximum wavelength for excitation is adjacent to the minimum wavelength in the emission spectrum.

Furthermore, a large number of organic compounds, such as eosin, fluorescein, and rhodamine *B*, have been found to exhibit fluorescence. The last-named compound emits radiation in the orange-red under the influence of radiations in the near-ultraviolet region, and has therefore been suggested for use with the quartz capillary lamp described previously. In this case the dye is painted on a reflector surrounding the lamp.

During recent years the problem of utilizing fluorescent materials to increase the efficiency of light-sources has received considerable attention. In Germany, M. Pirani and his associates in the labora-

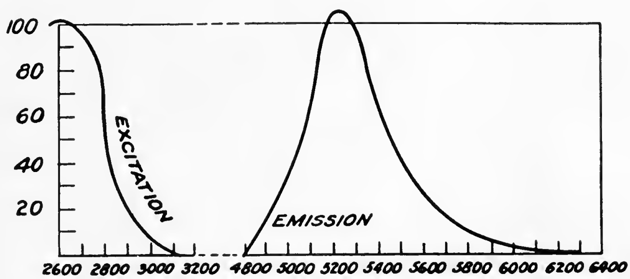


FIG. 11. Excitation and emission ranges of wavelength for activated zinc silicate.

tories of the Osram Company have made notable contributions in this field, and in this country G. Inman of the Incandescent Lamp Division of the General Electric Co., in Cleveland, has recently described a type of fluorescent lamp that is a highly efficient source of light.

A positive-column discharge is passed through mercury vapor at low pressure (corresponding to the vapor pressure at slightly higher than room temperature). This constitutes a very efficient source of the mercury resonance radiation, and, by coating the inside of the discharge tube with a silicate or tungstate, light in the visible range is obtained. The color emitted and the luminous efficiency vary with the composition and mode of preparation of the fluorescent material. Thus, by using a specially prepared zinc silicate, it is possible, according to Inman, to obtain light of a green color at an efficiency of 60 lumens per watt and even higher.

Many of these phosphors, as, for instance, the silicates and sulfides, continue to emit light for a short interval after the exciting source has been removed. This phenomenon is known as phosphorescence, and phosphors that exhibit this effect can be operated on a 60-cycle circuit without any observable flicker.

From the point of view of an interpretation of the mechanism of fluorescence these observations should prove important. While our understanding of these phenomena is very indefinite at the present time, there is no doubt that the whole problem is intimately related to the presence of energy bands and localized levels in crystalline solids. Consequently, we may expect that further investigations will be of material assistance in interpreting the phenomena of fluorescence and phosphorescence in general.

REFERENCES

[1] DUSHMAN, S.: "The Search for High-Efficiency Light-Sources," *J. Opt. Soc. Amer.*, **27** (Jan., 1937), No. 1, p. 1.

[2] FOUND, C. G.: "Fundamental Phenomena in Sodium-Vapor Lamps," *Gen. Elect. Rev.*, **37** (June, 1934), No. 6, p. 269.

[3] FONDA, G. R., AND YOUNG, A. H.: "The A.C. Sodium-Vapor Lamp," *Gen. Elect. Rev.*, **37** (July, 1934), No. 7, p. 331.

[4] FOUND, C. G.: "Fundamentals of Electric Discharge Lamps," *Trans. Illum. Eng. Soc.* (Presented at White Sulphur Springs, W. Va., September 29, 1937).

[5] BUTTOLPH, L. J.: "High-Intensity Mercury and Sodium Arc Lamps," *J. Soc. Mot. Pict. Eng.*, **XXIV** (Feb., 1935), No. 2, p. 110.

[6] RYDE, J. W.: "The Electrical Characteristics of the New 'Osira' Lamp," *Gen. Elect. Co. J.* (England), **4** (Nov., 1933), p. 199.

[7] ST. LOUIS, J. A.: "Characteristics of 400-Watt and 250-Watt Type *H* Mercury Lamps," *Trans. Illum. Eng. Soc.*, **31** (June, 1936), No. 6, p. 583.

[8] ELENBAAS, W.: "Über die mit den wassergekuhlten Quecksilber-Super-Hochdruckrohren erreichbare Leuchtdichte," *Zeit. für techn. Physik*, **17** (Feb., 1935), No. 2, p. 61.

[9] HELLER, G.: "Dynamical Similarity Laws of the Mercury High-Pressure Discharge," *Physics*, **6** (Dec., 1935), No. 12, p. 389.

[10] A similar curve is shown by MARDEN, J. W., BESSE, N. C., AND MEISTER, G.: "Brightness of the Mercury Arc," *Illum, Eng. Soc.* (Presented at White Sulphur Springs, W. Va., September 27, 1937).

PROJECTS OF THE COMMITTEE ON STANDARDIZATION OF THEATER SOUND PROJECTION EQUIPMENT CHARACTERISTICS

OF THE

ACADEMY OF MOTION PICTURE ARTS AND SCIENCES*

JOHN K. HILLIARD, *Chairman*

Summary.—*This report presents the revised specifications of the Research Council's standard electrical characteristics for two-way reproducing systems in theaters, as well as other Research Council standards relating to power reference level, cross-over frequency, output requirements for theaters, and standardization of harmonic content.*

In addition, data on the Research Council standard frequency test-film and theater test-film are presented, as well as specifications for the proposed standard nomenclature for filters.

STANDARD ELECTRICAL CHARACTERISTICS

Since the addition of recorded sound to motion pictures, the major studio sound directors have recognized a need for standardization of theater sound projection equipment in order that there would be a practical uniformity of product from all companies regardless of the theater in which it was reproduced. Uniformity and standardization of sound projection equipment would obviously react beneficially to the entire industry and would make certain that the character and expression put into the film would be reproduced in all theaters meeting the standard conditions.

Recognizing this, the Research Council of the Academy of Motion Picture Arts and Sciences, upon the recommendation of the sound directors, appointed a Committee to undertake a study of the problem of theater sound equipment standardization.

It was realized that one of the first objectives of this project should be the establishment of a standard electrical characteristic to which

* Presented at the Spring, 1937, Meeting at Hollywood, Calif., during a meeting sponsored by the Academy Research Council, May 27, 1937, at Metro-Goldwyn-Mayer Studios; received Aug. 13, 1937.

the equipments of all theaters might be set. After a series of tests and necessary compromises, the Council, upon the recommendation of this Committee, adopted the Standard Electrical Characteristic for two-way reproducing systems in theaters described below as being the most suitable for present conditions.

It has been customary in the past to adjust theater reproducing equipment to satisfy the ears of individual groups. To obtain these results, test tracks of various characteristics made by the separate and many organizations were used. Since the adjustments made with a sound-track from one organization did not always meet with the approval of other organizations, they in turn modified their character-

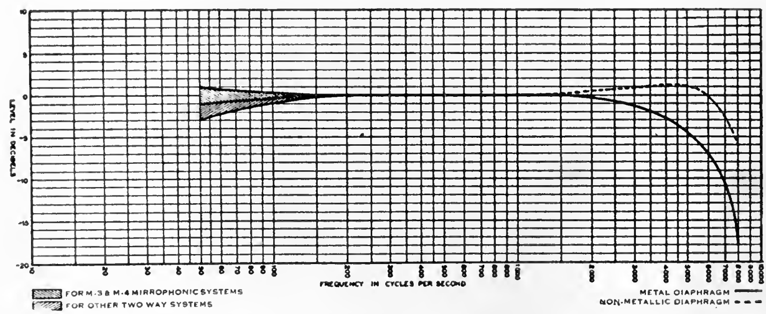


FIG. 1. Research Council standard electrical characteristic for two-way reproducing systems in theaters (June 8, 1937). Electrical run measured at the output of the power amplifier with a response equivalent to the speaker load, using ERPI test-film (*ED-20, corrected*), or RCA test-film (*cat. No. 27637*).

(Curve applying to non-metallic (bakelite) diaphragm supersedes curve in specifications of March 31, 1937. Curve applying to metal diaphragm remains unchanged.)

istic to obtain optimal results from this theater adjustment, which, as a consequence, was ever changing. This practice created a vicious cycle of theater adjustment and studio compensation adjustment. It was finally recognized by those familiar with and responsible for the projection of studio sound recording that this situation was becoming more and more impracticable.

In inaugurating its program, the Committee prepared a test-reel containing a 250-ft. section of release print from each studio, so chosen that the assembled reel contained representative examples of both dialog and music recordings made under average as well as under extreme conditions by each studio sound department.

A series of test runnings was made with this reel at the Carthay Circle Theater in Los Angles, Grauman's Chinese, the Filmarte, Oriental, Pantages, and Warner Brothers' Hollywood Theaters in Hollywood, during which the electrical characteristics of the equipment installed in each of the theaters were varied in order that the Committee might determine an optimal electrical characteristic that would most nearly fit the acoustic characteristics of this group of theaters. These particular theaters were chosen as having divergent characteristics to which a standard might be fitted, the Committee operating upon a premise that a standard that would fit these would, in general, fit at least a majority of the theaters throughout the country.

Fig. 1 shows the electrical characteristics for theaters that have been adopted as standard by the Academy, having been approved by the sound directors of all the major studios, the sound equipment companies, and the Academy Research Council. In the opinion of the Committee, this characteristic will give the best reproduction of the film product from all studios today. It covers a frequency range of 50 to 8000 cps. with reductions in volume at the upper and lower ends of the range. These are necessary to minimize the effects of noise and extraneous signal material introduced mostly in the later links of the recording processes.

As improvements are made and the recording characteristics changed in the studio, similar compensation can be made in all modern theater reproducing systems at little or no cost for additional equipment.

Some of the factors that made it desirable to depart from linearity for the standard electrical characteristics follow:

(*1*) Film and system noise of high-frequency content.

(*2*) High-frequency extraneous noise caused by phase shifts and intermodulated effects. The magnitude of these depends upon the type of light-modulator used.

(*3*) Variable dynamic high-frequency distortion effects caused by the variation in average slit-width due to both signal and noise-reduction components during modulation.

(*4*) Flutter due to improper motion of the film. (This limitation is rapidly being improved with the current change to new sound-heads.)

(*5*) Extremely low-frequency components introduced by the noise-reduction system.

In the early days of the application of noise-reduction systems, efforts were made to improve the reproduced signal-to-noise ratio in the upper part of the frequency range by pre-equalization and post-equalization methods.

As is well known, this consists in the use of equalizers to increase the relative upper-frequency level before the signal is recorded, and the employment of other post-equalizers in the reproducing chain to restore the signal to normal. The results attained, however, were not a definite improvement, because for light-valve operation in the high-frequency range the reproduced volume does not vary in a linear manner with the signal volume applied to the light-modulator. Post-

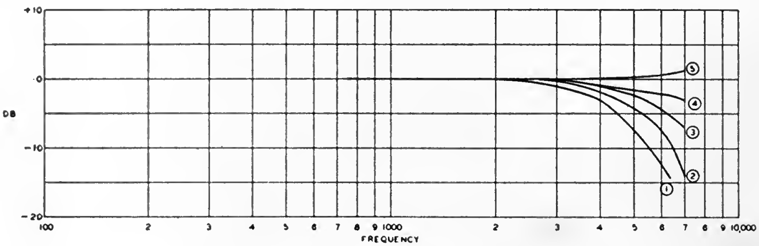


FIG. 2. Loss of high-frequency volume level with increasing modulation, recorded with four-ribbon valve, one-mil spacing, no back stop rectifier in noise-reduction amplifier.

(*1*) Full modulation
(*2*) −6 db. from full modulation
(*3*) −12 db. from full modulation
(*4*) −21 db. from full modulation
(*5*) −30 db. from full modulation.

equalization thus became impracticable because there were required changes in equalization with changes in volume. For the galvanometer type of modulator with either variable-width or variable-density type of recording these non-linear restrictions do not apply, and it may be possible in the future to use pre- and post-equalization with this type of equipment.

Fig. 2 shows the response of a light-valve from full modulation to −30 db. This test was recorded on a four-ribbon push-pull light-valve having a 1-mil fixed spacing, and then biased to a 0.2-mil spacing by the noise-reduction amplifier. The biasing circuit was so arranged that any signal requiring more than 100 per cent modulation would drive the ribbons beyond the normal 1-mil spacing.

This practice causes a wide variation in slit width, which in turn causes a decrease in high-frequency output. When the effect of slit width variation is reduced by decreased ribbon movement, or its equivalent optically, this change in response is decreased at some expense in output level.

The specifications for the standard electrical characteristic discussed above follow:

STANDARD ELECTRICAL CHARACTERISTIC FOR TWO-WAY REPRODUCING SYSTEMS IN THEATERS*

(*Revised specifications superseding specifications of March 31, 1937*)

Systems to Which These Specifications Apply.—The two-way reproducing systems for which this characteristic, indicated below and by the associated curve which is a part of these specifications, is recommended, are:

Type I.—Mirrophonic system using *594-A* mechanisms (loud speaking telephones) (metal diaphragm) and *TA-4181-A* low-frequency mechanisms (loud speaking telephones).

Type II.—RCA system using *MI-1435* (metal diaphragm) and *MI-1432-A* low-frequency mechanisms.

Type III.—RCA Lansing equipped system using *284* (metal diaphragm) and *15X* low-frequency mechanisms.

Type IV.—RCA system using *MI-1428-B* (non-metallic diaphragm) and *MI-1432-A* low-frequency mechanisms.

Measurement Point.—This characteristic is valid for measurements made at the output of the power amplifier, including the low-pass filter, with a resistance equivalent to the speaker load, using the Electrical Research Products, Inc., test-film *ED-20* (corrected),** or the RCA test-film Catalogue No. *27637*, and is subject to modifications to fit special acoustic conditions that no doubt exist in many theaters, due to the fact that the reverberation time or other acoustic characteristics are not optimal.

Gain-Frequency Characteristic.—The following table indicates the characteristic for both the metallic and non-metallic types of diaphragms used on the high-frequency mechanisms:

---

* Reprinted from the *Bulletin* of the Research Council, Academy of Motion Picture Arts and Sciences, June 8, 1937.

** The correction factor, printed on the back of the can in which this test-film is furnished, indicates the deviation from constant percentage modulation for each frequency.

Frequency	Metal Diaphragm Mechanisms	Non-Metallic Diaphragm Mechanisms
50	−1 to − 3*	−1 to −3
100	− 1/2 to − 1**	− 1/2 to −1
200	0	0
1000	0	0
1500	0	0
2000	− 1/4	+ 1/2
3000	− 1 1/4	+1
5000	− 4 1/2	+1
7000	−10 1/2	−2 1/2
8000	−18	−6

Tolerance.—A tolerance of ±1 db. is specified for any of the above gain-frequency measurements.

Acoustic Correction.—Whenever such conditions exist that this characteristic does not give satisfactory results, it is recommended that the acoustic characteristics of the auditorium be corrected.

Mechanism Adjustment.—With the presently available equipment as specified, operating with the standard electrical characteristic, it is necessary in some instances that the sensitivity of the high- and low-frequency bands be relatively adjusted to obtain a flat acoustic response on both sides of the cross-over. This adjustment usually takes the form of attenuating the high-frequency band by means of the taps in the dividing network to varying degrees from 0 to 5 db., depending upon the relative efficiency of both low- and high-frequency units and the specific acoustic properties of the auditorium involved. Typical values are as follows:

ERPI, Mirrophonic system: attenuate the high-frequency band 2 to 4 db.

RCA, *MI-1435* and *MI-1432-A:* attenuate the high-frequency band 0 to 2 db.

RCA, Lansing equipped: attenuate the high-frequency band 0 to 2 db.

RCA, *MI-1428-B*, *MI-1432-A:* attenuate the low-frequency band 0 to 2 db.

Note.—It should be remembered that the type and condition of screen used in the theater will in a measure affect the high-frequency response of the reproducing system.

* For M-3 and M-4 Mirrophonic Systems, 50 Cycles, + 1 to −1.

** For M-3 and M-4 Mirrophonic Systems, 100 Cycles, + 1/2 to − 1/2.

STANDARD POWER REFERENCE LEVEL

During the past few years there have been several standards for reference power level, such as 6, 10, and 12 milliwatts, which fact has led to certain confusion in the interchange of knowledge of equipment.

It has been considered desirable to adopt a single reference standard, which by common agreement has been designated 6 milliwatts, and all organizations have agreed to rate and measure all equipment in terms of this reference.

CROSS-OVER FREQUENCY

The distortion present in a horn is directly proportional to its length, and in the early development of the two-way speaker, effort was made to construct the high-frequency horn as short as possible.

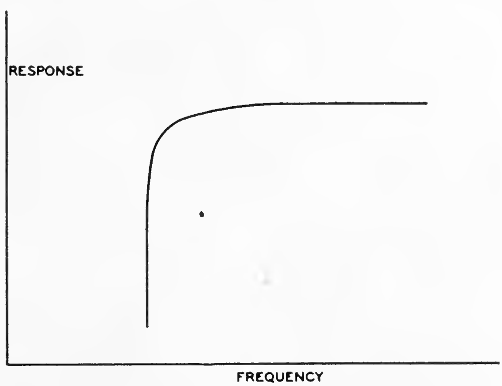


FIG. 3. Horn frequency characteristics.

The theoretical cut-off was taken as approximately 200 cps., and networks were used with a cross-over as low as 250 cps.

However, after continued tests certain distortion was noted, and subsequent tests indicated that a higher cross-over would be desirable, 300 cps. in some, and as high as 400 cps. in other, equipment. Recently further tests have been completed and the results have indicated that a cross-over no lower than 400 cps. will give optimal performance. This is undoubtedly due to the uniform impedance presented by the horn at frequencies above this point, which does not apply to frequencies within an octave of the theoretical cut-off. Fig. 3 shows the change of impedance of a horn near the cut-off frequency.

OUTPUT POWER REQUIREMENTS FOR THEATERS

The use of the wide volume range film that is now being released requires that the theater reproducer have sufficient output capacity and efficiency to reproduce this volume range adequately and without compression.

The history of the reproduction of sound has been one of continual increase in amplifier carrying capacity. Originally output powers from 2.5 to 12 watts were considered adequate for the volume range encountered. Since the studios have found that it is necessary to have at least a 60-db. volume range for future requirements, it has been considered necessary to increase the power-carrying capacity by large amounts. Sound-effects involving screams, earthquake noises, gun shots, and other sounds incident to warfare demand sensation levels considerably higher than those that could be delivered in the past. For that reason, a maximum output level of not less than 90 sensation units is now considered necessary (whereas in the past, amplifier carrying-capacity had been limited to 80 db. above the threshold of hearing).

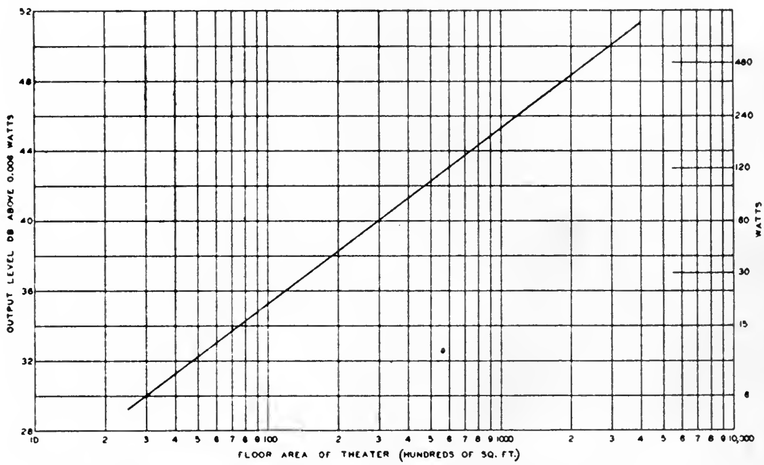


FIG. 4. Amplifier capacity assuming output of one acoustic watt per 1000 sq. ft. of floor area (*RCA*). (*Note.*—The auditorium must be adjusted for optimal reverberation time.) (Two electric watts equal one acoustic watt.)

Accordingly, to obtain a yard-stick to measure the power necessary for a theater when either the floor area or the cubical content is known, Figs. 4 and 5 indicate the installed amplifier capacity necessary to maintain the standard required. Since the required power is a function of the absorption or reverberation in the theater, the curves are based upon a condition of optimal reverberation. In practice, therefore, deviation will be required, depending upon the variation from the optimum.

The optimal reverberation time at 512 cps. is shown for auditoriums of various volumes in Fig. 6. Fig. 7 shows the optimal reverberation times in the frequency range used in recording, for an auditorium of approximately 300,000 cubic feet capacity.

STANDARDIZATION OF HARMONIC CONTENT

With the increase of fidelity of theater reproducing systems it has been found necessary to standardize the load-carrying capacity of an

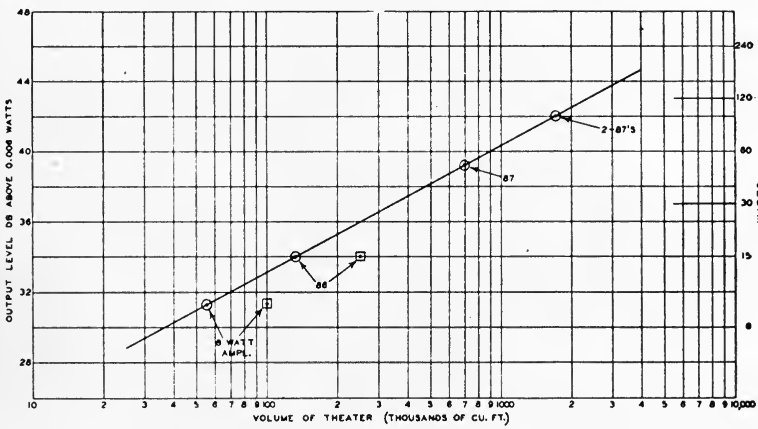


FIG. 5. Installed recommended electric watts/cubical content (*ERPI*).

amplifier. The standardized rating has been taken at that point at which the amplifier introduces 1 per cent third harmonic or 2 per cent total harmonics.

STANDARD FREQUENCY TEST-FILM

The application of the standard electrical characteristic for two-way theater reproducing systems is measured in terms of a standard frequency test-film.

At the time this standardization program was started there were several test-films prepared by various organizations, the use of which required a correlation of their calibration. Before the Committee had gone very far it appeared that the adoption of a new single test-film would be advantageous to all concerned.

A variable-width test track was recorded with one of the latest variable-width recorders using ultraviolet light for recording and printing. This negative was then circulated among several laboratories, and all the prints were measured on a common reproducing channel with known characteristics as shown.

Fig. 8 shows the variation in level for the different frequencies as indicated on a continuous level-recorder (it will be noted that the variation is less than 0.2 db. within any one frequency). Fig. 9 shows the film output from a standard *RA-1010* ERPI recorder, and Fig. 10 shows the response from different laboratories.

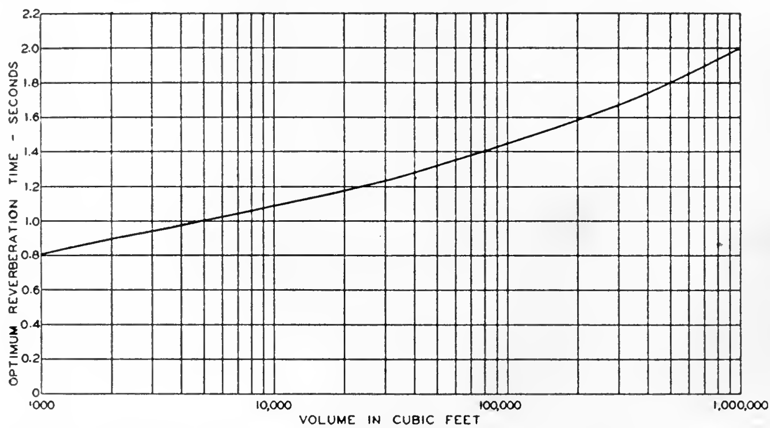


FIG. 6. Optimal reverberation time *vs.* volume in cu. ft. for 512 cps. (*after MacNair*).

A standard warble frequency test-film is also available using 24 test frequencies from 40 to 10,000 cps., having a 5 per cent warble. This film is used to determine the acoustic output of the speaker system. In addition, a warble continuous-sweep test-film from 40 to 10,000 cps. is available.

When this variable-width frequency film (known as Test No. 1775) is used, the following corrections should be applied to the readings obtained.

Cycles	Db.	Cycles	Db.
440	+0.4	1,000	−0.0
80	+0.4	3,000	−0.6
150	+0.2	5,000	−2.4
300	+0.3	7,000	−6.6
375	+0.3	8,000	−6.0
500	+0.1	10,000	−8 2

The plus sign indicates modulation above normal and the negative sign indicates modulation lower than the reference point. With these corrections applied the film becomes equivalent to the ERPI *ED-20* (corrected) or the RCA test-film No. 27637.

THE RESEARCH COUNCIL THEATER TEST-FILM

The original test-film comprising sections of release prints from each studio has been used by the Committee for a period of six months, and changes in recording technic required to fit the standard electrical

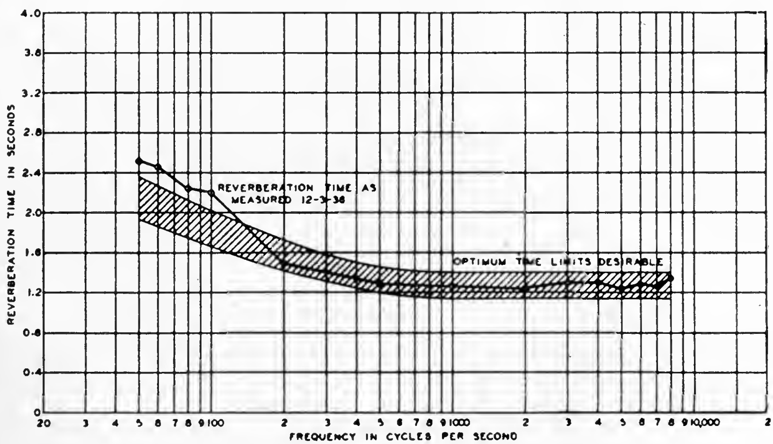


FIG. 7. Optimal reverberation times in the frequency range used in recording, for an auditorium (*Carthay Circle Theater in Los Angeles*) of approximately 300,000 cu. ft.

characteristic have made this particular test-film obsolete and a new one has taken its place.

The Research Council will soon make available to the industry a Movietone test-film containing samples of dialog and music recording from each of the eight major studios, so chosen that the assembled reel will contain representative examples of sound recorded under average as well as under extreme conditions by each studio sound department.

This film will be similar in make-up to the test-film used by the Committee in arriving at the standard electrical characteristic, and will be extremely useful in the field for routine checking and maintenance of adjustment of the theater sound systems.

Prints of the film may be obtained for a nominal fee by sound equipment service companies, theater circuits, and other organizations concerned with the maintenance of sound quality in the theater.*

A PROPOSED STANDARD NOMENCLATURE FOR SOUND FILTERS

In consideration of the confusion arising from the variety of methods by which wave-filters are designated in the field, this Committee recently undertook, as a second step in its program, the standardization of filter nomenclature.

The following quotation from the report of the Committee** prepared for consideration of the Research Council will best describe this portion of the work:

"At the present time there are two general methods for designating filters, neither of which conveys such information as is needed to

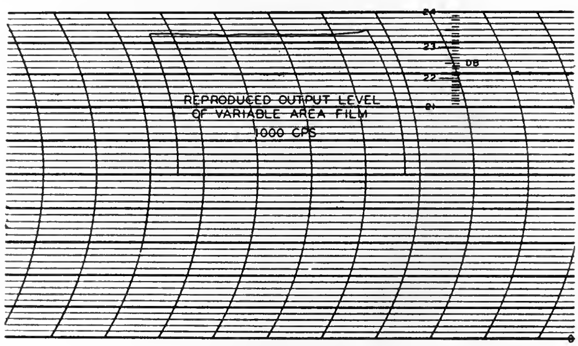


FIG. 8. Variation in level with frequency, of standard frequency test-film, as indicated on continuous level recorder.

establish the filter characteristics, and it was consequently recognized by the Committee that in addition to adopting a standard, any method worked out should convey definite information concerning the limits of the transmission bands.

Since the presentation of this paper, the proposed standard nomenclature for filters has been approved for use in the theater field by

* Since the presentation of this paper, this reel has been completed, and prints are now available. Inquiries should be addressed to the Research Council of the Academy of Motion Picture Arts and Sciences, Suite 1217, Taft Building, Hollywood, Calif.

** Bulletin of the Research Council of the Academy of Motion Picture Arts and Sciences, August 10, 1937.

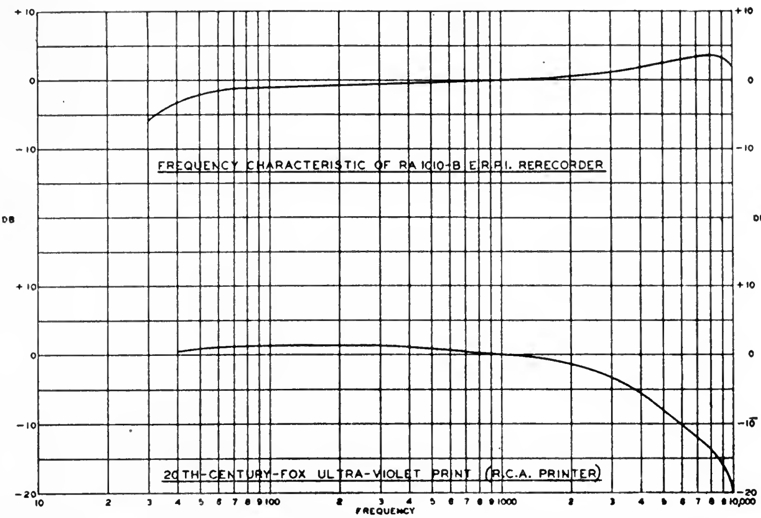


FIG. 9. Reproduced output of standard test-film from *RA-1010* ERPI recorder.

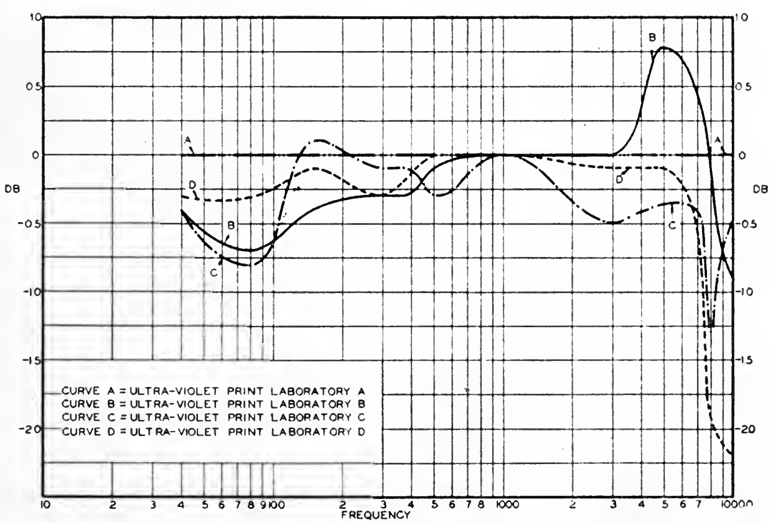


FIG. 10. Response curves of prints of standard test-film made at four laboratories. (*Note.*—The print from laboratory *A* (indicated as flat from 40 to 10,000 cps.) has been arbitrarily chosen as the print to which the others are referred. The chart shows deviations of the other prints from print *A*.)

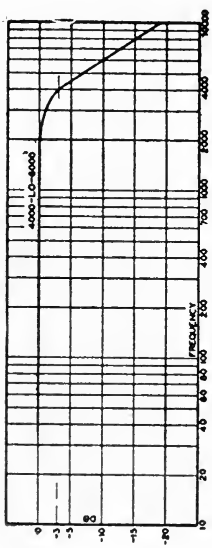


FIG. 11. Low-pass filter.

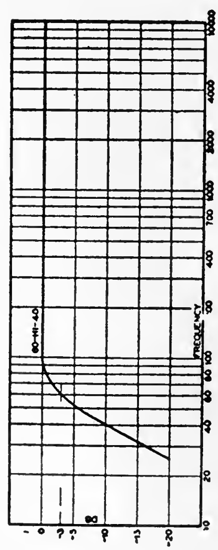


FIG. 12. High-pass filter.

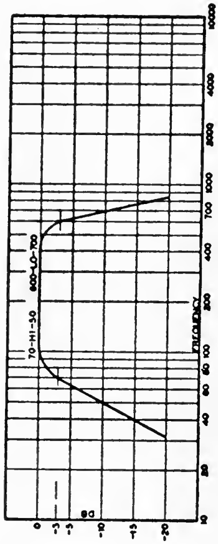


FIG. 13. Band-pass filter.

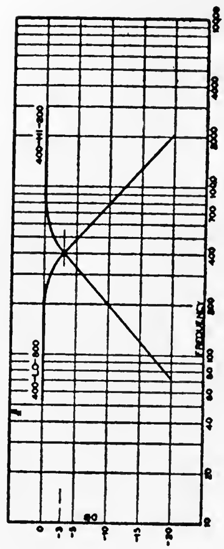


FIG. 14. Dividing network.

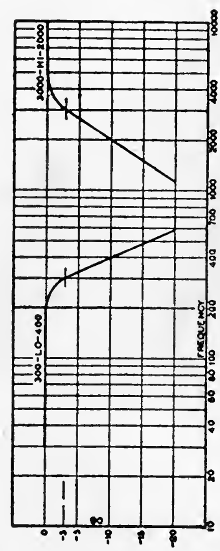


FIG. 15. Band elimination filter.

Electrical Research Products, Inc., the RCA Manufacturing Company, and technical representatives of many of the theater companies coöperating in this standardization program, and for use in sound recording circuits by the sound directors of all the major producing companies; and has subsequently been approved by the Research Council of the Academy of Motion Picture Arts and Sciences as an industry standard effective August 15, 1937.

"Both methods now in use for designating filters employ the frequency that separates the transmission range from the suppression range. For band filters two such separation frequencies are necessary, while for low-pass and high-pass filters only one is needed. Inasmuch as the insertion loss of a filter changes gradually in the cross-over region, the specification of a separation frequency is a matter of definition. The two methods now used differ from each other in their manner of defining these frequencies—one method defines the separation point as the frequency at which a 10-db. insertion loss is obtained, whereas the other method uses theoretical cut-off frequencies.

"Neither of these methods conveys sufficient information regarding the insertion loss characteristic of filters within their transmission band. The 10-db. loss method does not give information as to the manner in which the insertion loss characteristic approaches this point; and the theoretical cut-off frequency method gives no loss information whatsoever, although anyone familiar with the design of filters can visualize roughly the manner in which the change occurs.

"Consequently this Committee recommends that both the methods described above be discarded and that a standard nomenclature for filters, as specified, be used exclusively hereafter:

"*Specification.*—The standard symbol describing any filter shall consist of three characters, the first designating the frequency of 3-db. insertion loss; the second the character *Hi* or *Lo* to indicate high-pass or low-pass; and the third the frequency at 10-db. insertion loss (all frequencies in cycles).

"Thus, the following describes several low-pass filters: *4000 Lo 6000* (Fig. 11); *5000 Lo 7000* or *4500 Lo 5500* and the following describe several high-pass filters: *60 Hi 40* (Fig. 12), *80 Hi 30* or *100 Hi 50*.

"It might be pointed out that a combination of two of the above symbols may be used to describe a band-pass filter (Fig. 13) or a dividing network (Fig. 14), or a reverse combination of symbols may be used to describe a band-elimination filter (Fig. 15)."

JOHN K. HILLIARD, *Chairman*

RECENT DEVELOPMENT IN HILL AND DALE RECORDERS*

L. VIETH AND C. F. WIEBUSCH**

Summary.—*A new sound-on-disk recorder has been developed in which is used the principle of feeding part of the output of the system back to the input of the associated driving amplifier in properly controlled relationship. The use of this principle, which is widely used in feedback amplifiers, replaces the usual practice of providing dissipative elements for the control of an electrically driven vibrating system. Heretofore no practical application of feedback to electromechanical systems has been made, possibly because the requirements for stable operation of such systems are difficult of achievement. Through recent developments these requirements have been satisfactorily met. The new recorder is capable of recording on wax or direct-recording material without appreciable effect upon its characteristics, which include uniform response from 30 to 12,000 cps. and exceptional freedom from distortion. The recorder is extremely simple and affords easy means for field calibration from the feedback element, whose output is in direct proportion to the stylus velocity. These means also make available a monitoring voltage which, properly amplified, gives a precise aural picture of the stylus behavior during recording.*

The successful application of new principles to a design for an electromechanical recorder to be discussed here offers great possibilities in the general treatment of electromechanical transducer problems. In the usual treatment of these problems, resonant and dissipative elements, each carefully controlled within predetermined limits, comprise the vibratory system. The high degree of perfection to which this procedure has been followed in certain types of disk recorder may be judged by the data given previously by H. A. Frederick.[1] The simplicity of the new device, whose individual elements require control only within broad limits, is made possible through the principle of regenerative feedback, an added advantage of which is the reduction of distortion and noise components arising in the recorder and amplifier.

Broadly speaking, feedback may be defined as coupling from the output of an amplifying system to its input. During the early development of high-gain amplifiers, the avoidance of feedback constituted

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received October 1, 1937.

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

a serious problem. The familiar singing or howling was a common and discouraging manifestation of uncontrolled feedback, which was ultimately eliminated by improved shielding and wiring methods. Feedback, properly controlled, found very early uses in oscillating and other forms of regenerative electrical systems. In January, 1932, H. Nyquist[2] published the conditions necessary for stabilizing regenerative circuits and in January, 1934, H. C. Black[3] discussed practical feedback amplifiers in which these conditions were met.

Electromechanical Feedback System.—The theory of a feedback system for an electromechanical device is not unlike that for an amplifier except that the relations must include factors for the electromechanical conversion of energy. Fig. 1 shows diagrammatically a feedback disk recorder-amplifier system. The purpose of the system is to

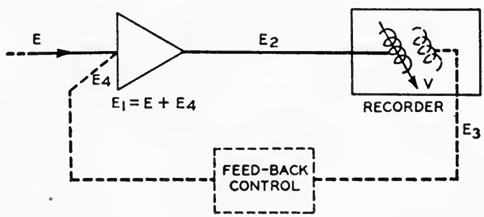


FIG. 1. Schematic representation of an electromechanical feedback system.

move a cutting stylus in a recording medium with a vibrational velocity whose wave-shape is an exact replica of the wave-shape of the signal voltage. The output voltage E_2 of the amplifier is supplied to the terminals of the recorder, thereby driving the stylus with a velocity V. The motion of the stylus in turn generates the voltage E_3 by means of a suitable generating element such as a small coil moving in a magnetic field. This voltage is returned to the amplifier input through a control circuit which may be either passive or active. The voltage available after modification in the control circuit is designated E_4, and adds to the signal voltage E. It must be mentioned that the voltages and velocities here referred to are to be considered as having both magnitude and phase, and hence can be represented in complex number notation. The sum of E and E_4, which is the voltage E_1 actually applied to the amplifier, may be greater or less than the signal voltage E depending upon the phase relation of E and

E_4. If the sum is less than the signal voltage alone, the system is said to have negative feedback; if the sum is greater, it is said to have positive feedback.

To obtain a simple expression for the relation of the stylus velocity V to the signal voltage E, let

$$A = \frac{V}{E_1} = \frac{E_2}{E_1}\frac{V}{E_2} \tag{1}$$

and

$$B = \frac{E_4}{V} = \frac{E_3}{V}\frac{E_4}{E_3} \tag{2}$$

and hence

$$AB = E_4/E_1 \tag{3}$$

The product AB thus defines the transmission around the loop formed by the amplifier, recorder, and feedback control. The value of E_4 from this equation can now be substituted in the relation $E_1 = E + E_4$ to obtain

$$E_1 = E\frac{1}{1 - AB} \tag{4}$$

which, together with equation *1*, gives

$$V = E_1A = E\frac{A}{1 - AB} \tag{5}$$

The factors A and B can be calculated from a knowledge of the elements of the amplifier, the feedback control, and the recorder; or they may be individually measured for an existing structure. Equation *5* permits the calculation of the overall performance of the system; that is, its amplitude *vs.* frequency characteristic and its phase-shift *vs.* frequency characteristic. Several interesting and instructive conclusions may be drawn from the relations just discussed. It is obvious that if, at any frequency, the quantity AB becomes equal to $1 + j0$, the denominator of equation *5* becomes zero and the system will sing or oscillate. Actually the condition for stability is somewhat more complicated than the mere avoidance of an AB product of exactly unity. Nyquist showed that for stable operation of a system such as is here considered, a polar plot of $|AB| \underline{|\theta}$ and its conjugate from zero to infinite frequency must not enclose the point $1 \underline{|0}$. Fig. 2(*a*) is a plot of this factor for a typical stable system, and Fig. 2(*b*) is for a possible unstable one. It is apparent that to minimize the danger of singing, the phase-shift must be kept well within the limits of 180 ± 180 degrees for all frequencies for which there is a transmission gain around the loop, that is $|AB| > 1$.

Of greatest interest, perhaps, is the effect of feedback upon the frequency characteristic. If the feedback is zero, B is zero, and the system will perform as a simple amplifier and recorder. If B is now increased until, over some chosen frequency range, the magnitude of AB is large compared to unity, equation 5 becomes

$$V = \frac{1}{-B} E \qquad (|AB| \gg 1) \tag{6}$$

which indicates that over the frequency range considered the velocity of the stylus is independent of the amplifier gain or the efficiency of the recorder. Variations in B, however, directly affect the perform-

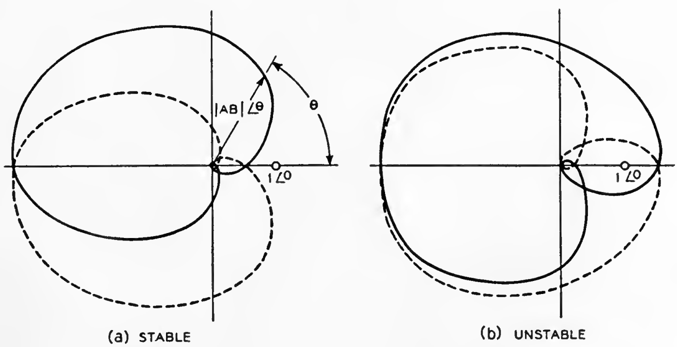


FIG. 2. Typical polar plots of the factor $|AB| \underline{|\theta}$. (*a*) For a stable feedback system. (*b*) For an unstable feedback system.

ance, and hence if a flat frequency response is desired, B must remain constant. However, since B is the product of the mechanical-electrical conversion factor E_3/V and the control factor E_4/E_3 it will be seen that these factors may vary so long as their product remains constant. As indicated later it is a simple matter to maintain the factor E_3/V constant and hence a flat response characteristic depends only upon keeping the control factor constant.

If equation 5 is rewritten to include noise and distortion products as well as signal, it becomes

$$V = E\frac{A}{1 - AB} + \frac{n}{1 - AB} + \frac{d}{1 - AB} \tag{7}$$

where n and d are the noise and distortion, respectively, introduced in the amplifier and recorder without feedback. Hence, when AB is large compared to unity, both the noise and the distortion components are reduced as compared with the corresponding effects in a non-feedback system.

Forces acting upon the stylus during cutting may be regarded as noise or distortion introduced in the recorder and their effect upon the vibrational velocity is also reduced by the above factor. This is equivalent to a manifold increase in the stiffness and massiveness of the moving element.

Requirements for an Electromechanical Feedback System.—From what has been said it will be apparent that the requirements to be met by the feedback amplifier-recorder system in order to realize the foregoing results are:

(*1*) The voltage wave from the feedback generating element, actuated by the stylus velocity, must be the exact replica of the stylus velocity wave.

(*2*) The sum of the phase-shift contributed by the electrical to mechanical to electrical conversion in the recorder, and the phase-shift contributed by the amplifier and that contributed by the feedback control circuit, must be well within the limits for stable operation.

(*3*) The power capacity of the amplifier and of the recorder must at any frequency be sufficient to drive the stylus at the desired velocity.

The third requirement, of course, applies whether or not feedback is involved, and it is desirable from a power economy standpoint to make the electromechanical conversion efficiency as high as possible within the desired frequency range.

Description of Electromechanical Transducer or Recorder.—The first requirement may be met by assuring a rigid connection between the stylus whose velocity is to be controlled and the feedback generating element. A moving-coil generating element and a moving-coil drive suggest themselves as a convenient way of meeting the second or phase-shift requirement. The principal source of phase-shift in such an electromechanical transducer is the mechanical vibrating system itself; that is, the phase relation between driving force and resultant velocity. A singly resonant system offers the most advantageous solution because its inherent phase-shift for frequencies from zero to infinity is only ± 90 degrees. A more complex system obviously would be less desirable from this standpoint. The fulfillment of the third requirement involves well-known principles and will not be discussed.

Fig. 3 is a cross-sectional view of a portion of a recorder that embodies all these features and meets all three requirements. The driving coil is secured at the base of a cone-shaped vibrating element, the restoring force being furnished by a cantilever spring and a diaphragm, which serve also to restrict motion of the stylus to one mode. A second coil, the feedback coil, is secured to the cone near its apex, at which point the stylus is attached. The coils are free to move in annular air-gaps polarized by a common magnet. In the space between the two coils copper shielding is provided to reduce magnetic coupling. The output of the amplifier is supplied to the driving coil and the out-

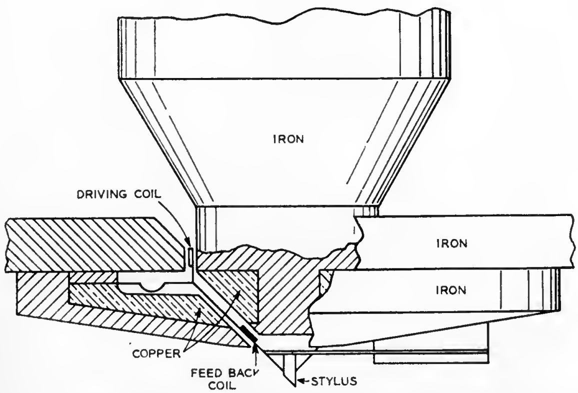


FIG. 3. Cross-sectional view of vibrating system and closely associated magnetic circuit of the feedback recorder.

put of the feedback coil is connected through the control circuit to the input of the amplifier.

In the actual design the device is provided with the usual accessories for disk recording, such as suction pipe, advance ball, *etc.* A photograph of the complete recorder is shown in Fig. 4.

With the recorder properly wired into the system the technic of recording is exactly the same as with non-feedback recording systems. Inasmuch as the feedback system provides a flat response, any desired alteration of the response characteristic may be accomplished by means of electrical equalizers either ahead of the feedback system or in the feedback control circuit.

As shown in Fig. 4 connections to the recorder are made through concentric jacks which terminate the leads from the driving coil and the feedback coil. Concentric wiring is used to avoid coupling between the circuits.

Performance Characteristics.—Curve A, Fig. 5, shows the frequency response characteristic of a laboratory model of the feedback amplifier-recorder system with the feedback circuit opened; *i. e.*, $B = 0$. Curve B shows the same characteristic with proper feedback circuit conditions.

As previously indicated, the load applied at the stylus has but little effect upon the performance of the system as long as the enumerated

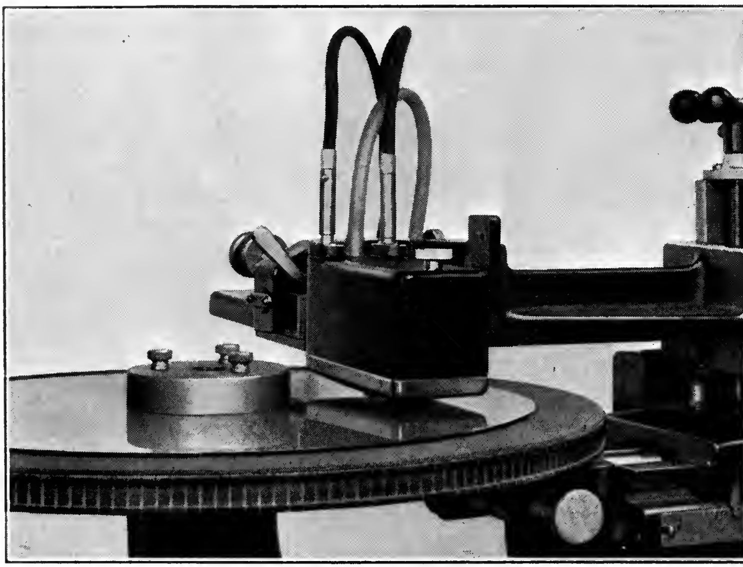


FIG. 4. Feedback recorder in place on a commercial disk-recording machine.

requirements are met. It is therefore interesting to note that the response measured with the stylus cutting a commercial direct recording material is, for practical purposes, identical with that measured with the stylus vibrating in free air.

Since the feedback coil is rigidly coupled to the stylus, the voltage induced by its motion is proportional to the stylus velocity. The feedback voltage, properly amplified, therefore, provides means for easy field calibration of the device and for monitoring purposes.

By virtue of the feedback feature, distortion and noise products created within the system are suppressed by the same amount as fundamentals of the same frequency. A harmonic analysis of the velocity of the stylus at 300 cps. while cutting commercial nitrocellulose direct-recording material showed second and third harmonics 36 and 43 db., respectively, below the fundamental.

The feedback feature of the recorder eliminates the critical elements found in earlier types of recorders, and the problem of careful adjustment and maintenance has been eliminated. The slight variations anticipated in the manufacture of the commercial product have no appreciable effect upon the ultimate characteristics, and, as a result, high uniformity of performance is anticipated.

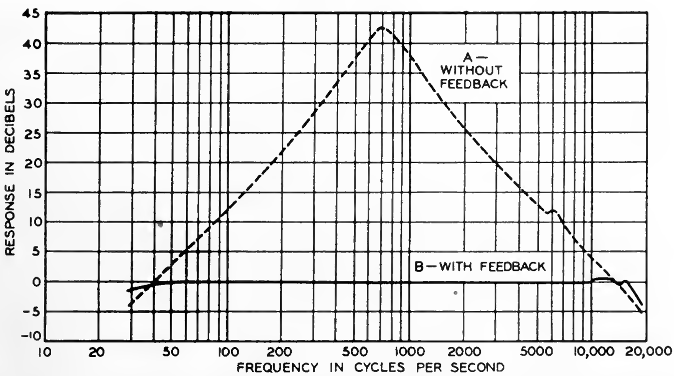


FIG. 5. Curves showing the stylus velocity for a constant signal input to the recorder amplifier system. (*A*) Without feedback. (*B*) With properly controlled feedback.

The device pictured in Fig. 4 has been subjected to an extensive field trial and has met all expectations both as to mechanical reliability and technical performance, and recordings made with it have a tone clarity not always attained with earlier recorders. Judged by the severest standards, the new recorder marks a definite forward step in the art of sound recording and warrants the consideration of the sound recording and reproducing industry.

REFERENCES

[1] FREDERICK, H. A.: "Vertical Sound Records: Recent Fundamental Advances in Mechanical Recordings on 'Wax,'" *J. Soc. Mot. Pict. Eng.*, **XVIII** (Feb., 1932), No. 2, p. 141.

[2] NYQUIST, H.: "Regeneration Theory," *Bell Syst. Tech. J.*, **XI** (Jan., 1932), No. 1, p. 126.

[3] BLACK, H. C.: "Stabilized Feedback Amplifiers," *Bell Syst. Tech. J.*, **XIII** (Jan., 1934), No. 1, p. 1.

DISCUSSION

MR. KELLOGG: How much of the voltage developed in the exploration coil is due to motion and how much to direct induction? Also, what does the voltage due to direct induction, do to the characteristic?

MR. WIEBUSCH: If we depended solely upon the induction, we should get a rather poor characteristic. The voltage due to direct induction must be small compared to the voltage generated due to the velocity, even at frequencies somewhat beyond the range of interest. This is one of the major design problems. At 10,000 cps., the voltage due to direct induction may be 5 or 10 per cent of that due to velocity. In the middle range it is, of course, very small—perhaps a small fraction of one per cent.

METHODS OF BLOOPING*

F. D. WILLIAMS**

Summary.—*A brief outline of a photographic method of "blooping," devised to overcome the disadvantages of the previously used patching methods.*

In the first several months during which sound-track work was done in this laboratory, we became acutely aware that the prevailing methods of "blooping" or silencing the noise made by splicing two pieces of film presented a definite problem. All the conventional methods in use, while partially effective, were not quite satisfactory due to steadily increasing improvements in sound recording and reproducing which tended to magnify the disturbances caused by the splices.

The most common blooping patch in use was the triangular cut-out, which consisted merely in punching out a triangular portion of the negative at the position of the splice. The cut-out is one-half inch wide at the base and approximately one-eighth inch long. Although the "bloop" is reduced by this method, an objectionable sound still remains due particularly to the recent increased use of push-pull track.

The first deviation from the conventional triangular cut-out is what is known as the half-moon bloop, increasing the length to five-eighths of an inch, and thereby improving the reduction of noise. Further improvement is attained by making the triangular shape still longer, this cut-out being three-quarters of an inch in length and intercepting the bias line at a smaller angle.

In our experiments on blooping we discovered that the means of making the cut was as important in reducing the noise as the angle or the shape of the cut-out. A dull knife caused ragged edges on the film, and failure to keep the film flat at the time of cutting adds complications in the way of scratches, scars, *etc.*

---

* Presented at the Spring, 1937, Meeting at Hollywood, Calif.; received June 11, 1937.

** Williams Laboratories, Hollywood, Calif.

A new blooper was built that much more accurately aligned the knife and also included a foot for holding the film firmly during the cutting. The new blade was set at an angle so as to shear the bloop. Although these improvements resulted in a decided reduction of noise, we were still not satisfied with the results.

A more satisfactory method of blooping consists in spraying ink from an air-brush, through a mask, upon the film. The method requires much time and skill in application, and also invariably tends to peel off the film and cause noisy tracks. However, graduating the densities to the bloop, as is done in this method, did eradicate the noise of the splice, so the problem was to create another and satisfactory method of achieving the same results.

The solution of the problem was a *photographic* method of graduating the densities. A light is placed on the printer opposite the back side of the raw stock. The film is notched five inches ahead of the splice, causing the light to flash as the splice passes. The change of thickness of the film at the splice may also be used for flashing the light. The flash causes a fogged spot, similar to the spot produced by the air-brush, resulting in a quiet bloop, and eradicating all possibility of dirt or variation in the size and shape of the area. Furthermore, the speed of the operation has been greatly increased, and the method is simple and consistently accurate.

NEW MOTION PICTURE APPARATUS

During the Conventions of the Society, symposiums on new motion picture apparatus and materials are held in which various manufacturers of equipment describe and demonstrate their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.

A COMBINATION PICTURE AND ULTRAVIOLET NON-SLIP PRINTER*

O. B. DEPUE**

The non-slip principle has been comprehensively discussed by E. W. Kellogg in a previous issue of the JOURNAL.[1] In printers employing this principle the exposure is made while the films are in contact on an idle roller located several inches

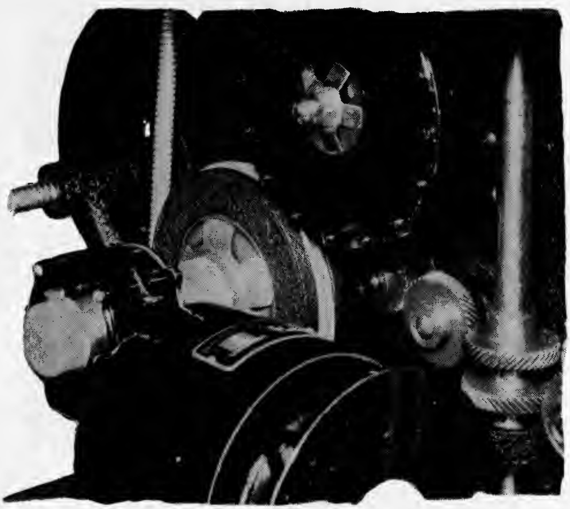


FIG. 1. Friction coupling, through whose action the motors are allowed to come into step.

from the film-driving sprocket. If, instead, printing is done on a sprocket, continual slipping occurs, with consequent detriment to the printed image.

In the earlier Depue continuous printer the film was moved through the two printing stations by sprockets having positive gear drives. Power was supplied

* Presented at the Spring, 1937, Meeting at Hollywood, Calif.; received May 17, 1937.

** O. B. Depue, Inc., Chicago, Ill.

by a $^1/_4$-hp. motor to a speed-reducing worm and gear unit which, in turn, drove the vertical main shaft. The feed, take-up, and printing sprockets were driven from this line shaft by right and left helical gears. The drive was positive and more uniform than one involving the use of a belt, and did not require a flywheel.

About two years ago it was discovered through stroboscopic observation that this drive, previously regarded as satisfactory, was far from perfect. Gear imperfections were found to cause most of the variation in motion, although the clutch and couplings contributed their share.

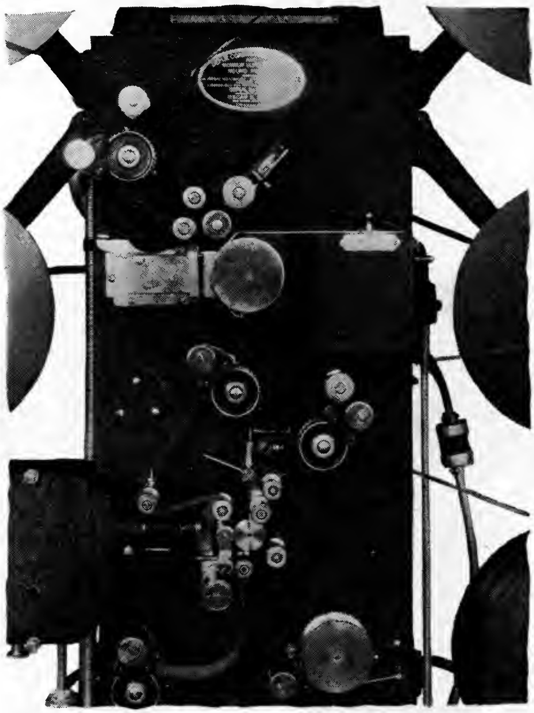


FIG. 2. Front view of printer showing film path.

In the search for constant speed, it was found that a synchronous motor with built-in worm and gear reduction furnished a very steady and accurate drive of the desired speed, and permitted direct coupling to the printing sprocket shaft. This coupling consisted of a rather heavy soft-rubber disk, 5 inches in diameter and $^3/_8$ inch in thickness, between two metal disks one of which was on the motor shaft and one on the sprocket shaft. Thus positive drive was attained with a vibration-absorbing coupling. This direct drive was later applied to the sound-printing unit, and the picture-printing sprocket was driven through a shaft and gearing. The picture sprocket showed the familiar unevenness of motion when viewed with the stroboscope. This arrangement was rejected because it failed to improve both printing drives. In the face of a demand for higher quality work in general, it would not have been sufficient to improve the sound printing only.

Finally, it was concluded that the film must have an independent constant-speed drive for each printing station. In order to maintain synchronism between the two printing sprockets during starting and stopping, it was necessary to provide a linkage between the respective driving units. At first this was attempted by

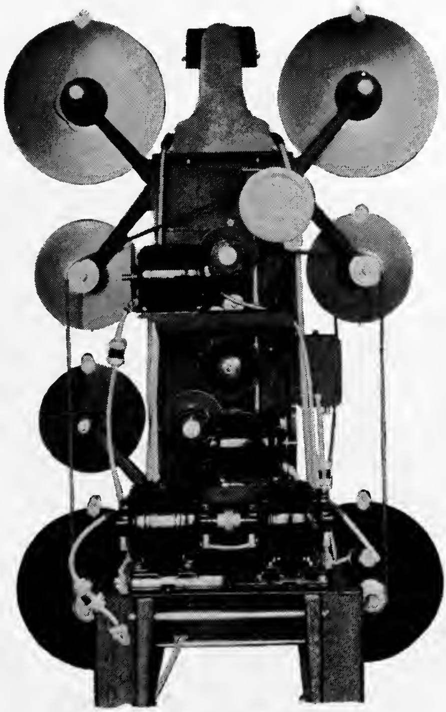


FIG. 3. Rear view of printer.

means of a positive drive connection through gearing. This resulted in intolerable instability of motor performance. With the mechanical connections employed, an angular displacement of the apposite field centers of one motor or the other occurred, with the results that only one motor could run properly at any time. The difficulty was happily cured by fitting to one of the reduction-gear shafts a friction coupling comprising an adjustable spring bronze spider with an adjusting nut and check-nut. This allowed the motors to slip instantly into step, and they remained so throughout the cycle of operation (Fig. 1). The stroboscope showed the device to be thoroughly dependable. It was necessary to limit the tension so as not to defeat the purpose of the coupling, but once adjusted by the nut it required no more attention. The resulting smooth motion of the printing sprockets not only provided higher-quality sound, but an improvement in the picture print as well. Kellogg, in the paper referred to previously, discussed and illustrated the non-slip and ultraviolet illumination features as well as the stabilizer utilized in connection with the picture-printing unit just described.

Figs. 2 and 3 show how the two printing units are located, the picture unit above and the sound below. It is common practice in printing to run the film in the forward direction relative to the subject matter, and to print the picture and sound on the same machine in one run. The resulting position of the sound-track in the printer called for special construction of the optical path of the printing illuminator to allow locating the oil-encased flywheel unit or stabilizer on the back of the main plate. The illuminator optics had to be mounted on the front of the

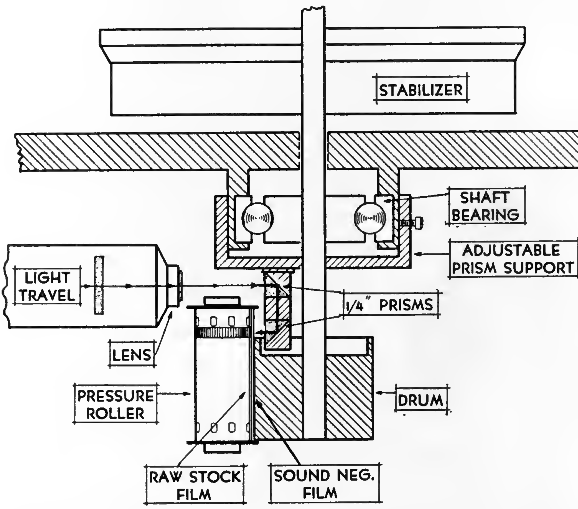


FIG. 4. Diagram of ultraviolet non-slip sound printer.

main plate in such a way as not to interfere with threading (Fig. 2). The illuminating slit image had to reach the negative emulsion at the point of contact with the positive film (Fig. 4) and had to be projected outward from a point near the axis of the constant-speed drum that supported the negative during printing. At this point the positive film was held in contact with the negative by means of a flanged pressure-roller. To meet these requirements the illuminating slit image was formed by two $^1/_4$-inch right-angled prisms on a mounting extending under the overhanging portion of the constant-speed drum. The remainder of the illuminating system lay upon an axis displaced such a distance from the edge of the film as to permit easy threading of the sound printing station drum.

The light-source is a $7^1/_2$-ampere, 10-volt exciter lamp, supplied by a 10-ampere, 10-volt d-c. motor-generator. Lamp voltage is adjusted by means of a 35-ohm circular rheostat in the generator field circuit. The control knob is located on the upper part of the printer, just above the meter.

In the optical system is an adjustable mechanical slit 0.010 inch wide. The Bausch & Lomb objective has a focal length of 32 mm. Light of wavelength longer than the required ultraviolet is filtered out by means of a Corning No. *584* ultraviolet transmitting glass filter, $^5/_8$ inch in diameter and 0.045 inch in thickness. By employing 6.8 amperes with this arrangement of lamp, slit, and prisms, sufficient exposure is obtained for variable-width records. It is possible to use an automatic light-control device in the lamp circuit by utilizing the scene-end switch located in the idler unit of the sound feed-out sprocket at the right and immediately above the printing unit. Lamp life is extended by using less than the full

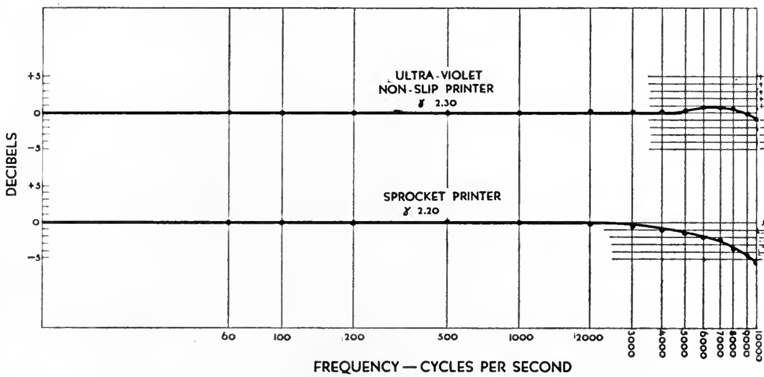


FIG. 5. Overall frequency response of printer.

rated voltage. A 200-watt, 100-volt projection lamp has been employed by at least one user but has developed excessive heat, requiring two forced-ventilation units for cooling. Such a lamp having two vertical filament coils is inefficient for illuminating a horizontal slit.

The overall response characteristic (Fig. 5) obtained with this non-slip printing device and ultraviolet illumination compared to that of the sprocket printer shows that both are uniform up to 3000 cps. Then the characteristic obtained with the sprocket printer falls off approximately 1 db. for each increase of 1000 cps., reaching a total loss of 6 db. at 10,000 cps. The non-slip printer yields a generally straight line except for an increase of 1 db. between 5000 and 9000 cps. (due, possibly, to the recording), followed by a decrease at 10,000 cps. of but slightly more than 1 db. The sprocket-wheel print shown in the chart was made on this same printer, but through an ultraviolet glass 0.045 inch thick.

REFERENCE

[1] KELLOGG, E. W.: "A Review of the Quest for Constant Speed," *J. Soc. Mot. Pict. Eng.*, **XXVIII** (April, 1937), No. 4, p. 337.

CINE KODAK MODEL *E**

L. R. MARTIN**

The primary consideration in the design of the Cine Kodak Model *E* (Fig. 1) was simplicity of operation and control. To obtain this simplicity, a single-plane film path with the supply reel above and ahead of the take-up was adopted. This retains the easy threading of a vertical camera with the added advantage

FIG. 1. Cine Kodak model *E*.

of greater stability (Fig. 2). The resulting form resembles the Cine Kodak Special with the 200-ft. film chamber. One of the principle advantages of this shape is the fact that the camera can be used without interference with the brim of a hat.

The mechanism is built as a unit, with all controls mounted on the mechanism

---

* Received Feb. 18, 1937.

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

frame (Fig. 3). The spring motor, which is wound by a large key, pulls about 18 feet of film per wind at $1^1/_2$ feet per revolution. The rotating disk shutter, with a 165-degree opening, is driven by a pair of spiral bevel gears. The pull-down claw is a single formed steel piece driven by an eccentric and guided by a fixed stud with a cam surface on the claw element. The camera operates at three speeds: 16, 32, and 64 pictures per second, controlled by a variable-speed governor running at 2.4 times the speed of the pull-down. The governor weights act upon the disk through a cam surface, so the relation between the weights and the spring changes automatically and correctly with speed. The camera can be

FIG. 2. View showing magazines and film path.

operated with the trigger half-way down, from which position it will return when released, or the trigger can be locked in the running position to allow the operator to get into the picture.

The lens support, shutter housing, and film-track are combined into a unit, rigidly mounted upon the mechanism frame. This makes it possible to disassemble the camera completely without disturbing the focus or the alignment of the lens. Both aperture plate and pressure pad are relieved to avoid damage to the picture area. The pressure pad withdraws the claw from the film path when it is moved back to admit the film. The pressure pad is easily removable to permit cleaning the gate.

Despite the fact that the camera is in the "inexpensive" price group, the same standards of accuracy at important points are maintained in production as with all other Cine Kodaks. All gear centers are bored and reamed in a single substantial fixture. Gears are generated and checked, shafts are turned to a tolerance of 0.0005 inch and burnished, and mechanisms are "run in" before final timing and checking.

The case contains the finder and film meters. The finder system is built through the case in such a position as to have extremely short parallax. A feature of the camera is the addition of a supplementary film meter scale adjacent to the field of the finder.

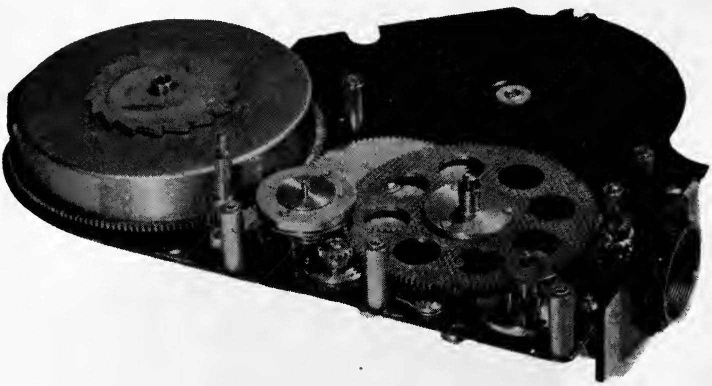


FIG. 3. The mechanism.

Standard equipment is an $f/3.5$ 20-mm. fixed-focus Kodak anastigmat lens in a standard threaded mount. Additional external features are the conventional self-setting film meter, a simplified etched exposure guide, tripod nut, and a carrying handle. A safety guard on the cover prevents closing the camera with the sprocket guards open. The camera can be used on the Cine Kodak titler or on a tripod. Without lens the camera is 8 inches long, $6^3/_4$ inches high, and $2^1/_4$ thick. It weighs approximately 5 pounds when loaded. It will take standard 50- or 100-ft. 16-mm. reels.

AN AMPLIFIER FOR CAMERA BLIMPS *

W. W. BROCKWAY** AND D. C. BROCKWAY†

The use of blimps to house motion picture cameras for making sound pictures places a burden upon the cameraman in that he can not be heard outside the blimp when directing the line-up of a scene. This was realized some years ago, and attempts were made at that time to overcome this obstacle. W. Daniels, cameraman at Metro-Goldwyn-Mayer Studios at that time, mounted an amplifier upon the platform of his rotambulator and placed a microphone inside the blimp.

* Received Oct. 9, 1937.

**Metro-Goldwyn-Mayer Studios, Culver City, Calif.

† Los Angeles City Schools, Los Angeles, Calif.

This enabled the cameraman to direct the placement of lights and establish the movement in the scene without removing his eye from the eyepiece or his head from the blimp.

The amplifier answered the purpose, but obviously was quite bulky, and the need of a well designed amplifier was evident. Analysis of the situation showed the following requirements of such an amplifier:

(*1*) It must operate on 110 volts d-c. or a-c. continuously for twelve hours at a time.

(*2*) It must have adequate power and distribution to cover a whole sound stage.

(*3*) Its frequency range should cover the voice range.

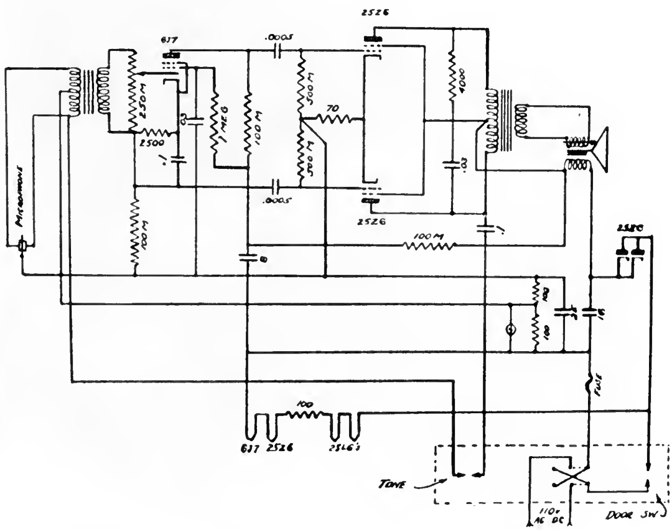


FIG. 1. Circuit diagram of the amplifier.

(*4*) Distortion should be at a minimum.

(*5*) It should have enough gain to operate to the point of feedback when the gain-control is 90 to 100 per cent open and the microphone in the blimp.

(*6*) It should be automatically turned off when the blimp door is closed.

(*7*) A switch should be provided for changing the polarity of the supply voltage at the blimp.

(*8*) Visual means should be available of knowing when the amplifier is ready for operation.

(*9*) A protective fuse should be provided.

(*10*) It should be insulated from ground throughout.

(*11*) Complete operation without batteries should be possible.

(*12*) Adequate filtering should reduce the a-c. hum to a minimum.

(*13*) Extra switch should be provided to enable the amplifier to be operated without the automatic switch.

(*14*) It should be compact, sturdy, and rigid.

(*15*) Single-bracket mounting should be arranged, without interference with light-mounting brackets.

(*16*) Storage space should be available for all cable tied to the amplifier.

(*17*) Automatic switch, reversing polarity switch, and tone switch should be mounted in a convenient position near the blimp door and the operator.

(*18*) The microphone should be insulated.

(*19*) Microphone mounting should be adequate.

(*20*) The design should be standard.

(*21*) It should harmonize with surrounding equipment.

(*22*) It should be accessible for servicing.

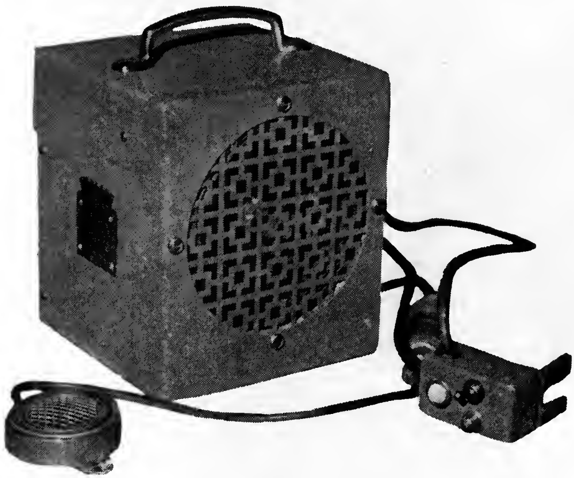


FIG. 2. The complete unit.

The introduction of the *25L6* tube made possible a design of amplifier that could meet in all respects the demands listed above. Fig. 1 shows the circuit used in the amplifier, making use of the cathode phase-inversion circuit using a *6J7* to drive two *25L6's* in push-pull. A *25Z6* single-phase rectifier operating into a condenser input filter is used. The overall gain of the amplifier is sufficient to give full output from the *25L6's* under normal operating conditions when the gain is 75 per cent open. The point of feedback is usually reached when the gain is totally on and the microphone is in position in the blimp. No more gain is needed, and it was found that the annoyance factor is practically minimized by providing only sufficient gain to eliminate feedback at all times. The circuit harmonic distortion is less than 5 per cent. The acoustical characteristics have some distortion due to cabinet resonance, but the distortion is not objectionable;

in fact, it gives to the output a character that enables the amplifier to be heard over normal production noises.

A six-inch dynamic speaker provides adequate coverage for the average set. Screened openings in the back of the cabinet allow for some sound distribution behind the camera as well as serving for ventilation of the unit.

The unit is operated completely on a 110-volt d-c. or a-c. circuit. The current is fed through a switch that turns on the amplifier when the blimp door is open. A polarity reversing switch enables the cameraman to change the supply polarity at the blimp when operated by direct current. A switch operating a buzzer or feedback circuit producing an amplified tone in the speaker is also built into the switch-box. The tone is used to attract attention upon the set when the cameraman has completed his work. This type of signal has been found to reduce confusion upon the set and to save production time.

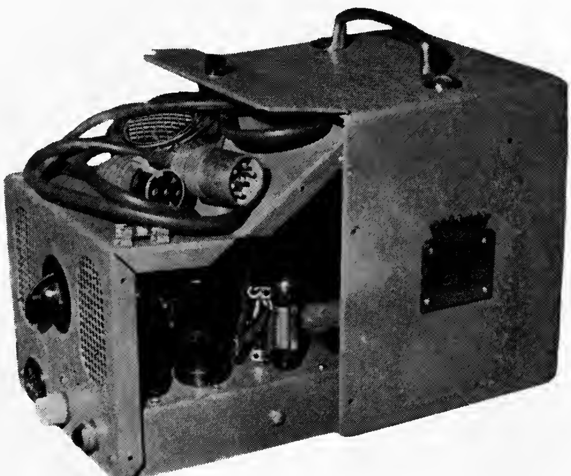


FIG. 3. Cabinet and chassis, opened.

A pilot-light is operated from the rectified current, and is used to notify the operator when the unit is operating and when the d-c. supply is properly polarized. Due to the fact that a separate voltage is supplied to the blimp to operate the camera, and in some cases one side of this camera supply voltage is grounded, it is necessary to insulate the amplifier and all other parts carefully.

Sometimes the amplifier unit is used with silent shots. In such cases the blimp may not be used and an additional switch is then used with the amplifier.

The two-button carbon microphone is suspended from the camera eyepiece, conveniently located for the cameraman when looking through the lens.

The cabinet and chassis are made of a 20-gauge body steel with reinforced corners, and is $6^1/_2$ inches square and 7 inches high. A compartment to hold the cables and microphone is built in the upper part of the cabinet. All resistors and condensers are mounted rigidly upon a strip of formica. A volume control, fuse holder, pilot light, and a four-prong adapter are mounted upon the rear panel below the cable compartment. A metal grill protects the loud speaker on the front end of the cabinet. A single socket to receive a $^1/_4$ inch by 1 inch iron bracket is used to hold the amplifier alongside the blimp. The cabinet and switch-box are finished in gray crackle paint with chrome hardware. Access to the tubes and inside the cabinet is accomplished by removing the rear panel and chassis. Sheet metal screws hold the panel and chassis in place.

The number of different kinds of blimps in use makes it difficult to standardize upon the switching and mounting methods. It has been found that in most major studios there is enough standardization of camera equipment to design a switch-box and mounting bracket for these studios and use standardized amplifier units in all cases.

Cameramen have estimated that from forty-five minutes to an hour and a half a day are saved in production time by these camera amplifiers. Directors have remarked that less confusion and noise is experienced upon the set due to the fact that the cameraman's instructions can be heard without repetition or excessive shouting.

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 copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in those magazines that are available may be obtained from the Library of the U. S. Department of Agriculture, Washington, D. C.

American Cinematographer

18 (Sept., 1937), No. 9

Reaction on Making His First Color Production (p. 408).	J. W. Howe
Cinematography with 8-Mm. Cameras Aid in Dentistry (p. 426).	H. A. Linek
Three-Lens Turret Built for 8-Mm. Users (p. 429).	
Automatic Development and Its Advantages (p. 435).	

Bell Laboratories Record

16 (Oct., 1937), No. 2

Diphonic Loud Speaker for Mirrophonic Sound Systems (p. 53).	R. C. Miner
Limitations in High-Frequency Band-Filter Design (p. 56).	C. E. Lane

Communications

17 (Oct., 1937), No. 10

Television Economics (p. 10).	A. N. Goldsmith
Linear Amplifier Adjustments (p. 11).	A. J. Ebel
A Simplified Theory of Filter Selectivity (p. 12).	H. Dudley
Disk Recording—Equipment and Its Quality Requirements (p. 17).	T. L. Dowey
Plate Resistance Control in Vacuum Tubes as Audio Gain Control Means (p. 23).	A. W. Barber

Educational Screen

16 (Oct., 1937), No. 8

The Motion Picture as an Aid to Learning (p. 252)	W. M. Gregory

Electronics

10 (Oct., 1937), No. 10

Scanning in Television Receivers (p. 18).	F. J. Somers
Quality in Disk Reproduction (p. 25).	C. J. LeBel
Reactance Amplifiers (p. 28).	
Television in Great Britain (p. 32).	H. M. Lewis and A. V. Loughren

Filmtechnik

13 (Oct., 1937), No. 14

Regelschnellschreiber, ein neues Messgerat (Regel Rapid Recorder, a New Measuring Device) (p. 161). — P. HATSCHEK

Fernseh-Filmabtastgerat (Television Scanner) (p. 163). — SCHRIEWER

Instruments

10 (Oct., 1937), No. 10

Commercial Cathode-Ray Tubes (p. 267) — R. R. BATCHER

International Photographer

9 (Oct., 1937), No. 9

Light Meters and Color (p. 11). — T. S. CURTIS

Superpan and Infrared (p. 14). — H. MEYER

Ready Playback Recordings (p. 36). — J. N. A. HAWKINS,

Albin Indicator (p. 37).

International Projectionist

12 (Oct., 1937), No. 10

An Analysis of Imperfections Apparent on the Screen (p. 7). — A. C. SCHROEDER

More Data on the W. E. Mirrophonic Speaker System (p. 20). — R. C. MINER

Typical Troubles in Modern Sound Reproducing Units (p. 24). — L. CHADBOURNE

Journal of the Acoustical Society of America

9 (Oct., 1937), No. 2

Factors in the Production of Aural Harmonics and Combination Tones (p. 107). — E. B. NEWMAN, S. S. STEVENS AND H. DAVIS

A New Interpretation of the Results of Experiments on the Differential Pitch Sensitivity of the Ear (p. 129). — W. E. KOCK

A Method for Evaluating Compliant Materials in Terms of Their Ability to Isolate Vibrations (p. 141). — W. JACK AND J. S. PARKINSON

Various Types of Absolute Pitch (p. 146). — A. BACHEM

A Direct-Reading Pitch Recorder and Its Applications to Music and Speech (p. 156). — J. OBATA AND R. KOBAYASHI

Sound-Waves in a Moving Medium (p. 162). — J. D. TRIMMER

Journal of the Optical Society of America

27 (Oct., 1937), No. 10

Orthostereoscopy (p. 323). — H. F. KURTZ

An Examination of the Principles of Orthostereoscopic Photomicrography and Some Applications (p. 340). — L. C. MARTIN AND T. R. WILKINS

Journal of Scientific Instruments

14 (Oct., 1937), No. 10

High-Gain Low-Frequency Amplifiers (p. 325). A. F. RAWDON-SMITH

A Note on the Calibration of Audio-Frequency Oscillators (p. 339). N. F. ASTBURY

Kinotechnik

19 (Sept., 1937), No. 10

Die Eurocord-Optik (Eurocord Optics) (p. 226). K. SCHWARZ

Die Photographie im Dienste der Dokumentation (Photography in Documentation Service) (p. 229). O. FRANK

Über widerstandslosen Bogenlampenbetrieb (Low Resistance Arc Lamp Operation) (p. 230). H. TUMMEL

Der Lautstarkenumfang der Eurocord-Schrift (Sound-Intensity Range of the Eurocord Recorder) (p. 232). H. WOHLRAB

Motion Picture Herald (Better Theaters Section)

129 (Oct. 16, 1937), No. 3

Theatre Acoustics Today (6. Mounting and Decorating Acoustic Materials) (p. 61). C. C. POTWIN

Proceedings of the Institute of Radio Engineers

25 (Nov., 1937), No.11

A Low-Distortion Audio-Frequency Oscillator (p. 1387). H. J. REICH

Review of Scientific Instruments

8 (Oct., 1937), No. 10

Two Simplified Technics for Synchronized X-Ray, Sound Recording, and Cathode-Ray Oscillographic Studies of Speech (p. 382). R. CURRY

SPRING, 1938, CONVENTION

WARDMAN PARK HOTEL
WASHINGTON, D. C.
APRIL 25th–28th, INCLUSIVE

Officers and Committees in Charge

W. C. Kunzmann, *Convention Vice-President*
J. I. Crabtree, *Editorial Vice-President*
G. E. Matthews, *Chairman, Papers Committee*
W. Whitmore, *Chairman, Publicity Committee*
E. R. Geib, *Chairman, Membership Committee*

Local Arrangements and Reception Committee

N. D. Golden, *Chairman*

D. Bennett
J. G. Bradley
H. T. Cowling
A. A. DeTitta
R. Evans
N. Glasser
C. L. Gregory
N. C. Haefele
A. Muto
R. F. Nicholson
W. K. Pettus
J. A. Pratt
R. T. Schlosberg
C. S. Stodter

Registration and Information

W. C. Kunzmann, *Chairman*

E. R. Geib
S. Harris
F. Hohmeister

Ladies' Reception Committee

Mrs. R. Evans, *Hostess*
assisted by

Mr. J. G. Bradley
Mrs. H. T. Cowling
Mrs. A. A. DeTitta
Mrs. N. Glasser
Mrs. N. D. Golden
Mrs. S. B. Riddick
Mrs. N. C. Haefele
Mrs. A. Muto
Mrs. J. A. Pratt

Banquet Committee

R. Evans, *Chairman*

J. G. Bradley
H. T. Cowling
A. A. DeTitta
N. Glasser
N. D. Golden
N. C. Haefele
W. C. Kunzmann
A. Muto

Publicity Committee

W. Whitmore, *Chairman*

J. R. Cameron
A. A. DeTitta
J. J. Finn
S. Harris
F. Hearon
G. E. Matthews
P. A. McGuire
A. Muto
F. H. Richardson

Convention Projection Committee

H. GRIFFIN, *Chairman*

N. C. HAEFELE — W. K. PETTUS — J. A. PRATT
W. HOLTZ — F. J. STORTY

Officers and Members of Washington Projectionist Local 224.

Membership Committee

E. R. GEIB, *Chairman*

J. G. BRADLEY — S. HARRIS
R. EVANS — J. A. PRATT

Hotel and Transportation Committee

J. G. BRADLEY, *Chairman*

D. BENNETT — C. A. LINDSTROM — R. T. SCHLOSBERG
F. HEARON — R. F. NICHOLSON — C. S. STODTER

Headquarters

The headquarters of the Convention will be the Wardman Park Hotel, where excellent accommodations are assured. A reception suite will be provided for the ladies, for whom also is to be arranged an interesting program of entertainment.

The following daily hotel rates, European plan, are guaranteed to SMPE delegates attending the Convention:

One person, room and bath	$ 3.50
Two persons, standard bed	5.00
Two persons, twin beds	5.00
Parlor suite, one person	9.00
Parlor suite, two persons	11.00

Room reservation cards will be mailed to the membership of the Society in the near future, and those who plan to attend the Spring Convention should return their cards promptly to the Wardman Park Hotel to be assured satisfactory accommodations. Local railroad ticket agents should be consulted with regard to trains and rates.

Technical Sessions

An attractive and interesting program of technical papers is being assembled by the Papers Committee. All technical sessions, apparatus symposiums, and film programs will be held in the *Little Theatre* of the Hotel.

Registration and Information

The Convention registration headquarters will be located at the entrance of the *Little Theatre,* where all the technical sessions will be held. The members of the Society and guests attending the Convention are expected to register and receive their badges and identification cards for admittance to special evening sessions. These cards will also be honored at several *de luxe* motion picture theaters in Washington during the four days of the Convention.

Informal Luncheon and Semi-Annual Banquet

The usual informal Luncheon will be held at noon of the opening day of the Convention, April 25th, in the Continental Room of the Hotel. On the evening of Wednesday, April 27th, will be held the Semi-Annual Banquet of the Society, in the Continental Room of the Hotel at 7:30 P.M. Addresses will be delivered by prominent members of the industry, followed by dancing and other entertainment.

Points of Interest

To list all the points of interest in and about Washington would require too much space, but among them may be mentioned the various governmental buildings, such as the Capitol, the White House, Library of Congress, Department of Commerce, U. S. Treasury, U. S. Bureau of Standards, Department of Justice, Archives Building; and other institutions such as the National Academy of Sciences, the Smithsonian Institution, George Washington University, Washington Cathedral, Georgetown University, *etc.* In addition may be included the Lincoln Memorial, the Washington Monument, Rock Creek Park, The Francis Scott Key Memorial Bridge, Arlington Memorial Bridge, the Potomac River, and Tidal Basin. Mt. Vernon, birthplace of Washington, is but a short distance away and many other side trips may be made conveniently *via* the many highways radiating from Washington.

Recreation

The Wardman Park Hotel management is arranging for golfing privileges for SMPE delegates at several courses in the neighborhood. Regulation tennis courts are located upon the Hotel property, and riding stables are within a short distance of the Hotel. Trips may be arranged to the many points of interest in and about Washington.

SOCIETY ANNOUNCEMENTS

OFFICERS AND MANAGERS OF THE SECTIONS

As a result of the recent elections, the Officers and Managers of the three Local Sections of the Society for the year 1938 are as follows:

Atlantic Coast Section

*G. FRIEDL, JR., *Chairman*

L. W. DAVEE, *Past-Chairman*	*H. GRIFFIN, *Manager*
*D. E. HYNDMAN, *Sec.-Treas.*	**P. J. LARSEN, *Manager*

Mid-West Section

*S. A. LUKES, *Chairman*

C. H. STONE, *Past-Chairman*	*B. E. STECHBART, *Manager*
*A. SHAPIRO, *Sec.-Treas.*	**G. W. BAKER, *Manager*

Pacific Coast Section

*J. O. AALBERG, *Chairman*

K. F. MORGAN, *Past-Chairman*	*H. W. MOYSE, *Manager*
*G. A. CHAMBERS, *Sec.-Treas.*	**C. W. HANDLEY, *Manager*

ATLANTIC COAST SECTION

At a meeting held at the Studios of RCA Photophone, Inc., 411 Fifth Ave., New York, N. Y., on December 8th, a paper was presented by Mr. P. Arnold of the Agfa Ansco Corp., Binghamton, N. Y., entitled "Agfa Ultra-Speed Panchromatic Negative." Following the technical presentation several reels of film were projected, showing the photographic results attained with the new ultra-speed film as compared with shots made on the super-pan.

About 250 persons attended the meeting and considerable interest in the subject was shown by the extended discussion following the presentation.

MID-WEST SECTION

Messrs. M. Townsley, L. B. Hoffman, and P. Foote, all of the Bell & Howell Engineering Laboratory, were the participants in a symposium on the subject of "High-Speed Photography," held on December 16th in the auditorium of the Bell & Howell Engineering Laboratory, Chicago.

The presentations were accompanied by motion pictures demonstrating the application of high-speed photography to the design and manufacture of appa-

* Term expires December 31, 1938.

** Term expires December 31, 1939.

ratus in engineering and commercial fields. The Bell Telephone Laboratory film, shown at the recent New York Convention by W. Herriott, was also included.

The next meeting of the Section will be held on Tuesday, January 11, 1938.

PACIFIC COAST SECTION

Four outstanding papers delivered at the recent Fall Convention of the Society in New York, selected as of particular interest to members in the Hollywood area, formed the program of the meeting of the Pacific Coast Section, held on December 9th at the Sunset Arbor Cafe Auditorium in Hollywood. The four papers were:

"Film Perforation and 96-Cycle Frequency Modulation in Sound-on-Film," by J. Crabtree and W. Herriott, Bell Telephone Laboratories, New York, N. Y.

"High-Speed Motion Picture Photography Applied to Design of Telephone Apparatus," by W. Herriott, Bell Telephone Laboratories, New York, N. Y.

"Modulated High-Frequency Recording as a Means of Determining Conditions for Optimal Processing," by J. O. Baker and D. H. Robinson, RCA Manufacturing Co., Camden, N. J.

"Reduction of Loop-Length Variations in Non-Slip Printers," E. W. Kellogg, RCA Manufacturing Co., Camden, N. J.

The meeting was well attended and considerable interest was shown in the presentation. The papers were read by several members of the Section.

ADMISSIONS COMMITTEE

At a recent meeting of the Admissions Committee, at the General Office of the Society, the following applicants for membership were admitted to the Associate grade:

DORN, H. P.
9007 Detroit Ave.,
Cleveland, Ohio.

FELSINGER, H.
973 Dumont Ave.,
Brooklyn, N. Y.

FLEMM, C. J.
556 Chelton Ave.,
Camden, N. J.

GOGTAY, R. L.
Indian Motion Picture
Producers' Assn.,
Bombay, India.

GOLDBERG, M. S.
1028 New York Ave.,
Brooklyn, N. Y.

HOPKINSON, K.
9 Kenilworth St.,
New South Wales,
Australia.

KAY, H.
1075 Grand Concourse,
Bronx, N. Y.

KEINIGSBERG, L.
5141 Ellis Ave.,
Chicago, Ill.

KLEINERMAN, B.
630 Ninth Ave.,
New York, N. Y.

KOSSOWSKY, A.
RCA Victor Co.,
Buenos Aires, Argentina.

LERNER, I.
Progressive Education Assn
1600 Broadway,
New York, N. Y.

MOTELOW, H. J.
653 Hendrix St.,
Brooklyn, N. Y.

RYAN, C. S.
Core Cinesound Productions, Ltd.,
New South Wales,
Australia.

SANSONE, M.
3440 Fish Ave.,
Bronx, N. Y.

SCHLESSINGER, I.
1931 E. 47th St.,
Brooklyn, N. Y.

SCHWEND, F. N.
Warner Bros. Pictures,
Burbank, Calif.

SZMETAN, A.
Banc of Boston,
Buenos Aires, Argentina.

TERHUNE, H. J.
Sea Island Beach,
P. O. Box 876,
Georgia.

THOMAS, R. C.
Sydney,
New South Wales, Australia.

VIDAL, J.
7655 Sunset Blvd.,
Hollywood, Calif.

WEIDNER, J. H.
33 Cooper St.,
Brooklyn, N. Y.

In addition, the following applicants have been transferred by vote of the Board of Governors to the Fellow and Active grades:

FRIEDL, G., JR. (*F*)
25 Hunter Ave.,
Fanwood, N. J.

KELLOGG, E. W. (*F*)
RCA Manufacturing Co., Inc.
Camden, N. J.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXX FEBRUARY, 1938 Number 2

CONTENTS

JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

Subscription to non-members, $8.00 per annum; to members, $5.00 per annum, included in their annual membership dues; single copies, $1.00. A discount on subscriptions or single copies of 15 per cent is allowed to accredited agencies. Order from the Society of Motion Picture Engineers, Inc., 20th and Northampton Sts., Easton, Pa., or Hotel Pennsylvania, New York, N. Y.

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

Publication Office, 20th & Northampton Sts., Easton, Pa.

General and Editorial Office, Hotel Pennsylvania, New York, N. Y.

West-Coast Office, Suite 226, Equitable Bldg., Hollywood, Calif.

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

DEMONSTRATION OF STEREOPHONIC RECORDING WITH MOTION PICTURES*

J. P. MAXFIELD**

Summary.—*As one of the events of the Fall, 1937, Convention at New York, N.Y., a demonstration of stereophonic sound with pictures was given in the auditorium of the Bell Telephone Laboratories. A special motion picture had been shot and recorded with twin sound-tracks, which were reproduced through separate channels by loud speakers located at the sides of the screen. So far as is known, this was the first public demonstration of stereophonic sound in conjunction with motion pictures.*

Sound motion pictures, as presented today, are equipped with a single source of sound, a loud speaker usually placed centrally behind the screen. There is therefore no acoustic illusion of sound movement from one side of the screen to the other. As a result, our eyes have been trained to "pull" the sound the necessary distance sidewise, to make it appear to come from the visual image of its source. With stereophonic recording and reproducing, this mental strain is relieved, since the sound, of its own accord, moves back and forth across the screen to follow the image of its source.

Stereophonic reproduction implies a localization of the apparent sound-source in both a sidewise and a fore-and-aft direction. This localization has been thoroughly accomplished. An unexpected accompaniment to this localization is a marked improvement in the quality and in the sense of reality of the sound that is heard. From a commercial standpoint, the latter property is at least as important as the first. It is the one that is almost always commented upon by members of the general public, since their eyes have always helped them to obtain some apparent motion of the sound.

In the demonstration presented here tonight, one should pay particular attention to the location of the apparent points, at or back of the screen, from which the various sounds appear to come, and should

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received October 11, 1937.

** Electrical Research Products, Inc., New York, N. Y.

coördinate these points with the positions of the picture image from which the sounds are supposed to come.

The illusion of position is very strong, and it is therefore necessary to correlate very carefully the apparent acoustic position with the visual image's actual position.

In the early days of the development of this method, recording technics were not used, and the correlation between sound location and visual image was obtained by the use of pantomime artists on a real stage. A very amusing and almost ghostly effect was attained by having the pantomimer walk in a direction other than that in which the sound was moving. As the pantomimer got a little out of position, a very uncomfortable effect was produced, and suddenly the sound seemed to jump away from the pantomimer and follow its own course, leaving the pantomimer silent and useless.

One can probably best appreciate the possibilities of this method by actually seeing and hearing a demonstration. The reel to be shown has been produced purely as an experiment, and is designed to show the engineering possibilities of stereophonics. We believe that these possibilities are so well demonstrated that those who are skilled in the arts will see the dramatic possibilities also.

This development of stereophonic recording has formed a natural part of the general developmental work carried on for the purpose of improving the quality of talking pictures. Whether or not it will ever be adopted by the motion picture industry depends upon the motion picture producers. It is certain, however, that to obtain the full, ultimate illusion of reality it will be necessary to combine with a colored stereoscopic picture, stereophonic sound.

At the close of these remarks by Mr. Maxfield, a specially produced motion picture, with stereophonic recording, was projected and reproduced. The recording had been done with a four-ribbon light-valve, one pair of ribbons being actuated by current from the microphone at one side of the stage and the other pair by current from the microphone at the opposite side of the stage. The sound-tracks look somewhat like the tracks of the push-pull track, except that they are not recorded 180 degrees out of phase. The loud speakers were located behind the mask at either side of the center.

The purpose of the picture was to afford opportunity for the spectators to localize the sounds being reproduced and to correlate the apparent sources of the sound with the images of the actors supposed to produce them. The first scene of the picture showed an orchestra of 40 or 50 players, the strings, brasses, tympani, *etc.*, being located in the usual places. The nature of the musical selection was such as to permit noting from what part of the orchestra the sounds of the various instruments emanated. Among other effects the clashing of the cymbals was particularly noticeable as apparently arising from the upper left-hand corner of the screen, where the image of the performer playing them was located.

The next scene of the picture showed two men playing a game of table-tennis, or ping-pong. It was interesting to note how the sound of the impact of the ball upon the table travelled back and forth across the screen with the image of the ball. At one point, when the ball bounced from the table to the floor, the sounds of the successive impacts of the ball upon the floor could be followed as the ball bounced out of the picture. Conversation between the players at the same time demonstrated the manner in which the reproduction of the voices would seem to jump from one side of the screen to the other.

The third scene of the picture started out with a black, or nearly black screen, the inside of a room at night, with the lights turned out. The sounds of an actor cautiously entering the room were heard; his collisions with furniture in the darkened room and his conversation with a companion could be heard as if the sounds were emanating from various portions of the screen as the actors moved about. Toward the end of the scene another actor entered the room and turned on the lights, permitting the audience to correlate the positions of the actors at the moment the light was turned on with their actual positions upon the screen. The picture concluded with another scene of the orchestra.

DISCUSSION

MR. PALMER: What does the sound-track of this film look like?

MR. MAXFIELD: The sound-track looks like a push-pull track, except that the two tracks are not 180 degrees out of phase. It is made with a four-ribbon light-valve; one pair of ribbons is fed from the microphone on one side of the stage and the other pair from the microphone on the opposite side.

MR. CRABTREE: I have been wondering why there are not more producing and exhibiting executives present this evening. It would seem to me that an exhibition of this nature is of vital importance to their future business. Unfortunately these days it seems to be necessary for the engineer to hand out any new idea or invention in its finished form and on a golden platter before its potential applications can be fully appreciated.

The industry owes a debt of gratitude to the Electrical Research Products, Inc., and, particularly to Vice-President Knox for this pioneering experiment, and the Papers Committee is especially proud to be able to give it a place of honor on our program. It was more than ten years ago that Dr. Steinberg demonstrated to me in the Bell Laboratories the astonishing dramatic effects attainable by binaural sound reproduction. Ever since, I have been looking forward to the time when such effects would be applied to the motion picture. Binaural reproduction, of course, requires the use of earphones and the dramatic effects which we have witnessed are by no means as impressive as the binaural effects but they are a step in the right direction.

Novelty is what the film industry is lacking at the present time. I can go into a small theater today and see as good a show for 20 cents as I can for 75 cents or a dollar on Broadway. It would seem as if the large exhibitor should be looking for some novelty that would enable him to put on a better show than the little fellow.

MR. MAXFIELD: With the stereophonic system we can not bring the sound out in front of the loud speakers, into the audience area. We can cover the whole area behind the screen from the face of the loud speakers back.

MR. CRABTREE: What effect do you get by placing the speakers in the auditorium and not behind the screen?

MR. MAXFIELD: There is a minimum distance in front of the loud speakers at which we can work and not have the sound break up into two distinct sources. Moving the speakers out into the auditorium would force us to move the audience farther back and nothing would be gained. That is one of the limitations of the technic.

One novelty would be to call attention to the position of the action on a darkened screen in some kind of play that calls for materializing a character or for the appearance of a ghost. The location of the sounds could be noted before the ghost is materialized. We can for the first time call visual attention to positions on the screen by the sound effect alone. The dramatic people can think of many things that could be done with such an effect.

MR. RICHARDSON: If sounds are picked up at the sides of the stage and then brought out to the center, how would there be any difference?

MR. MAXFIELD: If you are midway between the microphones, both microphones will get the same sound, and if these two similar sounds are reproduced from both sides of the screen they will appear as one sound coming from the center. Some of our theaters have loud speakers at the sides of the screen instead of at the middle, and the sound still seems to come from the middle of the screen because the same signal is fed into both loud speakers. If the actor moves a little to one side, the microphone on that side picks up a little more than the one at the other side. The complete explanation of that was published in the *Bell Telephone Record* two or three years ago by Fletcher and Steinberg.

MR. FRANK: Have any studies been made to determine what effect the distance from the screen and the angle of vision will have upon the appreciation of stereophonic sound?

MR. MAXFIELD: Only very rough determinations. At the present time it looks as if the distance of the audience from the screen will have to be of the order of one-half to two-thirds of the distance between the loud speakers. That means, for the front row of seats, about one-half to two-thirds of the width of the screen. The acoustics of the auditorium affect only the fore-and-aft illusion.

MR. KELLOGG: How far back must one be in an auditorium such as this before he will fail to notice the difference between two-channel or single-channel reproduction?

MR. MAXFIELD: I have never been in a big enough auditorium to lose the effect. At the front you do not lose the two-channel effect, but you are conscious that it is two-channel and not localized. At the back I have never lost the improvement in quality. The accuracy of localization from the back seats at the Philadelphia demonstration was a little better sidewise than localizing a performer on the darkened stage by listening to him.

MR. KENDE: Is there a difference between the starting points of the two sound-tracks?

MR. MAXFIELD: No, the sound-tracks are side by side on the same film. They start at the same place and are reproduced with the double photocell.

MR. CRABTREE: What is the relation between the fidelity of the reproducing equipment and the dramatic effect to be obtained, assuming the better the fidelity the better the dramatics? Would existing theaters require new equipment or could some of the equipment be adapted to this?

MR. MAXFIELD: The theaters would have to equip themselves with two amplifier channels and two sets of loud speakers. Any statement of quality relationship is a matter of personal opinion. Personally, I would rather hear two-channel reproduction good to 6000 cps., than one-channel reproduction good to 15,000 cps. It is more pleasing, more realistic, more dramatic. I am not sure that all other engineers will agree with me. In discussions with other engineers I have obtained figures ranging from 8000 to 5000 cps., as being equivalent to a 15,000-cps. single channel. We shall not have to increase the frequency range in the theater to get a rather large dramatic improvement with stereophonics.

MR. CRABTREE: What is the depth of field over which it is effective in a room of this size?

MR. MAXFIELD: From about half or two-thirds the width of the screen, all the way back.

MR. FRANK: In a very wide house, such as the Roxy Theater in New York, where the seats near the side are well off the center axis of the screen, what is the effect?

MR. MAXFIELD: The house in which we have done most of our work is the Academy of Music in Philadelphia, and there we covered the seats pretty well to the side. However, that is not an extremely wide house. We have not had experience in a theater like the Roxy. The experience we have had leads us to believe that as the picture begins to get a little out of shape, the reproduction will lose in accuracy of illusion; but even far around to the side, and at the front, we still have good quality. We merely lose accuracy of location.

REDUCTION OF LOOP-LENGTH VARIATIONS IN NON-SLIP PRINTERS *

E. W. KELLOGG**

Summary.—*Compensation for varying degrees of film shrinkage is accomplished in the Bedford non-slip printer by changes in the length of a loop of film between a sprocket and the printing point. This involves uncertainty of synchronism by the amount that the loop, as first threaded, differs in length from the final running loop. For most purposes, the present designs do not cause greater change in loop-length than may readily be tolerated.*

For certain purposes, especially if this type of printer is to be employed for 16-mm. films, there may be too much departure from synchronism. A guide-roller arrangement is described by which the necessary change of angle of approach of the raw stock to the printing point is attained with comparatively small change of loop length.

Several possible arrangements are considered and other features of the non-slip printer are discussed.

The principle of compensating for film shrinkage by automatically altering the curvature where a film is driven past an optical system, was first proposed by Bedford for application to projectors.[1] It might also be applied to recorders. The reason why it has not been applied in these fields is simply that other methods of accomplishing the purpose were available. As compared with use of a drum whose speed is controlled by the film, as for example, in magnetic-drive recorders and rotary stabilizer sound heads, the Bedford principle has the drawback of calling for a drum of small diameter with the light-beam crossing the drum. This would not present an insurmountable difficulty but would give rise to awkward design problems. On the other hand, since Bedford's principle permits use of a fixed-speed drum, the drum may be driven through gears with suitable filtering, which is favorable when quick starting is important.

An application in which this principle has found no competitors is sound printing. As both films are to be held against a drum, the

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received October 11, 1937.

** RCA Manufacturing Co., Camden, N. J.

speed of the drum may be controlled by one of the films, but on practicable ways other than employing the principle of curvature compensation have been suggested for equalizing the surface velocities of the negative and raw stock. Bedford early recognized that sound printers presented a problem to which his principle was peculiarly applicable,[2] and built a simple model of such a printer. It was not until several years later that active development of a printer of this type was taken up by C. N. Batsel[3] with coöperation and encouragement of A. C. Blaney. In the meantime, Wood had independently conceived the idea and had built and published a description[4] of a printer employing the identical principle. Such a delay in the utilization of many valuable ideas is typical of developments of this type. Engineers who are in a position to carry through such developments to the commercial application stage may be under too great pressure to devote their attention to certain developments even though they may recognize their value. In this case, comparison of resolution attainable with a non-slip printer with that of a well adjusted sprocket printer did not fully reveal the advantages of the former, partly because of crudities in the experimental models and partly because at the time there were so many other causes of loss of resolution that the contribution of the printer to the losses was of secondary magnitude. Justification for developmental work under such circumstances may have to be based upon general principles, backed by the theorem that each element in a system must be made the best possible, even though other limitations may at the time be too serious to permit the benefit to appear. Subsequent refinements in recording, especially the advent of ultraviolet recording, have so far removed some of the other limitations in resolution that the faults of contact printers now assume much greater relative importance.

The modulated oscillator test described by Baker[5] has provided a very sensitive tool for checking performance, and has facilitated making comparisons capable of showing relatively small differences. Thus the advantages of the non-slip printer can now be demonstrated in comparison with even the best conditions attainable on a sprocket type of printer.

As has been explained in previous publications, the mean linear velocity of the raw stock as it passes the printing point is determined by the direction from which it approaches the point. Thus, as the guide-roller shown in Fig. 1 is at position A, the raw stock approaches

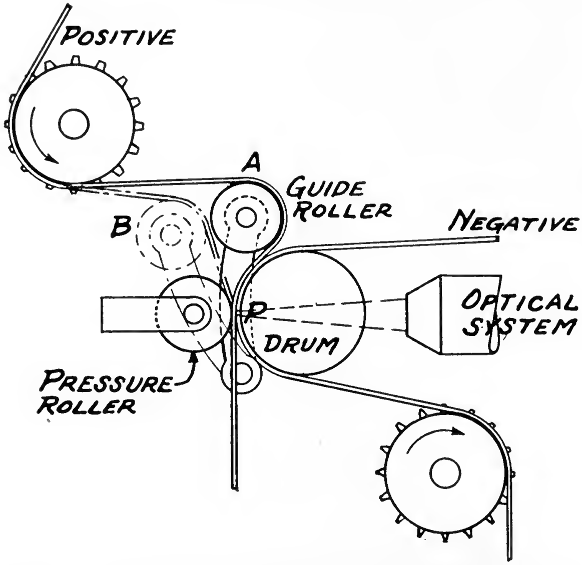


FIG. 1. Drum and guide-roller arrangement in general use in non-slip printers.

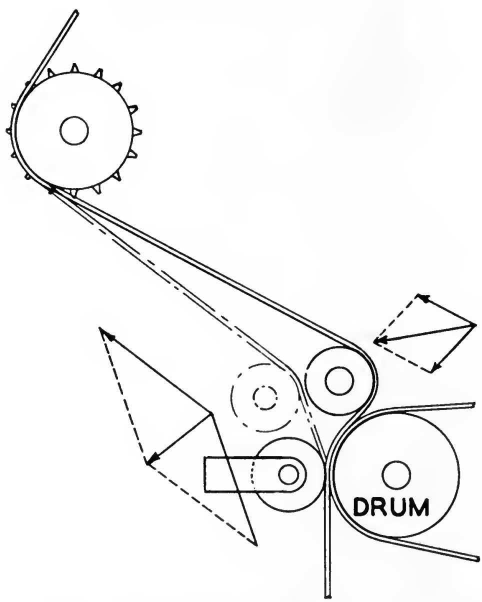


FIG. 2. Printer with sprocket so located as to reduce loop-length variations, and vector diagrams showing film tension required to displace guide-roller.

the printing point P from the right, and therefore presents a concave or compressed surface against the negative that drives it. This is the condition when the raw stock is long compared with the negative. If the films are of substantially equal length, the loop becomes shorter and the guide-roller is drawn over to position B so that the raw stock presents a convex surface where it is pressed against the negative.

However the operator may thread up the machine, the guide-roller reaches a stable position within a few feet of film, and thereafter there is a fixed relation between the place where a given sound appears on the negative and where it appears on the print. Obviously the operator can not control this relation any more closely than he can anticipate the final running position. If, for example, he threads the printer with such relation between the synchronizing marks on the sound and picture negatives as to obtain perfect synchronism with the roller in the middle position, and the film condition happens to be such that the roller moves to the right, the sound will be printed slightly ahead of the ideal position, on account of the unanticipated increase in loop length. Deviations from exact synchronism from this cause have been well within tolerances, but inasmuch as there are numerous other causes of lack of synchronism and the effects may be cumulative, it is desirable to minimize even this small variation.

Fig. 2 shows an arrangement adopted in one of our models of non-slip printer, in which the variation is less owing to the oblique angle at which the sprocket is placed. This arrangement however, has a disadvantage in that the film tension required to hold the guide-roller near the left-hand limit of its swing tends to become excessive. Adjacent to the roller, shown in the two extreme positions, are force vector diagrams showing the tension on the film required to exert a given force upon the roller in the direction in which the roller is free to move. It is practically necessary to apply, by means of spring or weight, a biasing force on the roller in order that it may control the shape of the loop. It is this biasing force that must be overcome by the film tension. The expedient of placing the sprocket in an oblique position, as shown in Fig. 2, is not an altogether satisfactory solution of the problem of reducing the loop-length changes. With the guide-roller near the right-hand position, the action differs only slightly from that of the arrangement shown in Fig. 1. Therefore, a large part of the length variation is still required for covering this part of the range. On the other hand, near the left-hand position the required film tension rises almost abruptly to values that may cause danger of slipping. For this reason, we have recommended designs more nearly in accordance with Fig. 1.

Any loop arrangement in which loop shortening is accompanied by increase of tension has an insidious quality of affording a slipping printer, which in appearance functions like a non-slip printer.

When film is held in contact with a moving surface (either a drum or the surface of another film) and is subjected to too much tension for true non-slip operation, the slipping seems to be almost of the nature of a creep. It is too gradual and continuous to be noticeable to the eye in the appearance of the film loop, but sufficient in magnitude and irregularity seriously to impair the sound reproduction or the printing. Models of what were intended to be non-slip printers have been built in which it turned out that the range of possible compensation due to curvature control was inadequate, but when the raw-stock loop was short it was also under considerably increased tension and the machine had the appearance of functioning perfectly. Only careful tests showed that with the short raw-stock loop the apparent compensation was achieved in part by curvature and in part by slipping. This danger is not necessarily confined to machines in which the geometrical relations of Fig. 2 are employed. If the biasing spring in a design along the lines of Fig. 1 is short or too stiff, the tension required to hold the guide-roller in position B will be much greater than the film tension for position A. The ideal biasing means would be a counterweight, but a properly designed spring will approximate the action of a counterweight. It is necessary only that the average spring stretch be large compared with the change in stretch or extension, between positions A and B. As further assurance against slipping, it is advisable to maintain the tension at all times as low as practicable. This means that the guide-roller must be pivoted with the minimum of friction.

Assuming that the guide-roller is so mounted that there is little friction to be overcome and that the biasing force is kept low, there is still a certain amount of mechanical work that must be supplied to pull the roller from the long to the short-loop position. The mechanical work that the film supplies is the product of tension multiplied by the change of loop length. We must therefore permit some change of loop length, although it is feasible to make the change considerably less than is required with a design such as shown in Fig. 1. In order to reduce the variations of loop-length, an arrangement analogous to a lever must be employed to step up the motion, at the cost of re-

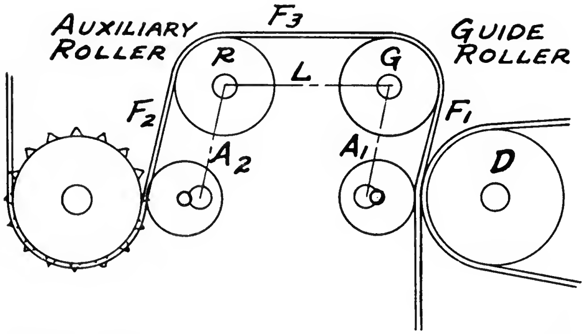


FIG. 3. Double-roller arrangement in which loop length is independent of guide-roller position.

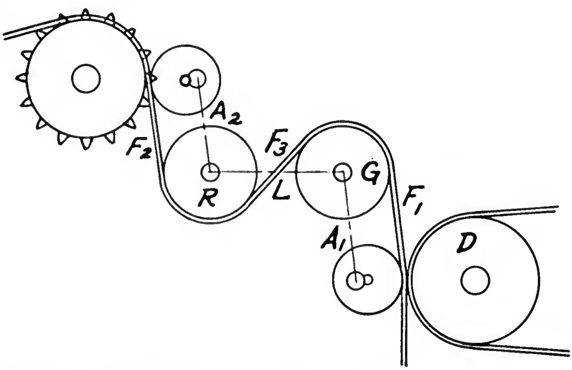


FIG. 4. Double-roller system similar to Fig. 3. in characteristics.

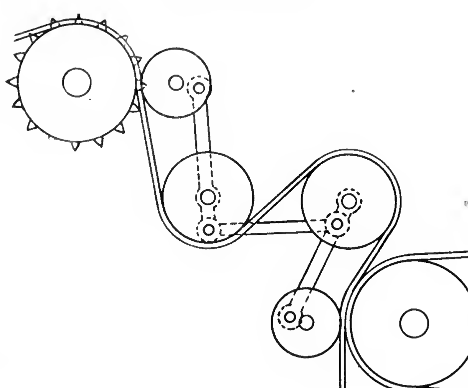


FIG. 5. Modification of Fig. 4, such that film tension will cause movement of rollers.

quiring greater film tension. In general, this means the employment of a second roller connected to the guide-roller in such a way as to offset the effects of the guide-roller; or, in other words, if the guide-roller moves in a direction that would tend to shorten the loop, the second roller moves in a direction that would tend to lengthen the loop. The required relation may be most easily appreciated by considering an arrangement of rollers by which the movement of the second roller completely cancels the effect of movement of the guide-roller, making the total loop length substantially independent of the position of the rollers. Such an arrangement is shown in Fig. 3. This, of course, is not a usable arrangement unless some other means of controlling the roller positions is provided. In Fig. 3, the guide-roller and auxiliary roller are maintained at constant separation by a link L. The arm A_1, on which the guide-roller is supported, is pivoted at such a point that the arm and the stretch of free film F_1 are substantially parallel and of equal length. Likewise, the arm A_2, which supports the auxiliary roller, is parallel to the stretch of film F_2 between the sprocket and auxiliary roller. Except for very slight shortening of the loop in the extreme positions where the film follows an appreciable arc around the drum, or sprocket, or the adjacent rollers, the three stretches of unsupported film in Fig. 3 are of constant length, and the sum of the angles of wrap around the two rollers is likewise constant, making the total loop length constant.

So long as the guide and auxiliary rollers are a constant distance apart, the film between them will be of constant length, whether it passes around them in the same direction or in reverse directions, as shown in Fig. 4. In Fig. 4 we have the sprocket in more nearly the position that has proved to be convenient from the design standpoint. The same reasoning that was used to show that the film loop is of constant length in Fig. 3 may be applied to Fig. 4. It is now very easy to see how the linkage may be modified so that the auxiliary roller will move slightly less than the guide-roller. Such a change can be effected by shifting the link downward on both arms as shown in Fig. 5. We now have an arrangement in which tension of the film will cause the rollers to move toward the left, and the links may be so proportioned that the total change of loop length is as small as desired, the limit being determined by permissible film tension. In this it must be remembered that the smaller the change of loop length the greater will be the required film tension in comparison with the biasing force on the roller. It is thus especially important when employing a linkage of this type, to keep the biasing force as small as possible.

One of the objections to the arrangements shown in Fig. 2, and to a less degree than that shown in Fig. 1, is that the wrap around the guide-roller is none too large for desirable guiding conditions when the guide-roller is in the right-hand position, and the wrap becomes less when the roller reaches the left-hand position. It will be noticed that in Fig. 5 a large angle of wrap around both rollers is maintained at all times, while the reverse bend in the film is of assistance in forcing the film between the flanges of the guide-roller. This condition makes it possible to achieve satisfactory guiding with less film tension than would be required for smaller angles of wrap. This in turn al-

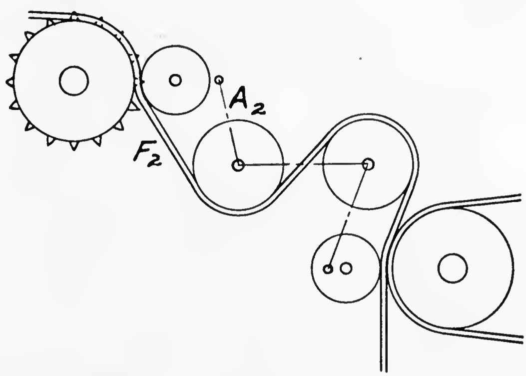


FIG. 6. Alternative method of providing control by film tension.

lows the employment of a very light biasing spring or counterweight.

Instead of modifying Fig. 4 by altering the position of the connecting link, a similar effect may be obtained by shifting the sprocket and pad-roller slightly to the left, as shown in Fig. 6, so that the stretch of film F_2 and the arm A_2 are no longer parallel. The amount of this shifting of the sprocket controls the shortening of a loop.

It may not prove convenient to locate the centers of the swinging arms as shown in Figs. 5 and 6. There are numerous variations that will give substantially equivalent results. Fig. 7, for example, shows a linkage in which the shorter arm is adjacent to the longer stretch of free film, and the longer arm adjacent to the shorter stretch. As soon as we depart from the parallelogram arrangement as shown in Figs. 3 to 6, it becomes necessary to study very carefully the rate of change of loop length with respect to roller displacement. The ideal is that this should be constant, each increment of roller movement being accompanied by a proportionate change of loop length. This relation will assure practically constant film tension throughout the range of positions. It was pointed out in discussing Fig. 2 that the ability of the film to produce adequate force in the direction of roller movement became poor for certain positions. With an arrangement such as shown in Fig. 7, the force exerted upon the guide-roller by the film becomes less as the roller moves to the left, and, in particular,

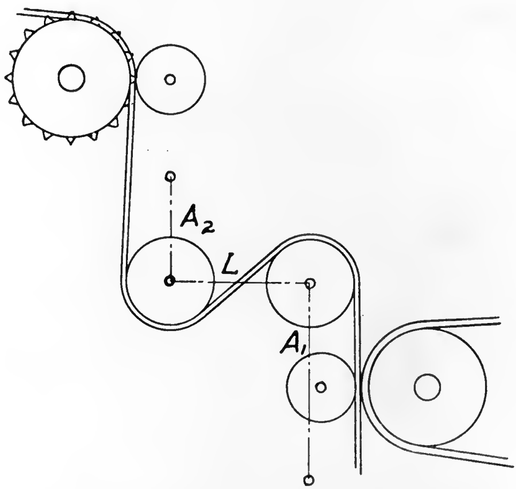


FIG. 7. Modification of Fig. 4 to meet exigencies of design but having essentially same characteristics.

the horizontal component of the resultant force decreases rapidly. At the same time the opposing horizontal force exerted by the film upon the auxiliary roller tends to increase. The effect is compensated by the large change of angle of the short arm A_2. The radial thrust of this arm has a component in the right direction to relieve the film. At the same time the arm A_1 and the link L fall more nearly into line, thus affording a toggle effect enabling a given force exerted upon the guide-roller by the film to overcome a larger force exerted by the film upon the auxiliary roller. The design of such a linkage is largely a matter of cut and try. If it is not well done, there are likely to be hard spots where the film appears to work almost against a dead center, while at some other part of the swing there will be unnecessarily large changes of loop length. The analysis may be made by calculation, or graphically, or by trial with a model. Fig. 8 shows a model used for this purpose. The lengths of arms and locations of pivots and rollers could be changed quickly, and the action could be checked with reasonable accuracy by pulling the film and observing the movements.

In case design limitations make it impossible to obtain the desired relation between loop shortening and roller movement, and it is necessary to resort to some auxiliary device to keep the film tension more

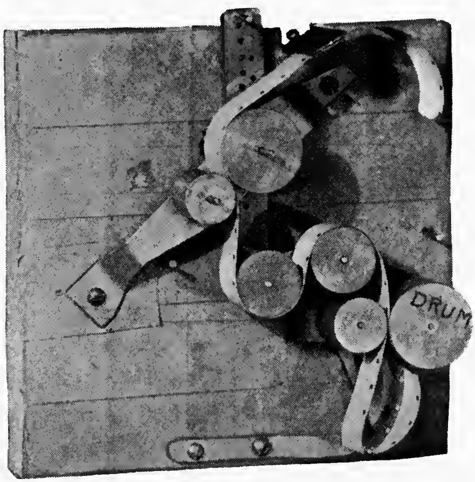


FIG. 8. Model used for determining suitable linkage proportions.

nearly constant, a toggle spring or a counterweight above a pivot point, as shown in Fig. 9, might be employed. It is far preferable, however, to work out linkage proportions that will make this unnecessary, for if the film must for any position work too near a dead center, no amount of reduction in the force exerted by the spring will enable it to function properly. Fig. 10 shows the roller and link arrangement employed in a laboratory model of non-slip printer. This linkage was worked out with the help of the model shown in Fig. 8. H. A. Backus, who has coöperated in this development, analyzed a number of arrangements, both graphically and by calculation, before arriving at the proportions adopted, and also checked the contemplated design experimentally.

One of the requisites for avoiding too much variation in loop length is to keep the guide-roller as close to the pressure-roller as possible. The employment of a small-diameter guide-roller also assists in bringing about this result, but the small-diameter guide-roller is undesirable in that it affords less satisfactory guiding, and more tension is required to make the film ride snugly against the guide-roller. If a compensating linkage, such as has been discussed, is employed, it becomes less necessary to keep down the size of the guide-roller. In fact, the total required variation in loop length is not materially altered by adoption of a fairly large diameter guide-roller, provided the linkage is designed to suit the roller size chosen.

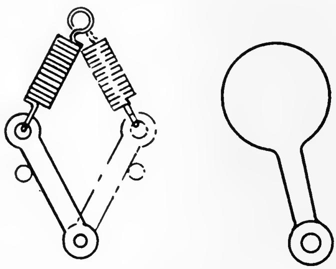


FIG. 9. Toggle spring and overhead counterweight used to equalize film tension in certain applications.

If the stretches of unsupported film took the form of straight tangents from one roller to the next, there would be no purpose in complicating the design beyond the adoption of such a linkage as has been described. There is, however, a loss in range of angle due to bowing, as shown in Fig. 11, which must be offset by increased movement of the guide-roller. This bowing of the film becomes greater when the tension is kept low but is somewhat helped by the employment of a larger guiding roller. Fig. 12 shows the manner in which an extra movable roller may be employed further to minimize the changes of loop length. The extra roller is not needed and does not come into play when the guide-roller is in the right-hand position, or, in other words, when the film is bent around the drum. In fact, there is no room for such a roller under these conditions. It comes into play as the guide-roller swings to the left, and presses against the free film sufficiently to produce a slight reversed bend, thereby causing the film to follow the pressure-roller more closely and bring about the desired change of angle. If the linkage of the type shown in Fig. 12 is such as to maintain the two rollers at constant separation, some special arrangement would be required for threading the film. If, however, the linkage is so designed that the extra roller

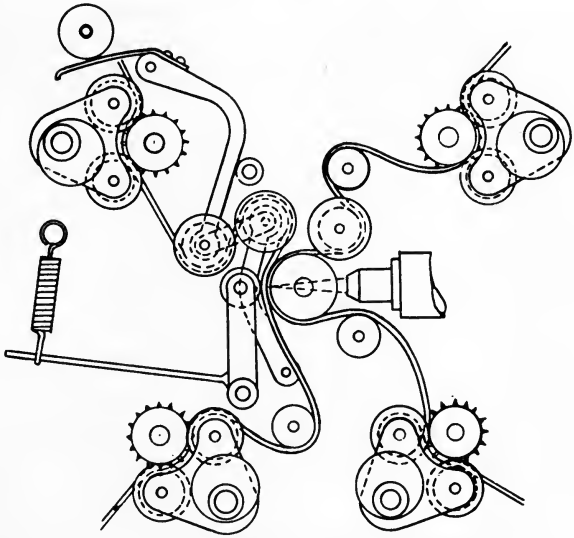


FIG. 10. Non-slip printer layout employed in experimental model.

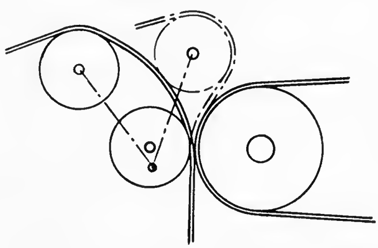


FIG. 11. Loss of control of angle through bending of film.

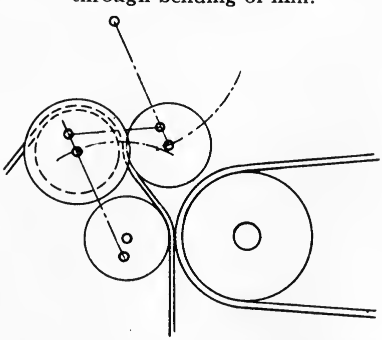


FIG. 12. Employment of auxiliary roller to increase range of angle for given movement of guide-roller.

has slightly more movement than the guide-roller, the separation can be caused to increase sufficiently with movement toward the right, so that threading may be accomplished by merely swinging the rollers to extreme right-hand position.

Although the method of driving the drum in a non-slip printer bears no necessary relation to the general subject of this paper, it is appropriate in any discussion of such printers to give consideration to the possibility of overdriving the drum. From the standpoint of guiding the negative there is an advantage in supplying enough torque to the drum, by means of an auxiliary drive such as the magnetic drive used in recorders, to cause the negative to run moderately tightly where it is fed onto the drum, and loosely where it leaves. The auxiliary drive also helps to bring the drum up to speed. Caution must be observed to insure that the torque supplied is not sufficient to cause slipping of the negative on the drum. A soft-tired pressure-roller below the drum, or on the side of the slack loop, is usually employed when the drum is overdriven. Such a pressure-roller provides assurance against slipping, but is not entirely necessary in the printer since the main pressure-roller insures a fair amount of traction. If the extra pressure-roller is used, precautions need to be taken to prevent the film from running off during starting. The film stability problem has been discussed in detail in an earlier paper on recorders.[6]

Acknowledgment should be made of the valuable assistance of H. A. Backus of the Engineering Department of RCA Manufacturing Co.

REFERENCES

[1] BEDFORD, A. V.: U. S. Patent No. 1,754,187.

[2] BEDFORD, A. V.: U. S. Patent No. 2,098,371.

[3] BATSEL, C. N.: "A Non-Slip Sound Printer," *J. Soc. Mot. Pict. Eng.*, **XXIII** (Aug., 1934), No. 2, p. 100.

[4] WOOD, R. V.: "A Shrinkage-Compensating Sound Printer," *J. Soc. Mot. Pict. Eng.*, **XVIII** (June, 1932), No. 6, p. 788.

[5] 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** (Jan., 1938), No. 1, p. 3.

[6] KELLOGG, E. W.: "A New Recorder for Variable-Area Recording," *J. Soc. Mot. Pict. Eng.*, **XV** (Nov., 1930), No. 5, p. 653. (The title of this paper is misleading, in that the main features of the recorder were in no wise related to the type of sound-track to be recorded.)

DISCUSSION

MR. ROBERTS: In that type of printer it has been our experience to find more trouble in controlling the raw stock than the negative. Are there any particular advantages to positive stock guidance in overdriving the drum?

MR. KELLOGG: The overdrive has nothing to do with the action of the raw stock, but the suggested guide-roller arrangement will, I believe, help the guiding.

MR. CRABTREE: Are there any advantages in increasing the weight beyond the slippage point?

MR. KELLOGG: I believe not. We usually like to keep it as light as we can. I should be very much interested to know what experience the Consolidated Laboratories have had in regard to static. That has at times become a serious problem, and it is aggravated by excessive pressure. I understood that by lessening the pressure, they were able to alleviate it. Their first tests were run at 180 feet a minute. That, plus considerable pressure, made static markings on the film. What was finally done to cure the trouble, I do not know.

MR. DAVEE: Those who have made comparisons of the non-slip printer with other methods of printing, I believe, can appreciate the advantage of printing sound with this printer. Would we not be able to obtain much better picture quality, comparable probably with the step printer, in contrast to the continuous printer, and thereby improve the picture quality considerably?

MR. KELLOGG: The main problem is, of course, that of framing. A picture printer must operate so that if the negative is made with a picture frame line directly opposite a pair of sprocket holes, it will make a print of which the same is true.

The non-slip printer for sound is subject to slight variation or uncertainty in the position of the print with respect to the sprocket holes. It is only at the sprockets that we have any control of the relative positions of the two films as they run through the machine, whereas the printing contact is on the drum with the variable loop between. Therefore, we can not make a continuous picture printer along these lines, and be sure that the pictures will stay in frame. I believe that a non-slip picture printer is a possibility, but I do not see how to utilize the Bedford sound printer principle for that purpose.

MR. ROTHBERG: Have you found any practical answer with regard to the extremes of diameter of the sound drums?

MR. KELLOGG: Such experience as I can report seems a little contradictory. We have furnished to those who requested them, prints of a design embodying our ideas at the time the drawings were made. These drawings showed a drum about an inch in diameter, and a pressure-roller about $^5/_8$ inch in diameter. In our laboratory work these diameters appeared to take care of all the variations of negative shrinkage that we had encountered. In our Canadian laboratory we never seemed to find the guide-roller running anywhere but pretty well toward the left, which would indicate that a larger diameter drum could be used. If the drum were made a little larger, the guide-roller would not have to run so far to the left, because the negative surface would not be stretched quite so much. Our laboratory model saw considerable service in Hollywood, and there I believe Mr. Blaney found it desirable to use a $^7/_8$-inch drum. After the machine was returned to Camden, experience seemed to indicate that we did not need quite so small a drum, and we went back to a 1-inch diameter.

A RECORDER FOR MAKING BUZZ-TRACK*

E. W. KELLOGG**

Summary.—*The only requirements of a buzz-track are that the track be of correct width and located properly with respect to the edge of the film nearest the track, and that the sound produced by a weave in one direction shall be readily distinguishable from the sound that results when the film is displaced in the other direction.*

It is desirable that the buzz-track film should be a direct recording rather than a print, since there is then less chance of inaccurate location. A simple recorder has been constructed for the sole purpose of making 35-mm. buzz-track film. It can readily be converted for 16-mm. film. All possible precautions are taken to insure correct track width and location. In view of the small quantity of buzz-track required, it is contemplated that only one such machine will be needed.

"Buzz-track" is the name given to a special recording made for the purpose of adjusting reproducers so that the scanning beam will fall at the correct location with respect to the guided edge of the film. Fig. 1 is an enlargement of a small section of 35-mm. buzz-track. The space or strip normally scanned by a correctly located reproducing light-beam is free from modulation, but on either side of this strip is recorded a tone. A one-thousand-cps. note has been recorded on the side next the sprocket holes and a 300-cps. note on the side farthest from the sprocket holes. If the film-guiding and optical systems of the projector under test are adjusted in proper relation to each other, no tone is produced. If the projector needs adjusting, a tone is heard, the frequency of the tone telling the service man which way to shift the film-guiding roller. On 35-mm. buzz-track film the modulation-free strip should be centered 0.2435 inch from the edge of the film, and should be 0.088 inch wide, which would clear a correct scanning beam by 0.002 inch on each end. The corresponding figures for 16-mm. buzz-track are 0.058 inch from edge of the film to the center of the track and 0.069 inch clear width.

Up to the present time, buzz-track films have been made by first recording a special negative and then making as many prints of the

* Presented at the Fall, 1937, Meeting at New York, N.Y.; received October 11, 1937.

** RCA Manufacturing Co., Camden, N. J.

negative as are required. It should not often be necessary to make a new buzz-track negative, but when it is necessary considerable labor is involved. One method is to shift the recording optical system in a standard recorder some twenty or thirty mils to the side, place a mask at the slit and by trial locate the mask so that one edge of the desired clear space falls at exactly the right distance from the edge of the film. The required footage of negative film is then run through the recorder. The optical system is now shifted toward the other side, the mask readjusted and the correct position determined by successive trials, each trial requiring processing a piece of test-film. The galvanometer is then modulated at the desired frequency, and the negative run through the recorder again, to record the other

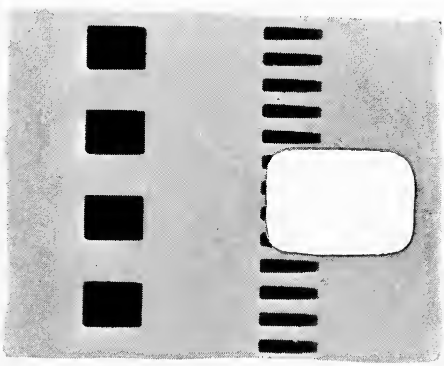


FIG. 1. Sample of buzz-track.

side of the buzz-track. In addition to the numerous trials required to adjust the optical system correctly, making a buzz-track negative means taking the recorder out of service and upsetting the existing adjustments. Making a negative and then printing it is furthermore undesirable in that possible imperfections in the guiding of the printer will cause errors in the location of the printed track and there will also be variations due to the combined effects of shrinkage of negative and print.

It recently became necessary to make an additional buzz-track negative, and it appeared that a special recorder might be built that would cost little more than the labor required for setting up the special recording system and making a negative in the manner just described. Once such a recorder is built, it would make further production of buzz-track film a very simple matter. Although there is no reason to suppose that additional machines will be built, a brief description of the design may be of interest.

In only one respect is accuracy required in a buzz-track. The modulation-free strip must be of correct width and accurately located with respect to the edge of the film. For once "wows" may be forgotten. The tones recorded on the two sides of the track must be readily distinguishable, but there is no other requirement as to the choice of tone. Fig. 2 shows a front view and Fig. 3 a rear view of the machine. The optical arrangements are shown in Fig. 4.

The film drum is driven by means of a string belt at approximately 90 feet per minute. A three-watt lamp is located at F in Fig. 4. The lamp filament is a small-diameter helix, and is imaged

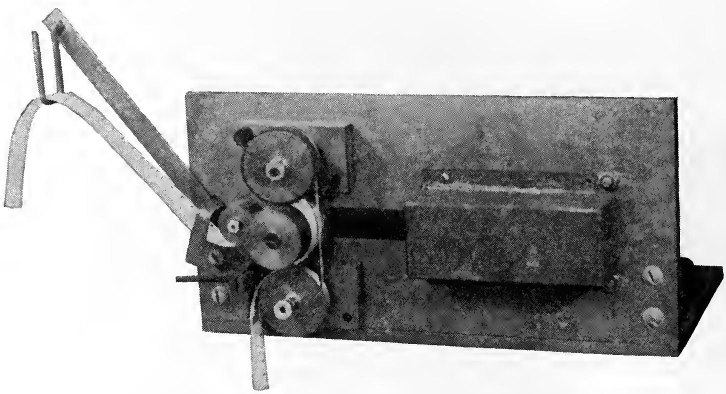


FIG. 2. Buzz-track recorder, front view.

upon the film by an objective lens L_1. The reduction ratio is such as to give an image height of the order of three mils. In the horizontal plane, the cylindrical lens L_2 throws the filament out of focus and changes the image on the film into a horizontal line of sufficient length to record the wide track that is needed. Lenses L_1 and L_2 in combination focus the mask M upon the film. Since L_2 is a cylinder, only vertical edges in the mask are imaged upon the film. An aperture in the mask is divided into two openings by a vertical bar indicated at B_1. The result of the combination is a rather long line of light upon the film, with a break in the middle. The shadow of the bar upon the film determines the position and width of the modulation-free portion of the track. The mask was set up without the tone wheel W, and the sides of the bar B_1 were filed until their images fell upon the film at exactly the right positions. The tone wheel W has ten notches in the periphery, and just inside the notches is a row of thirty-three holes. The opening to the right of B_1 is uncovered ten times per revolution of the tone-wheel, while that to the left is uncovered thirty-three times. The speed of the motor is such that this results in tones of approximately 300 and 1000 cps. The

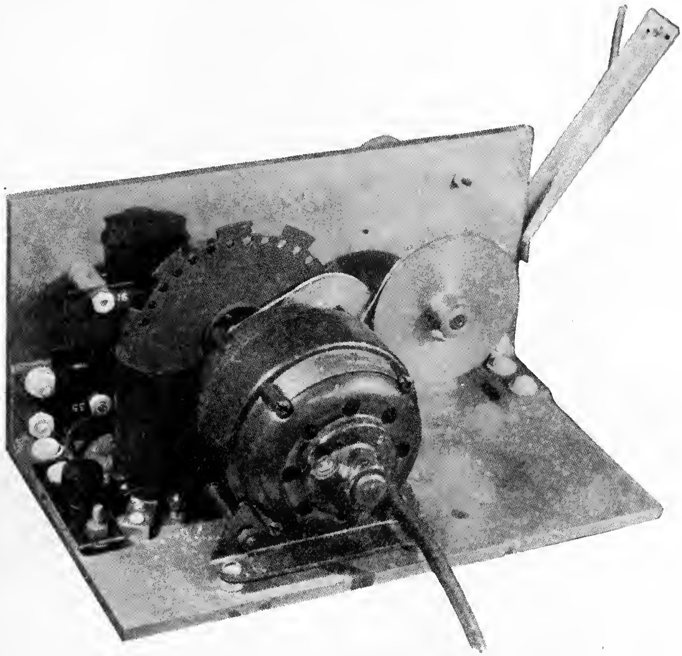


FIG. 3. Rear view of buzz-track recorder, showing motor, tone-wheel, and reversible mask.

exposure changes rather suddenly from full intensity to zero as the wheel is revolved, giving for each tone a series of black spots and clear spaces.

It was desirable that the same machine should be capable of making either 35-mm. or 16-mm. buzz-track. In order to make the change-over simple, the mask is mounted on closely fitting studs, and another pair of windows is cut in the opposite side. Simply reversing the mask produces an image on the film having the correct separation between recorded tones for 16-mm. buzz-track. The position of the recording beam with respect to the edge of the film must also be correct. Owing to the fixed position of the rows of holes in the tone-wheel, this shift in the track location could not well be taken care of at the mask. Therefore, the machine has been provided with interchangeable drums having slightly different flange locations. When making 35-mm. buzz-track, the drum is driven directly from the motor by a string belt. When 16-mm. buzz-track is being made, a pair of intermediate pulleys is employed so that the film is propelled at about normal speed, thereby giving approximately the same two tones as used for the 35-mm. buzz-track.

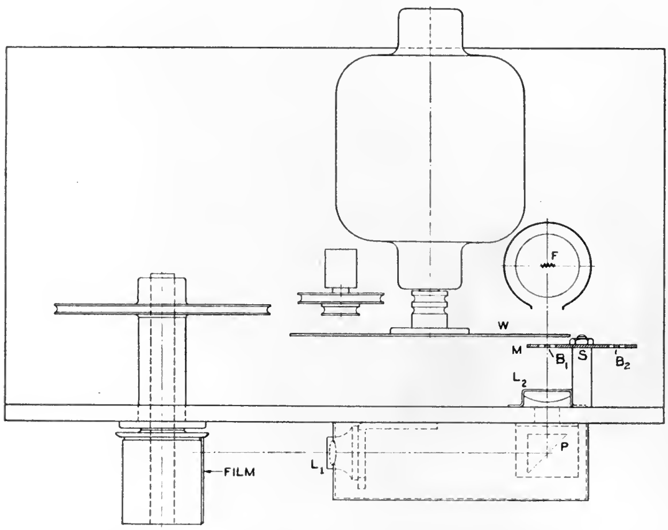


FIG. 4. Main elements of buzz-track recorder.

Since the machine will be used only at long intervals, no provision has been made for supply and take-up reels. When a few hundred feet of buzz-track are to be recorded, a film rewind may be placed near the machine and an assistant operate the rewind. Supply and take-up reels could, of course, be added easily if warranted.

As was pointed out at the beginning of this paper, there is one respect in which precision is required. There can be little doubt that the most accurate lateral guiding may be attained by providing the drum with a flange and insuring that the film will be held snugly against the flange. A stationary guide feeds the film to the drum from the proper position. As the film is fed to the drum it passes under a rubber-tired pressure roller which is mounted on a skew axis. This roller exerts a continuous thrust upon the film, tending to hold it against the flange. As the film passes the recording beam, it is held against the drum by a belt which passes around two idler pulleys and over the drum. The belt is under sufficient tension to exert the required pressure between the film and the drum. The idler pulleys are offset in such a manner that the belt must slide upon the surface of the film, exerting an additional axial force tending to hold the film against the flange. End-play in the drum shaft must be practically eliminated. It appears that this condition may be satisfactorily approximated by closely adjusting the pulley on the shaft. A spring washer may easily be provided if found desirable, in order to insure that the thrust surface on the drum will always run against the end of the bushing.

Recording buzz-track on this machine involves very little more labor than to run the same amount of film through a printer. There is therefore little to be said for resorting to the negative-positive method of making buzz-track films, whereas there is a distinct disadvantage in such a method because of the chance of wrongly locating the track. The directly recorded buzz-track, of which Fig. 1 is a sample, will differ from the buzz-track previously employed in that the modulation-free strip is clear instead of black. This may result in slightly more ground-noise, but unless the film has been abused, the ground-noise will always be so low that it will not mask either of the recorded tones, even though the light-beam extend into the recorded area ever so slightly.

PUSH-PULL RECORDING*

J. K. HILLIARD**

Summary.—*A discussion of some of the practical aspects of push-pull recording supplementing a discussion of the theoretical principles by O. O. Ceccarini on page 162 of this issue of the Journal.*

Sound that is to accompany motion pictures must necessarily be reproduced with the greatest possible accuracy in order to create the greatest illusion of reality. In seeing motion pictures the audience is aroused to a sound expectancy that is not necessarily essential to the radio or the phonograph. It is necessary that the recording and reproducing systems have frequency and volume ranges commensurate with those of the original sounds, and a high degree of linearity. To approximate this condition, a frequency range of 50 to 8000 cps. is necessary, and a volume range of 50 to 60 decibels. Reproducing systems are now available, and are being installed in theaters, that will meet these requirements, and recording practice has been developed to such a degree that it also fulfills the requirements. However, it has been found necessary to limit the volume range of releases until such time as the majority of theaters are adequately equipped.

To date, standard methods of recording on film, both variable-density and variable-width, have given a volume range of approximately 40 decibels, at the expense of considerable distortion. In the variable-density system the principal limitation has been the small linear range of density between the toe and the shoulder of the characteristic curve of positive stock, plus the distortion due to the noise-reduction system because of its slow operating time. Adoption of the push-pull feature would reduce these limitations by cancelling these internal distortions and, accordingly, development of such a project was undertaken.

The light-valve as shown in Fig. 1 has been modified to have two pairs of biplanar ribbons of the conventional type, each pair exposing

* Received October 11, 1937. The theoretical principles of push-pull recording are outlined by O. O. Ceccarini, p. 162 of this issue.

** Metro-Goldwyn-Mayer Corp., Culver City, Calif.

half of the sound-track. The valve is so connected that the ribbons act in the push-pull manner. Mechanically it is impossible to mount the ribbons in line with each other. In order to scan the track with a single slit, the image on the film is optically relocated. This is accomplished by placing an optical flat in the path of each light-beam in the form of a saw-buck as shown in Fig. 2. This arrangement moves the axis of the path in proportion to the angle at which the optical flat is interposed. As a result, the two lines of light formed by the valves are colinear on the film.

Any power that is added to the signal component to effect noise-reduction appears in phase on the track and is cancelled out in the push-pull reproduction. Since these added signals appear on the track in the form of changes of density, then, if the density is the same on

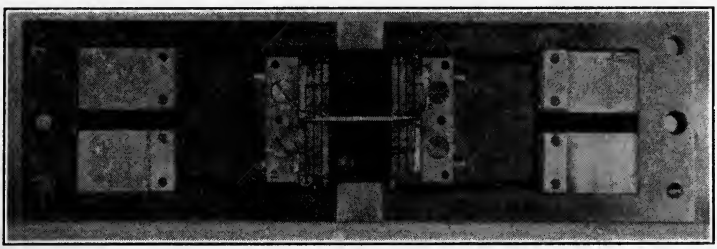


FIG. 1. Push-pull recording light-valve.

either side, zero signal results on the external side. Now it is possible to speed up the noise-reduction circuit so it will operate faster. This higher speed decreases the amount of clash, since the light-valve will clash at lower amplitudes if the noise-reduction is not able to pull it out of the way fast enough. The push-pull method allows greater exposure of the film, and in order to achieve maximum cancellation it is necessary to keep the exposure uniform from one side to the other. This is accomplished by checking the density gradient from time to time, and by adjusting the flat-ribbon filament lamp so that its field is as uniform as possible. Very often it becomes necessary to select lamps carefully when wide variation in manufacture is encountered. If a recording is made in which the two halves of the tracks are recorded in phase, then when the recording is reproduced on a balanced machine the output will be a measure of the cancellation.

In the variable-width class *A* push-pull system,[1] the images of the triangular slits are so placed that they are symmetrical with respect

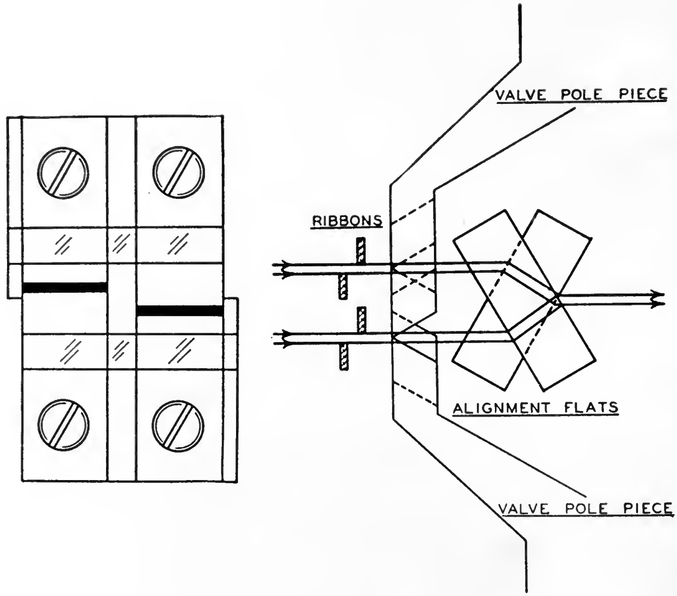


FIG. 2. Optical arrangement for push-pull recording light-valve.

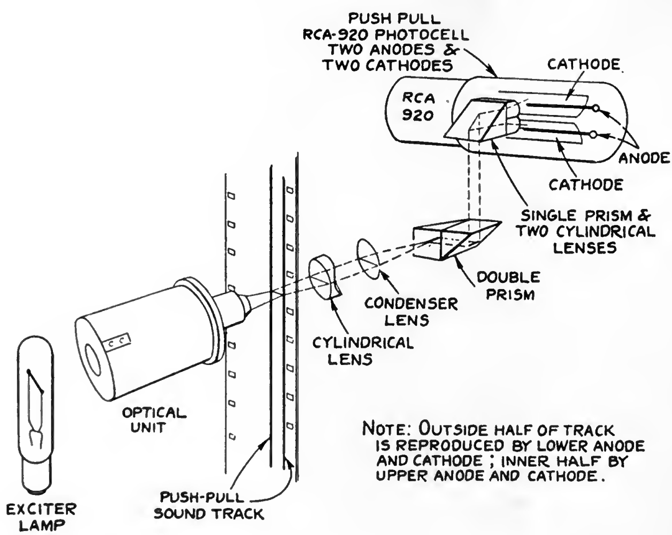


FIG. 3. Light train of RCA *MI-1070* reproducer.

to the center of the slits. Then the center of the track is made to correspond with the center of the slits. The residual width of the track will then give a measure of balance.

Fig. 3 shows schematically an RCA *MI-1070* sound-head, consisting of a push-pull photocell, a special lens, and a prism assembly, together with a push-pull photocell transformer. This combination makes it possible to reproduce either single-track or push-pull recording.

The *920* photocell contains two anodes and two cathodes. When connected through the selector switch for single-track reproduction,

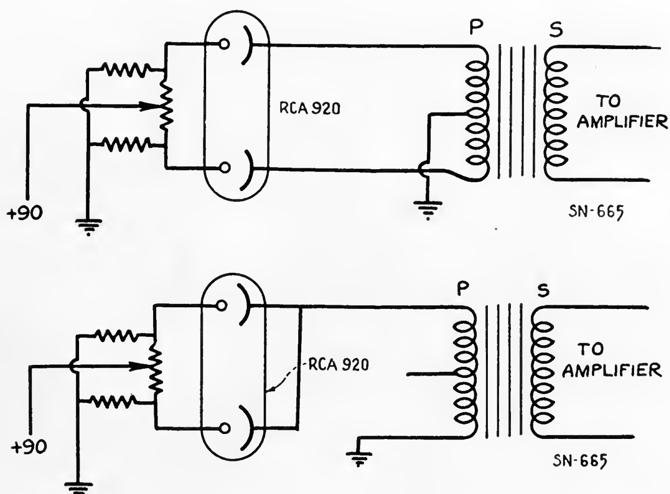


FIG. 4. (*Upper*) Push-pull circuit; (*lower*) standard circuit.

the cathodes are connected in parallel. The photocell then operates in the same manner as the standard cell. For push-pull reproduction the two cathodes are separated, and operate alternately through the photocell transformer (Fig. 4).

To balance the equipment for push-pull recording, any bilateral or standard variable-density film can be used. When set for push-pull reproduction, the balancing potentiometer is adjusted for minimum reproduction of the recording sound at high volume. Another method that is currently used in studio review rooms is to use alternating current as the source of supply for the exciter lamp and adjust the balancing potentiometer for minimum output. This type of sound-head is known as a direct scanning reproducer.

Fig. 5 shows another type of sound-head, manufactured by the Western Electric Company.[2] It employs a film scanning system known as the "projection, rear, or indirect type," which has been used in re-recording reproducers and consists essentially of an exciter lamp, condenser lens-prism assembly and objective lens, and a scanning slit, behind which is a collimating lens and a photocell.

The condenser lens-prism assembly should be adjusted so that it focuses the filament image some distance in front of the film plane on the lamp side so that the film is illuminated with a blob of light.

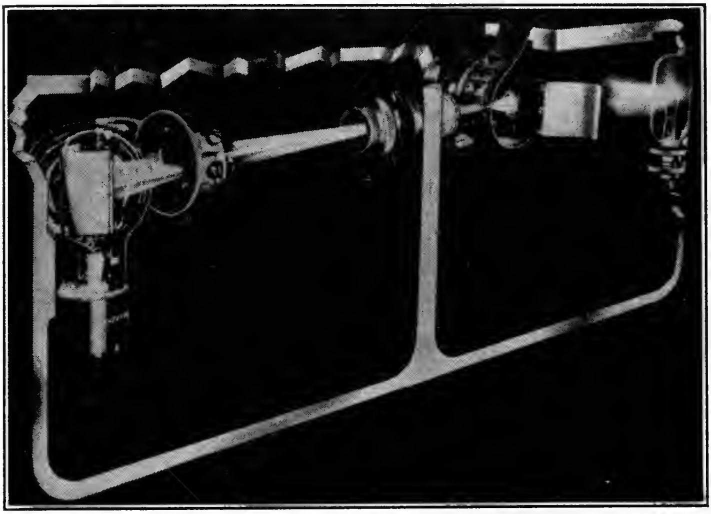


FIG. 5. Western Electric "projection" type sound-head.

The objective lens is adjusted to focus the track image sharply upon the scanning slit, whose width is approximately 12 mils. The drum that holds the film in place at the point of scanning is of the rotary stabilizer type, similar to that in the RCA sound-head. Fig. 6 shows the wiring diagram of the *TA-7400* reproducer set for both push-pull or single track recording.

To obtain the maximum benefit from the increased volume range, it is necessary that flutter due to the motion of the film at the point of scanning be reduced to a minimum. Two types of flutter are encountered. One is 96-cycle flutter (sprocket-hole frequency) which results from the fact that when sprocket-holes are used to pull the film the motion is not continuous. For that reason, methods that use sprocket-teeth have been eliminated in favor of drum scanners. The drum also reduces low-frequency flutter when the rotary stabilizer[3] principle is applied.

Push-pull variable-density recording has been in commercial use since the early months of 1935, and at the present time both the variable-density and variable-width methods are in wide use among the studios for original recording. The release of movietone push-pull sound-track is very limited, due to the small number of theaters

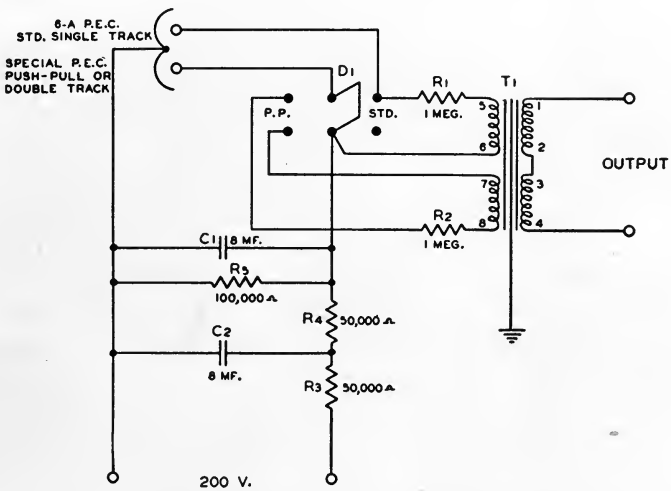


FIG. 6. Western Electric System *TA-7400* reproducer set.

equipped with push-pull reproducers. However, during the past year several pictures have been released with a limited number of push-pull copies. It is expected that within a short time enough theaters will be capable of playing push-pull so that it will be practicable to release push-pull prints on a larger scale.

REFERENCES

[1] DIMMICK, G. L.: "RCA Recording System," *J. Soc. Mot. Pict. Eng.*, **XXIX** (Sept., 1937), No. 3, p. 258.

[2] DAVIDSON, J. C.: "A New High-Quality Film Reproducer," *J. Soc. Mot. Pict. Eng.*, **XXVIII** (Feb., 1937), No. 2, p. 202.

[3] COOK, E. D.: "Technical Aspects of the High-Fidelity Reproducer," **XXV** (Oct., 1935), No. 4, p. 289.

THEORETICAL NOTES ON THE PUSH-PULL METHOD OF RECORDING SOUND*

O. O. CECCARINI**

Summary.—*A discussion of the mathematical principles underlying the push-pull method of sound recording, previously discussed by Douglas Shearer at a joint meeting of the Pacific Coast Section of the SMPE and the Academy of Motion Picture Arts & Sciences on June 4, 1936.*

The push-pull system of recording sound was first brought out for the purpose of improving the method of reducing background noise. It might be well, therefore, to state the principles upon which the system is based.

Assume a single frequency applied to a double light-valve or modulator, and let the customary sound-track be divided exactly into two. Record the positive half-cycle on one track and the negative half-cycle on the other, each half-cycle correctly displaced upon the film. For convenience of analysis assume these records to be made in the variable-width fashion.

Each track has then a sound record identical to the output of a half-wave rectifier of ideal characteristic (Figs. 1 and 2).

As a common starting point we may represent the track containing the positive half-cycles by $f_1(x)$ and the track representing the negative half-cycles by $f_2(x)$. Both $f_1(x)$ and $f_2(x)$ can be expanded in terms of a Fourier series, the necessary requirement being that the two series must be capable of representing respectively:

$$\begin{aligned} f_1(x) &= E \sin x & 0 < x < \pi \\ &= 0 & \pi < x < 2\pi \end{aligned} \qquad (1)$$

and

$$\begin{aligned} f_2(x) &= 0 & 0 < x < \pi \\ &= E \sin x & \pi < x < 2\pi \end{aligned} \qquad (2)$$

where E represents the maximum amplitude.

---

* Received October 6, 1937.

** *Consulting Engineer,* Metro-Goldwyn-Mayer Corp., Culver City, Calif.

These series are readily found to be

$$f_1(x) = \frac{E}{\pi} + \frac{E}{2} \sin x + \frac{2E}{\pi(1 - n^2)} \sum_{2}^{\infty} \cos nx \qquad (n \text{ even}) \qquad (3)$$

and

$$(x) = -\frac{E}{\pi} + \frac{E}{2} \sin x - \frac{2E}{\pi(1 - n^2)} \sum_{2}^{\infty} \cos nx \quad (n \text{ even}) \qquad (4)$$

The algebraic sum of f_1 (x) and f_2 (x) is obviously

$$f_1(x) + f_2(x) = E \sin x \qquad (5)$$

This algebraic sum is readily performed by connecting two photoelectric cells in push-pull position, as is done with vacuum tubes, from which type of connection the name was derived.

It is obvious by inspection that the amount of noise-reduction is the greatest possible without any additional equipment for the purpose. The ratio of signal amplitude to background noise is maximum and remains always constant.

The critical requirements of the system are that one record must not only be an exact counterpart of the other, but, also, that the line of division of the record must be exactly along the neutral axis. In projection the illumination of both tracks must be identical, and every electrical part up to the point of combining the records must be perfectly symmetrical.

It is physically impossible to close the ribbons of the light-valve completely to permit recording in the above-described manner. More likely the two records would be of the following forms (Figs. 3 and 4):

$$\begin{aligned} f_1(x) &= E \sin x && -\alpha < x < \pi + \alpha \\ &= 0 && \pi + \alpha < x < 2\pi - \alpha \end{aligned} \qquad (6)$$

$$\begin{aligned} f_2(x) &= 0 && \alpha < x < \pi - \alpha \\ &= E \sin x && \pi - \alpha < x < 2\pi + \alpha \end{aligned} \qquad (7)$$

where α is an appreciable angle. For this type of record the former discussion no longer applies.

Following the method adopted for the classification of amplifiers we have found it convenient to assign the term *class A push-pull record* to a record in which the wave is fully or integrally recorded in each track, and *class B push-pull record* to a record in which one-half of the wave is recorded on the first track and the following half on the second track.

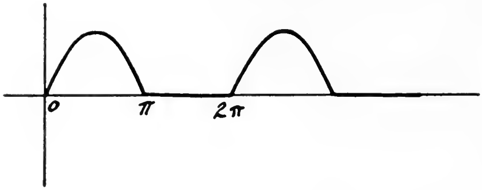


FIG. 1.

$$f_1(x) = E \sin x \qquad 0<x<\pi$$
$$= 0 \qquad \pi<x<2\pi$$

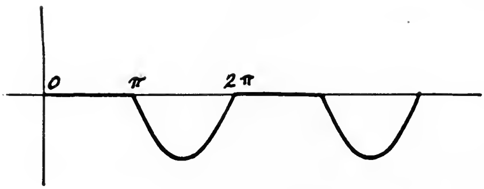


FIG. 2.

$$f_2(x) = 0 \qquad 0<x<\pi$$
$$= E \sin x \qquad \pi<x<2\pi$$

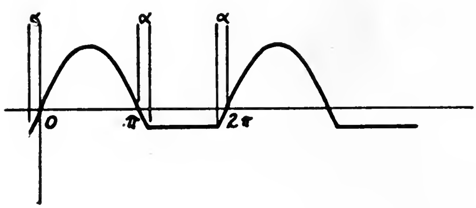


FIG. 3.

$$f_1(x) = E \sin x \qquad -\alpha<x<\pi+\alpha$$
$$= 0 \qquad \pi+\alpha<x<2\pi-\alpha$$

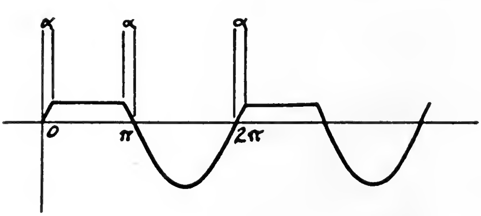


FIG. 4.

$$f_2(x) = 0 \qquad \alpha<x<\pi-\alpha$$
$$= E \sin x \qquad \pi-\alpha<x<2\pi+\alpha$$

In accordance with this classification, then, the type of record represented analytically by conditions *1* and *2* is a class *B* record, while the record specified by conditions *6* and *7* is a class *A-B* record.

The following important considerations are self evident: In reproducing class *A-B* records, the class *A* components will add numerically while the class *B* components will add algebraically, with the result that extremely weak sounds consisting only of class *A* components will appear twice as loud in proportion to stronger sounds.

With the variable-density system, correction for this irregularity can not be made. In the case of the variable-width system it is conceivable to subtract the class *A* components physically by suitable masks during reproduction, thus reducing the record to pure class *B*. The critical requirements of precise balance of the output circuits, faultless alignment and azimuth adjustment of the reproducing slit with respect to both tracks, and perfect balance of light on both tracks are, however, common to both systems.

It might, perhaps, be worth while to point out that poor alignment and azimuth adjustment of the slit will fail to produce perfect cancellation of the term

$$\frac{2E}{\pi(1 - n^2)} \sum_{2}^{\infty} \cos nx$$

only at high frequencies, while unbalance of the circuits and unbalance of light will have identical effect throughout the whole frequency range.

Before entering into details about the class *A* push-pull method it will be convenient to digress slightly to the subject of noise-reduction.

The pulsating direct current used to bias the light-valve is usually obtained by rectifying the audio signal by means of a full-wave rectifier. The open-circuit voltage output of this device can also be represented in terms of a Fourier series of the following form:

$$f(x) = \frac{2A}{\pi} + \frac{4A}{\pi(1 - n^2)} \sum_{2}^{\infty} \cos nx \qquad (n \text{ even}) \qquad (8)$$

The term $2A/\pi$ is the direct-current term used to bias the light-valve, while the harmonic sum represented by the second term at the right is usually more or less suppressed by an electrical filter. Because of this filter the direct-current term does not build up as fast as the signal, and, therefore, the beginning of each audio-frequency train will be somewhat chopped off. This effect is seldom apparent to the ear. The other effect is that the direct current will continue for some time after the audio signal has ceased. This produces at the end of each sound the familiar "swish" of surface noise, which is particularly noticeable with music of a staccato nature. The filtering action of the type of filter used with the noise-reduction circuit increases with the frequency, and any attempt to shorten the "time-constant" would result in degradation of the filtering action at low frequencies.

If we were to impress the signal represented by equation *8* upon both elements of the push-pull valve with proper polarity, then upon reproducing such records through a push-pull circuit, properly adjusted, nothing should be heard. Naturally enough, the conditions of critical balance are the same as mentioned before.

If we now introduce a moderate amount of filtering, that is, reduce the filtering of the present standard noise-reduction circuit enough to permit us to achieve a time-constant of, say, $^1/_{300}$ or $^1/_{500}$ of a second, then the alignment of the slit would cease to be critical, since the high-frequency components of the noise-reduction are no longer present.

We have now available all the elements of a good compromise, *i. e.:* the signal frequency is impressed upon the push-pull valve and is recorded in a class *A* fashion. The noise-reduction is obtained, as in the past, by rectifying the audio signal through a parallel circuit, and with filtering of moderate degree permitting the biasing current to reach its full value and to decay in a span of time as short as $^1/_{300}$ or $^1/_{500}$ of a second. This will eliminate the peculiar swishes so highly objectionable at present.

Since the only components that need to be cancelled are those of low frequency contributed by the noise-reduction circuit and of appreciably reduced amplitude, the strict balance requirements of the push-pull reproducing circuit are materially reduced.

The signal components being class *A*, will add numerically, and, therefore, the final signal is the numerical sum of the components from the two tracks.

Since the push-pull circuit will cancel the even harmonics produced during the process of exposure by the asymmetry of the film characteristic and by the behavior of the light-valve, it is possible to obtain much cleaner records and greater amplitude range.

It remains now to analyze the effect of imperfect balance upon the reproduced sound. The total input to each push-pull section of the light-valve under the new condition will be, respectively,

$$f_1(x) = E \sin x + \frac{2A}{\pi} + \frac{1}{f(\omega)} \frac{4A}{\pi(1 - n^2)} \sum_2^{\infty} \cos nx \qquad (9)$$

$$f_2(x) = E \sin x + \frac{2A}{\pi} - \frac{1}{f(\omega)} \frac{4A}{\pi(1 - n^2)} \sum_2^{\infty} \cos nx \qquad (10)$$

where $E \sin x$ is desired audio signal component, $2A/\pi$ is the direct-current bias, and

$$\frac{1}{f(\omega)} \frac{4A}{\pi(1 - n^2)} \sum_2^{\infty} \cos nx$$

represents the harmonic components from the noise-reduction rectifier not suppressed by the filter. The factor $1/f(\omega)$, which might be called the transmission characteristic of the filter, rapidly decreases with frequency; in other words, the summation term above represents substantially low-frequency components that will be cancelled out by algebraic summation of the push-pull output circuit.

Now let us suppose that the tracks are not perfectly colinear, due either to a faulty set-up of the push-pull valve in recording or to faulty orientation of the slit in reproducing. Obviously this error can be only of very small magnitude and, therefore, noticeable only at high frequencies. If the audio signal is of high frequency then the audio signal component from one track will appear out of phase with respect to the other by a small angle θ.

Therefore, we should have as the total output of the audio signal not $2E \sin x$ but $E \sin x + E \sin x_1$. Putting $x - x_1 = \theta$, we have

$$E \sin x + E \sin x_1 = 2E \sin \tfrac{1}{2}(x + x_1) \cos \frac{\theta}{2}$$

But since θ is constant for any one frequency we have

$$E \sin x + E \sin x_1 = 2kE \sin \tfrac{1}{2}(x + x_1)$$

$$\left(k = \cos \frac{\theta}{2}\right) < 1$$

In other words, the audio signal output will be of slightly lower amplitude but without harmonic distortion. This, however, is the only effect that could be noticed, since the term representing the harmonic components from the noise-reduction rectifier is absent due to the action of the filter.

Let us assume now that unbalance exists either in the reproducing circuit or in the illumination of the two tracks, or both. The amplitude of the audio signal component will be, say, E from one track and E_1 from the other, and let $E_1 < E$ or $E_1 = KE$ $(K < 1)$. Then the total audio signal will be

$$(E + E_1) \sin x = E\,(1 + K) \sin x < 2E \sin x$$

The apparent loss of volume will be

$$\text{Loss (db.)} = 20 \log_{10} \frac{2}{1 + K}$$

For the sake of clarity, if the unbalance is, say, 25 per cent, then the apparent loss of volume will be slightly greater than 1 db. This loss of volume will be present throughout the complete frequency range but without distortion to the wave form.

Under this condition of unbalance the harmonic components represented by the term

$$\frac{1}{f(\omega)} \frac{4A}{\pi(1 - n^2)} \sum_{2}^{\infty} \cos nx$$

will not be completely cancelled out, but will appear as the difference between the components of the two tracks. In the case of the numerical example above it is evident that the uncancelled amplitude will be about 12 db. lower than the amplitude of each harmonic component alone, which in itself is low due to the attenuation characteristic of the filter. The results should, therefore, be still quite satisfactory.

Without entering into extensive discussions, on the basis of push-pull class A operation over a long period of time, it appears that this system offers the most acceptable compromise of several difficult problems.

TWENTY YEARS OF DEVELOPMENT OF HIGH-FREQUENCY CAMERAS*

H. E. A. JOACHIM**

Summary.—*The high-frequency camera of the Zeiss-Ikon Company has behind it twenty years of development. The original model, designed by H. Lehmann, appeared in 1917 as the Ernemann high-frequency camera. The principle is based upon optical compensation, to which end a reflecting drum with exterior mirrors was employed as compensating element. Films were exposed at a frequency up to 500 pictures per second.*

The new model, which appeared upon the market in 1930, likewise depends upon mirror compensation, except that instead of the exterior mirrors a reflector drum is supplied with mirrors on the inside according to the patents of Professor Thorner.

In this way an extraordinarily simple driving mechanism has been obtained, and a very compact form; with a capacity of approximately 60 meters of standard 35-mm. film, the size of the camera does not exceed the dimensions of a normal cine camera. The latest model permits an exposure frequency of about 1500 pictures per second.

The camera is suited for use in technical photography of all kinds. It can be equipped with intermediate lenses for close-ups or with a supplementary distance tube for distance exposures. For photographing micro high-frequency films a particular apparatus has been developed.

To evaluate the exposures, a time-marking device is used, in which a glow-lamp, controlled by an electric tuning-fork, produces time records on the film at periods of $^{1}/_{1000}$ *sec.*

Whenever discussing the history of the motion picture we are accustomed, at least in Europe, to regard as the birthday of cinematography the date on which the first photographically recorded series of pictures was shown before a large public audience; that is to say, the year 1895.

Taking that date for granted, it seems strange that one special branch of cinematography, high-frequency or slow-motion cinematography, is older than standard cinematography. In the annals of cinematographic history the high-frequency camera stands first and foremost, and the problems surrounding it constitute the original root from which the sturdy tree of cinematography has grown.

---

* Presented at the Spring, 1937, Meeting at Hollywood, Calif.; received July 9, 1937.

** Technische Hochschule, Dresden, Germany.

In 1874 the French astronomer, Jules Janssen, created the photographic revolver, by means of which he made a photographic record of the transit of Venus across the sun's disk, at a frequency of 50 to 60 pictures a second. In 1877 the American photographer, Muybridge, made his celebrated photographs for studying the movements of the horse, which movements he was soon able to demonstrate by means of the so-called "wheel of life" (*Zoötrope*).

These two demonstrations must undoubtedly be regarded as the beginning of high-frequency cinematography—that is, of the method of reproducing at retarded speed, pictures taken in rapid succession, an effect known in Germany as "time magnification."

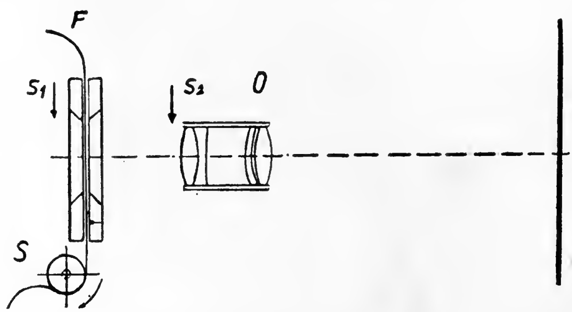


FIG. 1. Scheme of optical compensation by moving lenses (Jenkins 1894). The objective *O* is moved parallel to film *F*, so that the picture of the object rests steady upon the moving film *F*.

The French inventor, Jules Marey, in 1894 succeeded in making cinematographic pictures at speeds up to 120 a second by means of an intermittently moving negative photographic strip. His pictures of a falling cat, taken at that time at a frequency of 60 pictures a second, are well known. Reproduction of the pictures by means of the Zoötrope could be retarded six times.

Apparatus with Continuous Movement.—The American inventor, Jenkins, deserves credit for having, in 1894, increased the taking frequency considerably by abandoning for the taking apparatus the principle of the intermittently moving picture strip and by adopting the continuously moving picture strip. By this method he obtained a filming frequency up to 250 pictures per second. The principle of this camera is illustrated in Fig. 1. By means of the film sprocket *S* the film *F* is drawn past the film-gate in continuous motion. To enable the lens O to produce a well defined picture of the object, it must be moved in the same direction and with practically the same speed as the film. To achieve this, fifteen lenses were mounted on a rotating disk.

Another method of optical compensation by means of a reflecting drum was put on the market by the Frenchman, Reynaud. This apparatus was known as a *Praxinoscope* (Fig. 2). Instead of the simple reflecting drum, the French inventor, Mortier, in 1898 used an arrangement of square mirrors to project uninterrupted moving pictures (Fig. 3). In this apparatus the compensating mirrors lie between the film and the lens. The system of compensation may be described as interfocal compensation. The projected pictures show great lateral oscillation, as the virtual pictures lie in the axis of the mirror drum and oscillate.

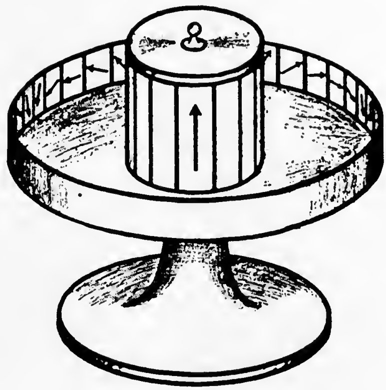


FIG. 2. Praxinoscope with mirror drum (Reynaud 1877); for inspection of moving pictures.

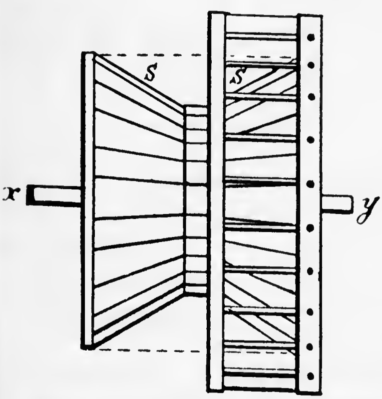


FIG. 3. Revolving drum with square mirror (Mortier 1898); for projection.

Thorner in 1900 overcame this trouble with his extrafocal mirror compensation (Fig. 4) whereby the separate mirrors of the reflecting drum lie outside the focal length, between the lens and the projection screen. The sprocket for film transport was rigidly connected to the reflecting drum m, and the perforated film traveled on the sprockets k on the circumference of the drum.

The illumination of the film pictures took place in the direction of arrow i. The light rays, directed parallel by the objective O, are thrown upon the prism p by the mirror of the reflecting drum m.

The diaphragms b, in the film drum, serve for separating the light-beams emanating from the various film pictures between the film and the lens. A variation of this form of mirror compensation was made in 1905 by the Austrian inventor, Musger, in which the rigid connection between the reflecting drum and the film transport sprocket was eliminated in favor of a gear-wheel coupling between these two parts.

The External Reflecting Drum.—Fig. 5 shows diagrammatically the range of optical compensation. The film F is fed continuously downward by the sprocket T. The objective lens O, having a focal length

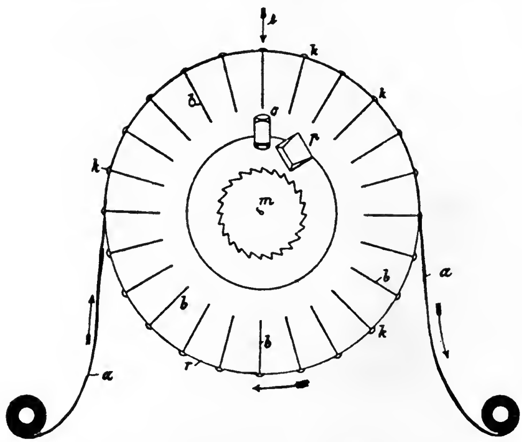


FIG. 4. Extrafocal mirror compensation (Thorner 1900, German pat. 124,932). The mirror drum m is outside the focal distance of the projection lens o.

f, is opposite the film. In front of the objective is the reflecting drum with pivot A. In Fig. 5 only one of the mirrors, S_1, is drawn in full detail, whereas the two laterally placed mirrors S_2 and S_3 are only roughly sketched. The object should be imaged in the direction Z, so that the optical axis of the taking apparatus XYZ is broken.

The mirror drum is coupled to the transport sprocket T by geared wheels. The connection between the mirror drum and the transport sprocket must be such that if one point P on the film is moved over the distance s toward P', the mirror S_1 is revolved through the angle $\sigma/2S'$ so that the light-ray issuing from the object Z is concentrated upon P'. The angle POP' then equals σ, or, in other words, the double of the revolving angle of the mirror drum, and it must have the value

$$s = f \tan \sigma \qquad (1)$$

Optical compensation requires that the rotational speed of the reflecting drum, as well as of the film transport, be constant. Therefore, the film distance s and the angle σ are proportionate to time t; that is,

$$s = c_1 t \qquad \sigma = c_2 \qquad (2)$$

Instead of (*1*) we can substitute:

$$c_1 t = f \tan (c_2 t) \qquad (3)$$

This conclusion must be valid for all values of t, or time, which is possible only when t is very small, so that the tangent may be substituted by its argument. The optical compensation is correct,

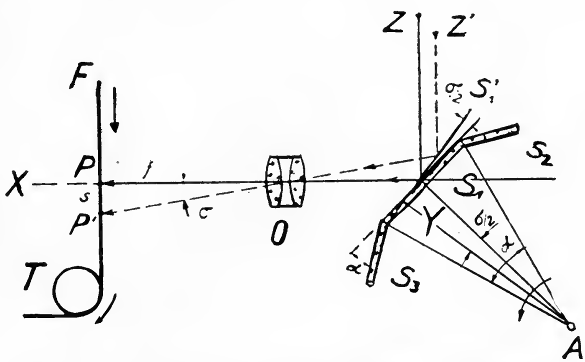


FIG. 5. Diagram of Thorner mirror compensation. During the revolution of the mirror drum $S_1S_2S_3$, the picture P of the object Z rests steadily upon the moving film F.

therefore, only for small values of σ. For large angles of rotation and large film distances (s) a skid is produced by the tangent discrepancy that leads to lack of sharpness in the direction of the film movement.

The definition of the picture can be improved by narrowing down the film-gate by means of a sliding stop, which allows for each point of the film a very much shorter exposure time and a proportionally shorter exposure distance. In general, the exposure distance is made not larger than the height of the picture. In the design of the camera with the compensating mirror drum, it is important that the focal length f of the lens, and also the number of mirrors n, be accurately determined from the picture spacing a. The angle α between the two mirrors S_1 and S_2 must be so calculated that the double distance PP' for the angle σ (= α) is equal to the picture spacing a on the film.

The beam of light emanating from the object Z, if reflected over two mirrors, must produce two images upon the film, the spacing between which is equal to the picture spacing a. Therefore, from equation *1*,

$$a = 2f \tan \alpha$$

Now $\alpha = 2\pi/n$; so for a small angle α the result is

$$f = \frac{n\alpha}{4\pi} \quad (4)$$

To avoid the "skid" when the slit diaphragm in the film-gate is wide open (for larger exposure distances), various methods may be applied. We can either bend the film-guide toward the lens, or place a cylindrical lens in the path of light in front of the film-gate (as described in German patent 464,509). In this manner the tangent skid is avoided, and with optical compensation of this type well defined pictures will result. It goes without saying that the picture definition of such machines employing optical compensation can not be identical to that of instruments employing intermittent movement of the film, since the inaccuracy of mechanical gearing between the mirror drum and the film sprocket can never be entirely eliminated.

The High-Frequency Camera of Lehmann.—The first to succeed in constructing and satisfactorily operating a high-frequency camera with mirror drum was H. Lehmann, who began his first designs in 1913. The first slow-motion camera of this type was put on the market in 1916 by the firm of Ernemann, under the name of *Zeitlupe*, meaning "time magnifier."

Fig. 6 shows the interior of the camera. The reflecting drum is equipped with 40 mirrors. Behind the opening through which the light enters the camera is a mirror that throws the incoming light-beam upon the reflecting drum. The lens behind the latter concentrates the beam upon the film strip located in the film-guide. Directly below the film-guide is the sprocket for moving the film. Feed and take-up sprockets are located above and below the film-guide. The capacity of the film cassettes is 375 feet. The complete apparatus is shown in Fig. 7, fastened to a four-legged support. The construction of the table is such as to provide lateral and vertical movement. In the front panel are placed the handle for manual operation, the buttons for adjusting the sliding diaphragm and the iris diaphragm on the lens, and a ground-glass finder. On the left panel is the motor for the mechanical drive, which operates the apparatus by magnetic coupling.

Before operating the Zeitlupe, the motor is started and at a given moment is connected with the machine by magnetic coupling. When operated by hand, a frequency of 300 exposures a second is

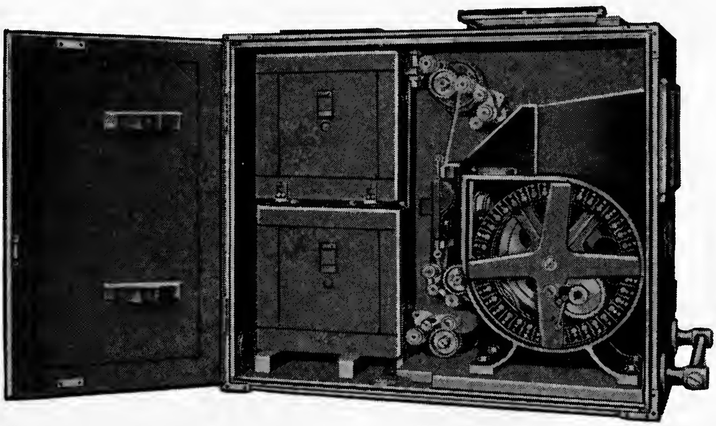


FIG. 6. Lehmann's high-frequency camera (Ernemann *Zeitlupe* 1916); view of interior parts with mirror drum.

attained; whereas when the apparatus is driven by motor a frequency of 500 can be reached.

The slow-motion camera in this form was used during the War for various industrial, technical, and ballistic purposes. The more frequent use has been for photographing sporting events. The well known film by Dr. Frank, entitled *The Wonders of Ski Sporting*, was made with this camera.

General introduction of the camera for cinematographic work was handicapped by its bulk and unhandy form, and by its great weight of some hundred pounds. In the meantime the cinematographic industry had succeeded in making apparatus employing intermittently moving film strips, up to a frequency of 200 to 250 pictures a second; so that the maximum speed of the old Zeitlupe, 500 pictures a second, did not offer such great advantages as to justify the higher price of the apparatus.

Interior Mirror Drum.—In order to improve the apparatus with regard to shape and efficiency, the design was entirely changed in 1927 to 1929, and instead of employing Thorner's exterior mirror drum, the *interior* mirror drum invented in 1911 by the same inventor was used. The advantage was that the film could be placed in the interior of the mirror drum, reducing the dimensions of the apparatus to a very great extent. With a capacity of 175 feet, the size of the taking camera was not very much greater than that of an ordinary motion picture camera.

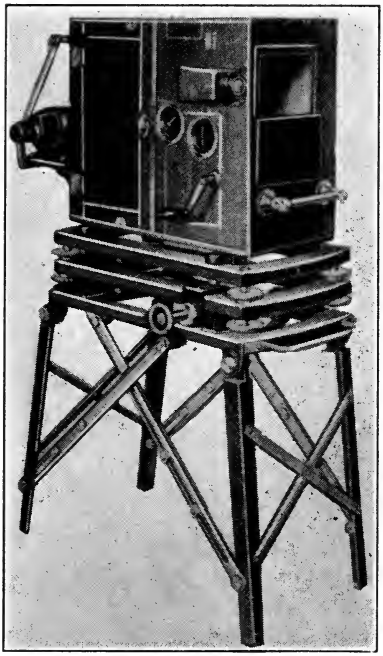


FIG. 7. Lehmann's high-frequency camera (1916).

On the other hand, the interior mirror drum offers certain advantages which depend upon its optical qualities, as Fig. 8 will demonstrate. Three parallel beams of light, *1*, *2*, and *3*, coming from the object and falling upon three consecutive mirrors, *1*, *2*, and *3*, of the mirror drum, are reflected by the interior mirror drum in a manner different from the way they are reflected by the exterior drum. In the first case, the reflected beams, *I*, *II*, and *III*, are divergent, as if they originated from a virtual point inside the drum. With the interior mirror drum the rays, *I*, *II*, and *III*, reflected by three consecutive mirrors, *1*, *2*, and *3*, seem to be concentrated in such manner as to meet at the point *Q*, a sort of focal point outside the drum.

With the taking lens system placed at *Q*, the beams *I*, *II*, and *III*, originating from three different mirrors, will pass through the objective. With the exterior drum, however, the only beam of light that passes through the objective is the beam *II;* the other beams, *I* and *III*, falling outside the taking lens. It therefore follows that the light-beam originating from the interior mirror drum is of greater intensity than that originating from the exterior mirror drum.

New Type of Time Magnifier or Zeitlupe.—The construction of the new type of "time magnifier" is shown by Figs. 9 and 10. Fig. 9(*a*) shows the apparatus viewed from the front when open, and Fig. 9(*b*) designates the various parts. In the interior part of the mirror drum *S* the film is contained in a double magazine *C*, with the take-up reel K_1 and the feed reel K_2. The film leaves the magazine at the film slit R_1 and returns into it through the slit R_2. Sprocket *T* moves the film in the direction of the arrow to the take-up reel K_2, while *N* acts as hold-back sprocket. Between the film channel R_1 and the transport sprocket *T*, is located the film guide *B*, with the

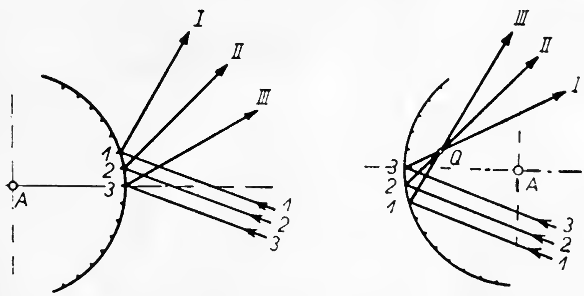


FIG. 8. Optical scheme for exterior and interior mirror drum; the beam of light is reflected by consecutive mirrors *1, 2, 3,* in the direction *I, II, III.* Interior mirror drum with "focal point" *Q*.

exposure gate into which the light-beam is concentrated by the taking lens *O* after having been reflected by the mirror drum. There are two additional mirrors, one located between the light entrance and the mirror drum, the other between the lens *O* and the film-guide *B*.

The lens is of the Ernostar type *f*/1.9. Due to loss of light on the surfaces of the intermediate mirrors, the aperture of *f*/1.9 is reduced to practically *f*/2.7. We have previously shown that the focal length of the taking lens depends on the number of mirrors on the drum. Therefore, the focusing of the camera can not be done by displacing the lens in the direction of the optical axis. It must be done by introducing secondary lenses, which are placed in the light entrance aperture of the apparatus. Without these secondary lenses the camera is focused at infinity.

Fig. 10 is a cross-section of the camera, looking from the rear left to the front. The driving motor M is on the outside of the housing G, with its shaft W supported by the bearings L_1 and L_2. The mirror drum S is attached to the end of the motor shaft. The film

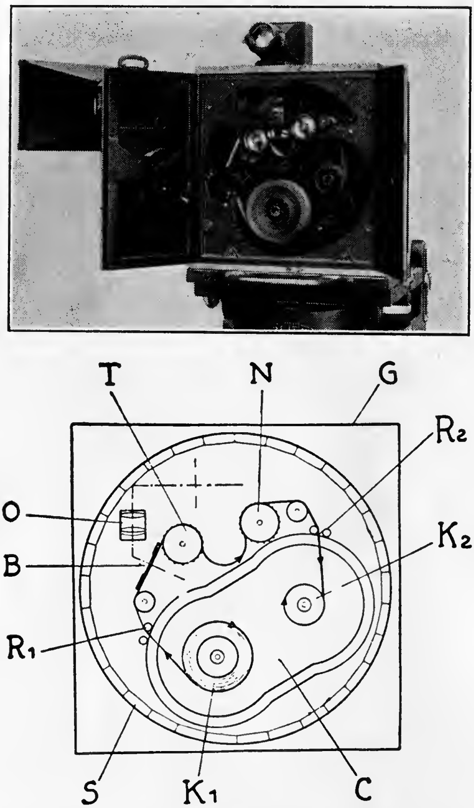


FIG. 9. (*a*) *Upper:* High-frequency camera, new type 1930; (*b*) *lower:* view of inside parts with 175-ft. film magazine.

sprockets T and N, as well as the take-up reel K_2, Fig. 9, are driven by gears on their shafts engaging directly with the inside gears of wheel E.

By a magnetic coupling U, the wheel E can be coupled to the shaft of the motor. Two brushes, V, serve to feed the current to the magnetic coupling. In order to start the camera, the motor, with mirror drum and magnetic coupling device, is first of all brought to a high revolving speed. At the moment of the exposure the magnetic coupling is actuated so that the film quickly reaches its constant speed. At that moment, the compensating mirrors come into full action, so that the pictures on the film are perfectly sharp.

The construction of the new type of "time magnifier" is such that under all conditions a frequency of 1500 pictures a second can be reached. Fifteen to twenty feet of film are wasted before the coupling is effective. A frequency of 1500 pictures a second means a film speed of 70 miles an hour.

Time-Recording Device.—For research or testing purposes, it is necessary to know the exact speed of the film; that is to say, the frequency of the pictures. For this purpose a time-recording device

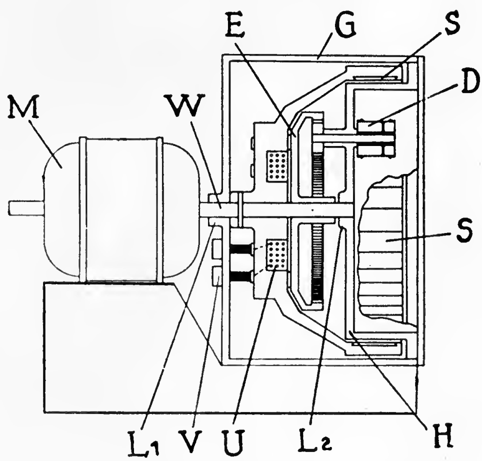


FIG. 10. Cross-section of new type of camera, showing magnetic coupling of mirror drum with motor shaft.

has been provided. It consists of a glow-lamp for producing recording-light marks upon the side of the film. The light is checked by an electric tuning fork having a frequency of 1000 cycles per second. Thus the edge of the film shows a time record in $^1/_{1000}$ths of a second, so that the picture speed can be easily calculated.

Microphotographic Time Magnifier.—As soon as a "time magnifier" for ordinary cinematography had been developed, the apparatus was applied to microphotographic purposes, especially in zoölogical research work such as bacteriology. In all research work pertaining to microörganisms, most movements to be studied are of such high speed that ordinary cinematography does not suffice to show the motion.

The difficulties encountered were to get adequate illumination and to provide convenient means of observation before and during the exposure. The apparatus used for the purpose is diagrammed in Fig. 11.

The lamp is an 80-ampere arc lamp with high-intensity carbons. The light is concentrated by a condenser upon the mirror of the

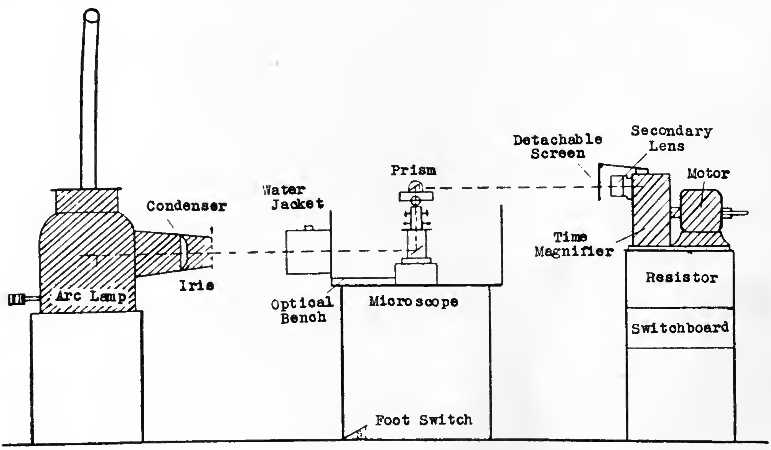


FIG. 11. Diagram of microphotographic time magnifier.

microscope. Between the condenser and the microscope are inserted an iris shutter and a water-cooling jacket, to protect the microorganisms in the microscope against destructive heat.

Above the ocular of the microscope a rectangular prism serves to reflect the light-beam in the direction of the "time magnifier." The microscope has been especially designed by Carl Zeiss. The ocular lens has been removed, so that the magnifying lens consists only of the microöbjective, which has been corrected to the longer picture distance. To provide for proper adjustment, the picture itself is imaged upon a detachable screen in front of the camera. For this short distance from the camera the secondary lens system must be used. To have the object under continuous observation, an auxiliary ocular has been inserted for the light-beam between microscope and reflecting prism. The camera has been used for various zoölogical purposes, and it has been possible to make exposures up to 1000 pictures a second with an enlargement of 600 to 700 times.

GRAIN SIZE DETERMINATION AND OTHER APPLICATIONS OF THE CALLIER EFFECT*

J. EGGERT AND A. KUESTER**

Summary.—*It has been shown that the median grain diameter of a developed photographic layer is a logarithmic function of the ratio of specular to diffuse density (Callier quotient). Also, it is possible from the Callier quotient to evaluate the number of grains per unit area, the mass of silver per unit area, and obtain a value that parallels the graininess of the photographic deposit.*

As far back as 1890, Abney recognized[1] that a developed photographic layer not only absorbs a portion of the incident light but also scatters some of it. The amount scattered determines the difference between the diffuse density $D\#$ and the specular density D'' of the layer. The diffuse density is obtained by measuring the total emergent light and the specular density by measuring only those emergent rays that are approximately normal to the layer surface. Thus the diffuse density $D\#$ will always be equal to or smaller than the specular density D''. The concept of specular and diffuse density may be explained by Fig. 1.

Fig. 1(A) indicates a developed photographic plate with a beam of light entering it normal to its surface. This is scattered by the developed emulsion. If the light-measuring device is close to the film, in the position shown, all the scattered light will be intercepted and measured. The density calculated from this light value is the diffuse density. In Fig. 1(B) the same layer is illuminated as above, and likewise scatters part of the light. Here, however, the light-measuring device is placed so as to intercept only the unscattered light. From this measurement the specular density is computed.

Callier[2] in his original paper mentions that the ratio of the specular to the diffuse density $D''/D\#$, is closely related to the grain size and increases with it. This ratio, expressed as $D''/D\# = Q$, has come to be known as the Callier quotient. Later Threadgold[3] investigated the

* Translated and read by K. Famulener, Agfa-Ansco Corp., Binghamton, N. Y., at the Fall, 1937, Meeting at New York, N. Y. Received October 4, 1937.

** I. G. Farbenindustrie Film Fabrik, Wolfen, Germany.

relation between the graininess and the scattered light, and, following Renwick's suggestion,[4] employed the Callier quotient.

The following work was undertaken, first to give quantitative value to the qualitative relation between the grain size of photo-

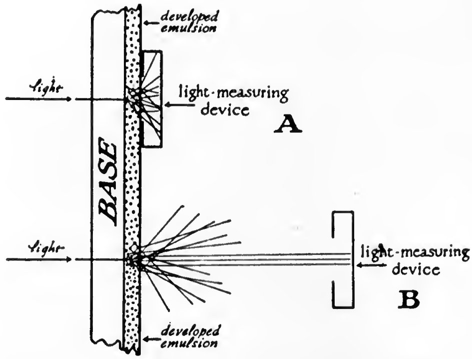


FIG. 1. Diagram illustrating concept of (*A*) diffuse density and (*B*) specular density.

graphic materials and the amount of light they scatter, and second, to show several possible applications of a measuring method based upon the Callier effect.

In order to determine the diffuse and specular densities the arrangement shown in Fig. 2 was used. This apparatus has been

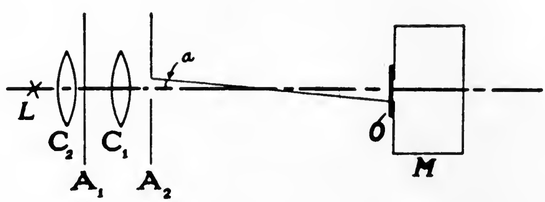


FIG. 2. Diagram of apparatus used for determining the Callier quotient.

thoroughly described by H. Brandes.[5] The small square aperture at A_1 is illuminated by the light-source L and the condenser C_2. The lens at C_1 images this aperture on the opal glass O through the aperture A_2. The photocell M of a densitometer is located behind O. If the developed film is placed at A_2, only the light passing through approximately normal to the plane of the film will strike the photocell M. Thus the specular density is determined.

If, on the other hand, the film is placed in contact with the opal glass at O, all the light passing through it will be measured by the photocell M, and the diffuse density determined. If the photocell is very close to O, the opal glass may be eliminated.

The value of the specular density and, therefore, the Callier quotient Q, depends, to a great extent, upon the optical arrangement and the color of the light. For different values of the angle between the optical axis and the extreme rays passing through A_2 and entering O (that is, the angle α), a layer of medium grain size with a diffuse density of 0.50 has the specular density values shown in Table I.

TABLE I

Values of D″ when D# = 0.50

α (Degrees)	D''
3.0	0.69
0.57	0.79
0.29	0.87

If α is kept constant at 0.57 degree and the wavelength of the light-source varied, the results shown in Table II are obtained:

TABLE II

Color	D''
Infrared	0.85
Red	1.09
Green	1.15
Blue	1.22

It is therefore apparent that the smaller the value of α and the shorter the wavelength of the light-source, the greater is the specular density and, necessarily, the Callier quotient.

In the following work, all measurements were made with α = 0.57 degree; that is, the ratio of the opening at A_2 to the distance from A_2 to O was 1:100. Also, all measurements were made with a normal low-voltage lamp and a caesium cell with high infrared sensitivity (the peak at 8600 Å). Since the color of the light greatly influences the values obtained for the specular density, all determinations, in order that they may be comparable, must be carried out with the same colored light and on similarly colored silver deposits.

The results obtained in the following work refer only to those layers that contain uncolored, black, developed silver grains.

It might be well at this point to make it clear that only the grains actually in the layer cause scattering of the light. Grain images printed from a negative on to a positive do not affect the light-scattering properties of that positive. If, for example, a negative

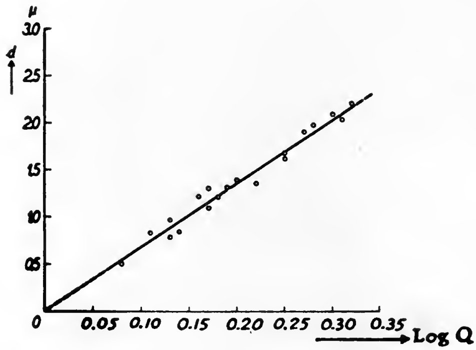


FIG. 3. Relation between average grain diameter (d) and Callier quotient (Q).

having a Callier quotient of 2.0 is printed upon a grainless positive, the Callier quotient of that positive will still be 1.0, because there is no substantial graininess in the positive material. If, however, the print is examined, images of the negative grains will be seen.

THE RELATION OF THE CALLIER QUOTIENT TO GRAIN SIZE

First the relation of the Callier quotient Q to the grain size, that is, the median grain diameter d, was investigated. For this work the median grain diameter d of different kinds of film was determined according to the method of Schaum and Bellach.[6] This is done by diluting the developed emulsion and spreading it out so as to have a layer not more than one grain thick. A photomicrograph is made of this and the average grain diameter determined by measuring the area of the projected grains and assuming them to be circular. The diameter is computed in microns.

The Callier quotient of the initial densities (*i. e.*, the densities before the emulsion was prepared for photomicrographic determination) was also determined and it was found that the grain diameter

d and the quotient Q were related to each other independently of the densities. (See Fig. 3.)

However, it is possible that the Callier quotient varies not only with the grain size, but also with the emulsion thickness and the grain distribution. In order to settle this question, artificial silver grain emulsions of uniform grain size and varying thickness and density were prepared. This was done by melting a developed emulsion, thinning it with gelatin, and coating it in various thicknesses and concentrations on glass plates.

If the value of the Callier quotient depends upon the layer thickness, or the density, then each of these coatings would give a different value for Q. As Table III shows, the Callier quotient Q is constant in all cases. In other words, for silver deposits with a uniform median grain diameter, Q is a constant independent of the layer thickness, density, and grain distribution.

TABLE III

Callier Quotient of Artificially Prepared Silver Grain Emulsions of Similar Grain Size

Coating Thickness (Microns)	Density D''	Callier Quotient $Q = \frac{D''}{D\#}$
15	0.23	1.29
15	0.29	1.31
15	0.36	1.30
15	0.46	1.28
15	0.60	1.30
15	0.75	1.29
15	1.14	1.30
30	0.42	1.30
30	0.57	1.30
30	0.72	1.29
45	0.65	1.31
45	0.86	1.33
45	1.14	1.30

Table III justifies the relation shown in Fig. 3. Since the curve is a straight line passing through the origin, its general equation will be

$$d = C \log Q \qquad (1)$$

In this particular case, which applies to the experimental conditions already outlined, the value of C, which is a characteristic of the apparatus, is 6.8.

We have, therefore, the relation between the grain size and density in parallel and diffuse light:

$$d = C \log D'' - C \log D\# = C \log \frac{D''}{D\#} = C \log Q \qquad (2)$$

It must be emphasized that only the light reduction (or density increase) caused by the silver may be considered. If, for example, a film has a gray base, the density of the base must be determined separately and subtracted from the values for the specular and diffuse density. Moreover, if, besides the silver, a light-scattering medium (such as a line-screen or matte surface) is present, no determination is possible by the above method. In general, the absorption or scattering effect of a clear, colorless film or plate may be neglected.

DETERMINATION OF NUMBER OF GRAINS PER UNIT AREA

It is possible from the general equation given above to determine the number of grains Z per unit area of a developed photographic layer. The relation between the diffuse density, the number of grains, and the grain area is as follows:[7,8]

$$D\# = \frac{(Z\ A)}{2.3} \qquad (3)$$

where A equals the median area of the projection of a single grain, and is considered circular. Then

$$A = \pi \frac{d^2}{4} \qquad (4)$$

Since the median grain diameter d and the diffuse density $D\#$ may be determined from density measurements, Z is easily obtained as follows:

$$Z = \frac{2.3\ D\#}{A} \qquad (5)$$

$$Z = \frac{(2.3)\ (4)\ (D\#)}{\pi d^2} = \frac{2.93\ D\#}{d^2} \qquad (6)$$

Table IV compares the value of Z obtained from the density measurements and by actual count.

TABLE IV

Determination of Number of Grains per Square Centimeter of Emulsion Surface

Case	$D\#$	Z Calculated from $D\#$ and D''	Z Observed
1	0.53	2.7×10^8	2.8×10^8
2	0.47	1.7×10^8	1.7×10^8
3	0.42	1.5×10^8	1.6×10^8
4	0.58	1.2×10^8	1.1×10^8

DETERMINATION OF PHOTOMETRIC CONSTANT FROM THE CALLIER EFFECT

A third application of the Callier quotient is the determination of the amount of silver per unit area of a developed photographic layer.

From numerous measurements on various kinds of emulsions that have been processed in various ways, it has been established empirically, that the amount of silver per 100 square centimeters of surface depends upon the density and the grain size, while it is independent of the type of emulsion, the developer formula, and the time of development.[9] Instead of the amount of silver M per 100 cm.^{2}, the photometric constant as defined by Hurter and Driffield may be used.

$$\text{Photometric Constant} = P = \frac{M}{D\#} \quad (7)$$

From this it appears that P is directly proportional to the median grain diameter. This relation is shown in Fig. 4.

The amount of silver per 100 cm.^{2} of surface may be determined in the following manner: $D\#$ and D'' are measured and the median grain diameter d determined by equation *1*. Knowing d, the photometric constant P is determined from Fig. 4, graphically. Rearranging equation *7* we obtain

$$M = P\,D\# \quad (8)$$

so by multiplying the diffuse density by the photometric constant the amount of silver per 100 cm.^{2} of emulsion surface is obtained.

It is evident that such a determination does not give as accurate results as an analytical method. The inherent errors of density measurement cause variations that depend upon the density measured. The lower the density and the smaller the grain diameter, the greater is the error. With densities that are not too low (greater than 0.4), the average accuracy is ±5 per cent. This has been discussed thoroughly elsewhere,[9] and it has been shown that the errors with this method correspond to the variations that are due to errors in determining the density.

THE EVALUATION OF GRAININESS WITH THE CALLIER QUOTIENT

It was of interest to learn whether any relation exists between the median grain diameter and the graininess. By "graininess" is meant that apparent graininess that one sees when examining a developed photographic layer under low magnification, or that shows visually in an enlargement. It is known that the median grain size decreases with an increase of density.[4]

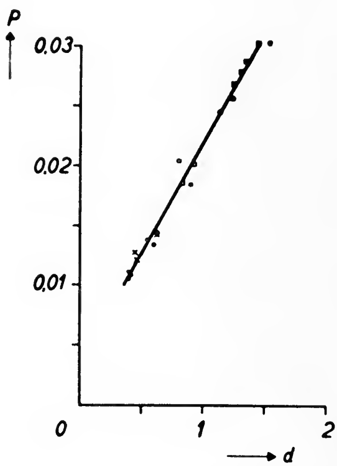


FIG. 4. Relation of photometric constant (P) to median diameter (d).

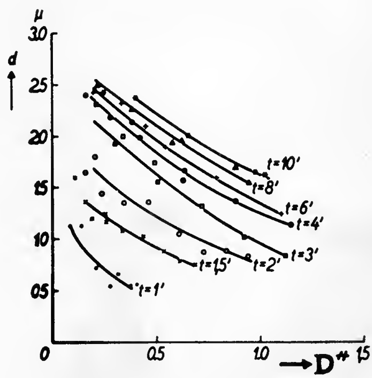


FIG. 5. Relation between median grain diameter (d) and diffuse density ($D\#$), for various times of development.

On the other hand, it is also known that the graininess at first increases with the density, reaching a maximum at approximately $D\# = 0.30$ to 0.40 and then decreases.[10] If the grain size and the graininess of several emulsions are to be compared, the comparison must be carried out at the same density. For the determination of the grain size of a developed photographic layer with the Callier quotient Q, we refer to the diffuse density $D\# = 0.50$. The grain size is arbitrarily taken as 100 times the log of Q for a layer with a diffuse density of 0.5 and is indicated by K.

$$K = 100 \log \frac{D''}{D\#}$$

when $D\# = 0.50$

The grain size K was determined for a large number of different films from light-scattering measurements to see whether a parallelism existed between this and the graininess apparent when the film was sufficiently enlarged. In all cases layers with a diffuse density of 0.5 were used. On film developed to a diffuse density of $D\# = 0.50$, K was first determined. Then photomicrographs were made and enlarged 250 diameters, the density and contrast being kept equal. These photomicrographs were arranged in their order of visual graininess by several observers. The results are shown in Table V.

TABLE V

Photomicrographs of $D\# = 0.50$ Arranged according to Increasing Visual Graininess

Observer 1	Observer 2	Observer 3	Observer 4
18	18	18	18
21	21	21	21
26	26	26	26
29	29	29	30
32	32	28	28
32	30	32	32
28	28	30	32
30	32	34	29
34	34	32	34
36	36	36	36
38	38	38	38

It is noticeable that the observers in general arrange the films in the same sequence as the increasing value of K. We may conclude that, with negatives of equal density, the grain size and graininess are approximately parallel.

That the visual graininess of prints, made under the same processing conditions, is parallel to the K value of the negative may be shown by the following tests:

Pictures were taken of the same subject under the same conditions with ten different kinds of film. In each case a range of exposure was used. Negatives of approximately the same density were enlarged 10 diameters in a condenser enlarger, under identical conditions. The exposure and development of the enlargement were selected in each case so that the most favorable impression of the picture with regard to contrast and density was obtained.

These enlargements were given to several observers for visual evaluation of the graininess. Table VI gives the order assigned by the different observers as well as that assigned by the same observer on three different days (indicated by *a*, *b*, and *c*).

TABLE VI*

10-Diameter Enlargements Arranged in Order of Increasing Graininess

Observer 1 a	Observer 1 b	Observer 1 c	Observer 2	Observer 3	Observer 4	Observer 5
18	18	18	18	18	18	18
21	21	21	21	21	21	21
26	26	26	26	26	26	26
30	29	28	28	28	29	29
29	30	29	30	30	30	30
28	32	30	29	29	28	32
32	28	32	32	32	32	28
32	32	32	32	32	32	32
34	34	36	34	36	34	36
36	36	34	36	34	36	34

Here also a parallelism is found between the K value of the negative and the visual graininess of the print.

REFERENCES

[1] ABNEY: *J. Soc. Chem. Ind.*, **9** (July 31, 1890), p. 722.
[2] CALLIER, A.: *Zeitsch. Wiss. Phot.*, **7** (1909), p. 257.
[3] THREADGOLD, S. D.: *Phot. J.*, **72** (1932), p. 348.
[4] RENWICK, F. F., AND BLOCH: *Phot. J.*, **55** (Feb., 1916), p. 49.
[5] BRANDES, H.: *Veroeff. Afga*, **4** (1935), p. 58.
[6] SCHAUM, K., AND BELLACH, V.: *Phys. Zeit.*, **4** (1902), p. 177.
[7] EGGERT, J., AND KUESTER, A.: *Kinotechnik*, **16** (1934), p. 127.
[8] ARENS, H., EGGERT, J., AND HEISENBERG, E.: *Veroeff. Agfa*, **2** (1931), p. 28.
[9] EGGERT, J., AND KUESTER, A.: *Kinotechnik*, **18** (1936), p. 381.
[10] ROSS, F. E.: "The Physics of the Developed Photographic Image," *D. Van Nostrand Co.*, New York, N. Y. (1924), p. 25.

DISCUSSION

MR. SHEPPARD: What method was used to determine the mean grain size from the point of view of the distribution of grain sizes—an arithmetical mean of 100, or how many counts?

MR. FAMULENER: I do not know how many calculations were made, but the method was purely arithmetical. The area of the individual grains on a photomicrographic breakdown was determined by Schaum and Bellachs' method; that is, the areas were measured, and the grains were assumed to be circular, and then the grain size was determined from those values.

MR. SHEPPARD: But the distribution of sizes was not determined?

MR. FAMULENER: No; merely the average. The distribution was not plotted against the diameter.

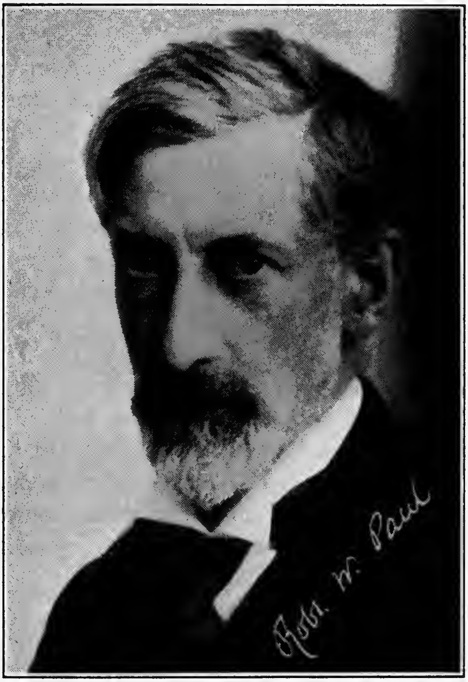
---

* The values of graininess, K, in Tables V and VI were determined with visual apparatus.

REPORT OF THE HONORARY MEMBERSHIP COMMITTEE TO THE BOARD OF GOVERNORS*

Summary.—*A brief résumé of the accomplishments of Robert William Paul in the motion picture field. At a meeting of the Society of Motion Picture Engineers on October 11, 1937, Mr. Paul was elected an Honorary Member of the Society.*

The Honorary Membership Committee has the honor to present the name of Robert William Paul for Honorary Membership in the Society. This proposal has the unanimous approval of the Historical Committee.



ROBERT WILLIAM PAUL

By his ingenious design of many instruments necessary to the development of the motion picture, Paul distinguished himself and enriched the history of this industry. He was one of the first pro-

* Presented at the Fall, 1937, Meeting at New York, N. Y.

ducers and exhibitors of motion pictures. During his association with the industry for sixteen years (1894–1910) his work embraced all branches of activity in the development of the motion picture. In 1894, when Paul became interested in this field, the status of the art was somewhat as follows:

Edison and Dickson completed their first camera using rollable film in 1888–89 and began making short lengths of picture (47 feet long). The studio where the bulk of these films was made was completed in February, 1892. Many films were produced for examination with the peephole *kinetoscope* between 1892 and 1895, when Dickson left Edison. The camera was so large and heavy that the pictures were all of vaudeville subjects. No satisfactory projector had been developed by Edison or his coworkers up to December, 1895, when Edison learned of the Armat *vitascope* and shortly afterward witnessed a demonstration.

Jenkins and Armat gave the first public demonstration of their projector (*phantoscope*) in September, 1895, at the Cotton States Exposition in Atlanta, Georgia. Armat then made important changes in the machine and subsequently remolded it to make it of commercial value. The improved projector, known as the *vitascope*, was used for a public exhibition in New York City, April 23, 1896.

Lumière began his researches on a camera and projector in 1894, and demonstrated them in March, 1895, at an industrial conference. The first exhibition for which admission was charged was given December 28, 1895, in Paris.

The work described below under Sections 1–7, inclusive, is considered, therefore, to be contemporaneous with the work of Lumière and Armat. It is concluded, therefore, that Robert Paul pioneered in the evolution of the motion picture camera and projector, and influenced greatly the development of the motion picture industry in Great Britain. Mr. Paul's accomplishments may be summarized as follows:

(*1*) Designed and built (with Acres) a camera with cam-driven intermittent movement (1895).

(*2*) Designed and built printing and developing apparatus.

(*3*) Designed and built an improved camera with a modified Geneva movement (1895). The camera was light and portable, as compared with the Edison and Dickson cameras.

(*4*) Designed and built a projector with 7-tooth wheel intermittent movement (1895–96). (For description, see *English Mechanic*, Feb. 21 and Mar. 6, 1896.)

(*5*) Designed and built an improved model projector having a revolving drum shutter cut away on two sides and equipped to show lantern-slides as well as motion pictures. Used arc or limelight (Brit. Pat. No. 4686, Mar. 2, 1896). Projector and camera preserved in Science Museum, London.

(*6*) Designed and built a three-slot star-wheel intermittent projector with a 30-degree shutter having a light-to-darkness ratio of 11 to 1 (1899) (Brit. Pat. No. 487, 1899).

(*7*) Gave the first entertainment with the projector known as *theatrograph*, at Finsbury Technical College, London, Feb. 20, 1896. (Same date as the first showing of Lumière's projector in England.)

(*8*) Built the first motion picture studio in England used for commercial production at Muswell Hill, N. London (1899). (Described in *Strand Magazine*.)

(*9*) Gave many exhibitions in and around London, and supplied pictures made under his direction for numerous exhibitions.

(*10*) Made pioneer investigations in trick photography and slow-motion studies of a scientific nature for distribution.

(*11*) Made some of the earliest news or topical pictures, during 1896, in Portugal, Spain, and Egypt as well as in England. Pictures shown with Paul's projector on the *S. S. Norman* on a trip to South Africa, April, 1896, were probably the first pictures exhibited at sea. Photographed the Prince's Derby in June, 1896, and Queen Victoria's Diamond Jubilee in 1897. Sent two cameras to the Boer War in 1899.

Mr. Paul began his career as a manufacturer of electrical and scientific instruments in London in 1891. He gave up the motion picture work in 1910 to devote himself exclusively to his original business. In the intervening years since that date he has made a notable reputation for his skillful design of instruments, until his health forced his retirement a few years ago.

J. I. CRABTREE, *Chairman*
A. N. GOLDSMITH
E. A. WILLIFORD

APPENDIX

British Patents granted to R. W. Paul between the years 1895–1905, inclusive:

17,677/95	Kinetoscope Apparatus
19,984/95	Exhibition on Entertainment
4,168/96	Reproducing Stage Performances
4,686/96	Projecting Kinetoscope Pictures on the Screen
10,310/97	Exhibiting Animated Photographs
486/99	Taking and Projecting Pictures
11,997/99	Animated Photography
14,372/00	Projecting Photographs
26,747/01	Taking and Projecting Animated Photographs

Election of Robert William Paul.—At a meeting of the Board of Governors of the Society of Motion Picture Engineers on October 10, 1937, in the Hotel Pennsylvania, New York, N. Y., Robert William Paul was proposed and unanimously approved for Honorary Membership.

In accordance with the provisions for electing honorary members the nomination was then placed before the General Society at the New York meeting on October 11, 1937, at which time the nomination of the Board received the unanimous endorsement of the general Society. At that meeting, an account of Mr. Paul's work in cinematography was read by Mr. G. E. Matthews, member of the Historical Committee.

On October 12th, Mr. Paul was notified by letter, from President S. K. Wolf, of his election to Honorary Membership.

SAFEGUARDING AND DEVELOPING OUR FILM MARKETS ABROAD*

NATHAN D. GOLDEN**

Summary.—*American motion pictures are maintaining immense popularity throughout the world, yet barriers and obstructions that tend to limit their sale continue to be imposed abroad. Safeguarding and developing our film market abroad, "contingents" taxes, and complex restrictions, which continue to be imposed in all too many instances, are some of the problems American producers must face. Some are legitimate from the standpoint of local interests, but others appear to be unreasonable. In certain cases our motion picture industry may be justified in taking a strong and positive stand with the object of bringing about the rectification of unfair measures.*

The efforts of the Bureau of Foreign and Domestic Commerce to safeguard and augment American motion picture markets by supplying factual data and utilizing trade-promotive methods is covered. The Bureau's motion picture unit has recently been raised to full divisional rank, in recognition of the industry's importance. Such helps as it provides are especially vital at the present moment because our motion picture producers and distributors are likely to find themselves puzzled, entangled, or thwarted by the ever-growing intricacy of the conditions that they face abroad; their continued success in foreign markets depends upon the functioning of a reliable intelligence service.

As motion picture engineers, the members of this Society all have a vital and immediate interest in the vigorous maintenance of our foreign markets for American motion pictures. Those foreign markets constitute a highly important field for the efforts of the industry; they play a significant role in its notable success. They can not be considered lightly; they must, on the contrary, be constantly cherished and cultivated and energetically safeguarded. Every endeavor along that line means much to a motion picture engineer—because the opportunity for his advancement, or even the security of his position may be dependent in no small measure upon the industry's ability to hold these foreign markets which have furnished, up till now, such important sources of revenue.

It is an easily demonstrable fact that any type of foreign legis-

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received September 20, 1937.

** *Chief*, Motion Picture Division, U. S. Bureau of Foreign and Domestic Commerce, Washington, D. C.

lation that operates to retard or prevent the sale of American motion pictures abroad inevitably reduces the income of American distributors—which, in turn, naturally leads to curtailment of production, with a resultant laying-off of trained personnel not only at the studios but in the research laboratories as well. Thus, a strong wave of nationalistic sentiment in Central Europe, finding expression in restrictive laws affecting motion pictures, or a movement toward control and rigid censorship somewhere in Asia, or some inimical reaction in a Latin-American country, may contribute to an ultimate effect whereby a motion picture engineer would find less in his pay-envelope or might even be confronted by more severe emergencies. On the contrary, smooth and favorable *expansion* of the foreign markets might involve substantial heightening of his personal income and well-being.

It is obvious, therefore, that the industry needs to maintain an attitude of the keenest and most alert watchfulness on all foreign developments. It needs all the detailed facts with regard to what is happening in the motion picture field abroad. It needs those facts promptly, and it is only fair to say that, in all such efforts as these, it needs the coöperation of the Commerce Service of the National Government.

Such needs were never more imperative than they are at the present moment, when world conditions are transitional, confused, and often muddled, when new situations develop with truly amazing suddenness, and the basic governing factors are frequently difficult to ascertain. Under circumstances such as these, our motion picture producers and distributors are likely to find themselves puzzled, entangled, or thwarted by the ever-growing intricacy of the conditions that they face abroad. Their continued success in foreign markets depends upon the functioning of a reliable "intelligence service" to keep them fully informed on all the foreign facts and figures, the quotas, the limitations, the control boards, the taxes, the fostering of local competition, and the many other vital factors that bear upon their business.

Such a service is of course supplied in considerable measure by the personal representatives of our larger motion picture interests, but the Government at Washington, through the Bureau of Foreign and Domestic Commerce, can assuredly be helpful. We believe that we are in a position to make an appreciable contribution to the safeguarding and developing of motion picture markets throughout the world. On July 1st of this year the Bureau recognized the great importance of the motion picture trade by raising this phase of our promotive work to full divisional rank. We now have a Motion Picture *Division,* eager at all times to serve the industry, and possessing the resources and equipment to do so with effectiveness. Quoting the words that our Director, Dr. Alexander V. Dye, recently applied to the entire Bureau, the Motion Picture Division aims to help the industry "to avoid errors, avert losses, and solve problems—to open pathways to wise planning, sound judgments, and ever-greater profits." That is the objective toward which we steadily strive.

To aid in its attainment we have Foreign Commerce Officers in thirty-four foreign capitals and great commercial centers who keep the home office at Washington promptly informed of every change, development, tendency, or measure that may have any repercussions on the American motion picture business. The reports of these representatives, as well as those of the State Department's consuls, are reviewed, analyzed, and coördinated in the Motion Picture Division and disseminated by it to the interested companies or persons. This is accomplished through the issuance of bulletins and circulars, through letters and personal interviews, and in other ways that seem best adapted to particular situations. Naturally there is often an opportunity for service by our district offices, such as the admirably equipped offices in Los Angeles and New York City. In key cities throughout the country our Bureau maintains twenty-four of these "service stations."

As an example of the kind of data furnished by our field service for the benefit of the motion picture industry, there is now available a concise yet complete report from one of our Assistant Trade Commissioners in London, presenting the details of the proposals for legislation on motion picture films recently submitted to the British Parliament by the President of the Board of Trade, which is the governmental body corresponding to our own Department of Commerce. This report tells all about the proposed continuance of the British quota system, the differing provisions for distributors and exhibitors, the "cost test," the excepted classes, the ban on blind booking, the penalties for violation, and the numerous other recommendations that the British are likely to embody in their new legislation on this subject. In this connection it appears that Britain will continue to be an eminently worth-while market for the splendid films created by our engineers and artists.

The Motion Picture Division advises the industry on all the phases of film conditions abroad, including markets for educational and industrial films and for motion picture equipment. Special statistical data, covering our exports and imports and the foreign production of films, are given to the trade each month, as are the reports of foreign censorship boards. Bi-weekly we publish a Foreign Market Bulletin, covering a wide variety of motion picture news from the oversea markets. A press service of pertinent items goes each week to export managers, trade associations, trade papers, and newspapers.

A significant function of the Division is its service in furnishing each month a bulletin on the latest production and distribution of non-theatrical films to home users, colleges, and schools. Equipment manufacturers, exporters, and associations are currently advised on the foreign-market potentialities for all types of motion picture and sound-reproducing equipment. We are constantly publishing information on competition abroad, the number of films distributed by countries over given periods, the number of theaters in the different foreign territories, and similar matters that ultimately mean much, in dollars and cents as well as in prestige, to the men and women who are making pictures here in the United States.

Let us look briefly at the Division's major publication, the *Review of Foreign Film Markets*, of which the number covering the year 1936 appeared some months ago. In this large processed bulletin, comprising about 180 pages, the situation in nearly every country of the globe is shown succinctly but in some detail. Here, to mention only a few facts out of many, it is found that film censorship in Nazi Germany has been greatly intensified and is proving most vexatious to motion picture importers; that more interesting scenarios, with better international value, are now being used by French producers; that filmgoers in the Dominican Republic are voicing vigorous objections to dubbing the native language into the pictured mouths of our American stars; that 73 per cent (by footage) of the pictures imported by India are of American origin; that in Mexico only seven companies regularly produce motion pictures; that there are 38,190 seats in the picture theaters of Montevideo; that importers of films to Latvia pay a special tax of 0.15 lats per meter for the benefit of the Latvian Culture Fund; and so on through the list of countries and the long categories of devices, regulations, and local measures that affect the market for our films abroad.

American pictures continue to maintain their immense popularity abroad. Theatergoers are enthusiastic about them—in Norwegian coastal cities and in the high Andean capitals, in the teeming Oriental centers and in the sophisticated, metropolitan theaters of western Europe. That is only natural, of course, when one considers the engineering genius, the artistic ability, and the business acumen that go into their making. Foreign peoples like them and demand them, because they realize their incomparable excellence. And yet the barriers and obstructions and hobbles that tend to limit their sale continue to be imposed abroad. Contingents and taxes and complex restrictions continue to be slapped on, in all too many instances. Some of these are legitimate enough, *from the standpoint of local interests;* others, however, appear to be inherently unreasonable. In certain cases our motion picture industry may be justified in taking a strong and positive stand with the object of bringing about rectification of unfair measures. We need not be unduly hesitant. Our producers and distributors can afford to make effective their opposition to merely narrow-minded or punitive practices, while at the same time conforming readily to rational and moderate requirements abroad. In any such stand they will have the backing of one momentous factor—namely, the avidity of foreign audiences to see and hear our magnificently entertaining films.

In any event, it is the unremitting effort and steady purpose of the United States Department of Commerce to safeguard and develop our motion picture markets abroad to the greatest possible extent through the instrumentality of factual data and a variety of tried and proved trade-promotive methods.

DISCUSSION

MR. CRABTREE: Can you outline briefly the pros and cons from the American standpoint of establishing studios in England by the motion picture producers?

MR. GOLDEN: In addition to what you have already read in the trade-press we have received reports from our trade commissioners in London indicating that American companies are either leasing or buying outright certain studios and space in studios. This is a precautionary measure, caused by the issuance of the White paper, which deals with the revision of the quota system that expires in 1938. It contains proposals that will have to be passed upon by the Parliament.

MR. CRABTREE: A certain percentage of the pictures must be of British production, is that not right?

MR. GOLDEN: Twenty per cent, at the present time.

MR. CRABTREE: If the pictures are made by an American producer in England, are they classed under the quota?

MR. GOLDEN: Provided they meet the terms of the quota act, which requires that a certain percentage of the employees or the personnel be British subjects; 75 per cent, I believe, must be British subjects.

MR. RICHARDSON: You have said that many objections were raised to showing American films. Do any of the objections relate to the action in the picture?

MR. GOLDEN: That depends upon the attitude of those in charge of permitting films to come into the countries. Some countries, based upon their censorship laws, may object to the slightest thing in the picture, to bar the picture from the market. We have such trouble in Czechoslovakia and in Germany. If the man who turns the crank of a camera or the producer happens to be of the Jewish faith, that is sufficient ground to bar the picture from the German market. The American motion picture industry has been very careful in selecting its pictures for foreign markets. At the studios there are experts who are well versed with the censorship laws of the various countries, and situations that may not get by in foreign countries are quickly eliminated from the pictures.

MR. RICHARDSON: What is the character of such objectionable items?

MR. GOLDEN: Almost anything. It might be a question of morals, or it might be political. Perhaps the dictator of a country may feel that his subjects should not see a certain kind of picture. It may be one of a thousand different things

HUNTING THE SONGS OF VANISHING BIRDS WITH A MICROPHONE*

P. KELLOGG**

Summary.—*A brief historical résumé of the subject of bird sound recording is presented, including a discussion of the idea behind the work and its usefulness to students of ornithology. Graphical methods of recording songs are mentioned, as well as some early attempts at phonographic recording.*

Problems of recording bird songs in the field are discussed. The high frequencies of bird song; the necessity of working at relatively great distances from the subject; wind and other noises; the need for portability and simplicity of equipment, all combine to increase the difficulties of the work. The use of parabolic concentrators in the work is discussed and it is concluded that the frequency distortion introduced by this type of pick-up device is more tolerable for bird song recording than it would be for records of human voice or music.

As in the beginnings of many things, we shall probably never know who first attempted to include the song of a bird in the repertoire of a phonograph, and we may not even know the names of many of those who were associated with the work. The problem, however, seems so obvious to the ornithologist that it must have been thought of many times before the literature recorded the event.

To the naturalist, song is no less a part of a bird's make-up than its form or coloring, although it has defied man in his attempt to record it for a much longer time.

There are many records of attempts to record bird songs with musical notations,[1] but since bird music rarely complies with man-made scales or time intervals, records of this type are so complicated that they are of little use to one who would like to know what the bird sounded like. Saunders,[2] in this country, has devised a very workable system of short-hand for writing down bird songs, and with a little study one may gain a fair idea of the song to be expected from any bird. Fig. 1 illustrates the use of this method in recording several

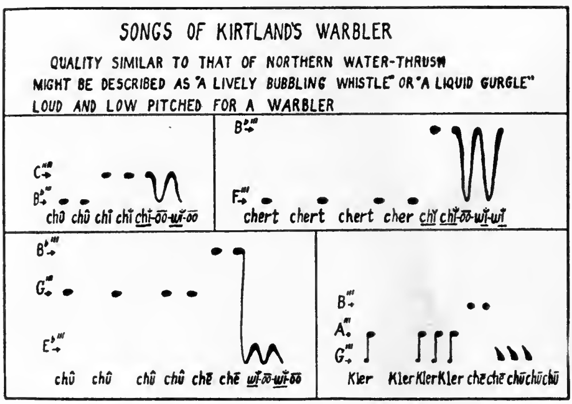
---

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received September 30, 1937.

** Laboratory of Ornithology, Cornell University, Ithaca, N. Y.

songs of the rare Kirtland's warbler, which is found breeding only in a restricted area in Michigan.

It was twenty-one years after the invention of the phonograph that Sylvester Judd,[3] on November 15, 1898, demonstrated a phonographic recording of the brown thrasher's voice before the 16th Congress of the American Ornithologists' Union in Washington, D. C. While this was recorded as a unique feature of the meetings, and as a method of study of great promise, nothing was said to indicate the quality of the recording or the opinion of the audience. Mr. Judd's work was cut short by his untimely death, and I have found no further record of



(*Prepared by H. H. Axtell*)

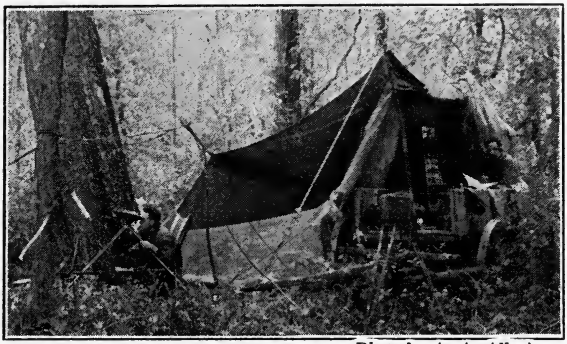
FIG. 1. Example of graphic method of recording bird songs devised by A. A. Saunders.

attempts to record bird song phonographically until 1909, which Heinroth[4] sets as the time he heard reproductions of North American bird songs at a public lecture in London. I have been unable to find the source of these recordings. The following year Heinroth states that he played several records of bird songs before the 5th International Ornithological Congress in Berlin, and specifically mentions a good reproduction of a nightingale's song. So far as I know, all these early recordings were of caged birds.

With the advent of electrical recording about 1926, many suggestions were published[5] indicating the possibility of using the new technic with birds, and in 1927 the RCA Victor Company published songs of several caged birds recorded in the Karl Reich Aviary in Bremen, Germany, and the song of a semi-domesticated nightingale from an English garden.[6]

In May, 1929, the Fox-Case Company sent out two men with equipment to Auburn, N. Y., to record sound pictures of some wild birds for a springtime release. After spending considerable time about Auburn, with no success, they came to Cornell to enlist the help of Professor A. A. Allen, to make the birds hold still. From his long experience with bird photography Dr. Allen was able to help them out, and that morning songs of three common birds were recorded synchronously with motion pictures.

This experience interested us anew in the possibilities of recording bird voices, but we were unable to get started on the project until 1931.



(Photo by A. A. Allen)

FIG. 2. Camp in swamp for studying ivory-billed woodpecker.

In 1930 A. R. Brand enrolled in Cornell as a special student in ornithology, and presently became interested in recording bird songs as a method of study. Since that time Mr. Brand has been actively engaged in this work and has financed the experimental work in this field in the Laboratory of Ornithology at Cornell.

The problems encountered in bird sound recording fall naturally into three groups: (*1*) those imposed by field conditions such as need for portability and ruggedness; (*2*) problems connected with sound pick-up; (*3*) problems arising from the character of the sound we are working with.

That it is very desirable that the equipment be portable and rugged is illustrated by our experience in recording the voice of the ivory-billed woodpecker in the swamps of Louisiana. Here we found this rare bird nesting in the middle of a deep swamp at least six miles from any road on which an automobile could travel. Fig. 2 gives some idea of the difficulties encountered. Our equipment was not portable, except by truck, and the task of moving it to a new location by mule-power required three days. Under normal circumstances only the microphone is removed from the small truck, which serves as a field laboratory; but, when working with rare birds, trails often lead to remote areas where a recorder in a back pack would be much more useful than one in a truck.

(Photo by A. A. Allen)

FIG. 3. Water ouzel or dipper. Only by getting the bird close to the microphone could the roar of the rushing water be overcome and the song of the bird recorded.

During the present summer (1937) the trail of the Leache's petrel, an oceanic bird, led to the islands of the Bay of Fundy. Being unable to get the truck conveniently to Kent's Island, where the birds were calling best, use was made of a small portable field amplifier and the short-wave radio station of the Bowdoin (College) Kent's Island Expedition to transfer the sounds of the petrels across the six miles of the Bay of Fundy to the Island of Grand Manan, where the recording took place.

The problems connected with picking up bird songs are most perplexing. Ideally, studio conditions should prevail; but birds are seldom at home indoors and critics are quick to detect the differences between the song of a free bird and that of a caged one. Even out of doors, studio conditions may often be simulated when one has the co-operation of the artist, but with birds this is a little too much to expect. Theoretically, many birds have regular song perches to which they go to sing, and it should be possible, by placing the microphone near such a perch, to record good sound. This is a good theory, but the times at which most birds return to their song perches are so unpredictable that in practice the method is seldom used. Fig. 3 illustrates the set-up for recording the song of the dipper or waterouzel of the West. Here the noise of the rushing stream frequented by this bird made it

(*Photo by A. A. Allen*)

FIG. 4. Thirty-two-inch parabolic concentrator being focused on ivory-bills by James Tanner.

necessary to study the song habits carefully until we had practically learned every spot from which the bird could be expected to sing. Only in this way could the bird's voice be recorded above the sound of the water.

In 1932 Peter Keane and the writer decided to build a sound concentrator in an effort to achieve better pick-up. We were thoroughly warned by our engineering friends that the frequency characteristics of any reasonably proportioned reflector would make it useless for our purpose.[7,8] However, we insisted upon going ahead with the idea, and constructed a parabolic concentrator 32 inches in diameter (Fig. 4). Measurements of the concentrator under field conditions are approximately shown in the curve of Fig. 5. Theoretically, such a response would be quite useless for any kind of recording, but for bird work two conditions make it at least tolerable, and this brings us to a consideration of the sounds with which we are working. Brand [9] has pointed out that the average frequency of bird songs he has studied is a little above 4000 cps., and in this region the gain from the use of the concentrator is about 22 db., which gives us a "magnification," thinking in terms of a field glass, of approximately 12.5 times. This is a distinct advantage. The second consideration that makes such a response tolerable is the relatively narrow frequency range of most birds. This has the effect of confining the distortion within relatively narrow limits, and even this may be somewhat further reduced by the

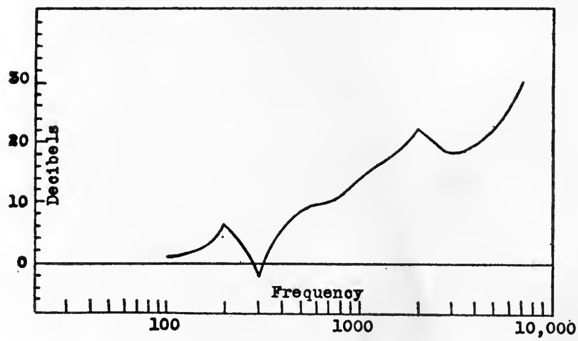


FIG. 5. Response of 32-inch parabolic concentrator compared to response of microphone alone, under field conditions at a distance of 60 feet.

tendency of most reproducing equipment to fall off with increasing frequency. For voice recordings or for ordinary music the distortion introduced by such a small reflector is very noticeable; but for bird sounds, listening tests show that recordings made with the parabola are preferable to those so far made with the microphone alone. However, we feel that much of this preference may be due to the lower background noise with the concentrator rather than to the emphasis upon the higher frequencies.

Two possible solutions to the attempts to make better recordings of bird songs in the open would be, first, to make more concentrated studies of individual species so as to place the microphone close to the bird; and, second, to use a larger parabola so as to concentrate more sound and give a better overall response. It is probable that the first suggestion would result in better quality when it could be achieved, but the parabola is so much more efficient that its use will probably continue, and sometimes it affords the only means of recording a song.

In our recording work we are particularly anxious to record the songs of rare and vanishing species of birds before it is too late. In modern times the passenger pigeon, the heath hen, the great auk, and the Laborador duck have become extinct. No one has accurately recorded the voices of these birds and they are gone forever. The ivory-billed woodpecker is on the verge of extinction.

(*The presentation was concluded with the projection of sound pictures of birds and their songs, these records being part of the results of an expedition sponsored in 1935 by Mr. Brand, Cornell University, and the American Museum of Natural History, to study and make records of vanishing species.*)

REFERENCES

[1] MATTHEWS, F. S.: "Field Book of Wild Animals and Their Music," *G. P. Putnam Sons* (New York, 1904), p. 262.

[2] SAUNDERS, A. A.: "A Guide to Bird Song," *Appleton-Century* (New York, 1935), p. 278.

[3] JUDD, S. D.: "Gramophone Demonstration of a Brown Thrasher's Song," *Auk*, **XVI** (Jan., 1899), No. 1, p. 52.

[4] HEINROTH, O.: "Gefiederte Meistersänger," *H. Bermühler* (Berlin, 1936), p. 96 (plus three 10-inch disks).

[5] STADLER, H.: "Das Freiland- phonographieren von Vogelstimmen," *Bericht des Vereins Schlesischer Ornithologen* (Breslau), **XII**, p. 95.

[6] Victor Records, Nos. 20968, V-1, V-15, V-50, V-71, V-85, 22344.

[7] DREHER, C.: "Microphone Concentrators in Picture Production," *J. Soc. Mot. Pict. Eng.*, **XVI** (Jan., 1931), No. 1, p. 23.

[8] OLSON, H. F., AND WOLF, I.: "Sound Concentrators for Microphones," *J. Acoust. Soc. Amer.*, **I** (April, 1930), No. 3, p. 410.

[9] BRAND, A. R.: "Method for the Intensive Study of Bird Songs," *Auk*, n.s. **LII** (Jan., 1935), No. 1, p. 40.

DISCUSSION

MR. BRADLEY: Did you make any attempt to record sounds of birds by the phonographic method only, without the picture?

MR. KELLOGG: Yes; many of the sounds have been transcribed upon disks and published as illustrative material for a book, by Mr. Brand, who financed the work that I mentioned. With a good phonograph we can get fairly good results. The frequencies average about 5000 cps., and with the 78-rpm. speed and fine-line recording we do not obtain good results on an ordinary acoustical phonograph.

MR. BRADLEY: Recently, the American Foundation for the Blind offered The National Archives some phonograph records, made by Columbia University, of wild birds and their songs. The National Archives Act states that we may accept motion pictures and sound recordings pertaining to historical activities of the United States. The question has been raised as to whether or not recording birds' songs constitutes an historical activity and hence whether or not such recordings would be admissible under the provisions of the Act. I should be interested to have your opinion.

MR. KELLOGG: Within the memory of man in the United States about six birds have become extinct, and no one will ever know what they sounded like, except from graphic descriptions of them. Personally, I think it should be regarded as part of our national history to know what kinds of birds, what kinds of animals inhabited this country before man came here or during his early stages here. It seems to me that would be a rather legitimate inclusion for The National Archives.

The records of which you speak were made in our laboratories at Cornell—that is, the editing was done there—and Mr. Brand wrote the continuity that goes with them. He is now producing a second book. But I suppose if we get out victrola records that are good enough and if the master will stand up, whether The National Archives keeps them or someone else, we shall have permanent records of them.

MR. POPOVICI: Has any attempt been made to improve the response of the parabolic microphone with networks?

MR. KELLOGG: Yes. But as soon as we try to suppress the high end of the curve, where the response is so great, we very soon find ourselves back almost at the point from where we started. The most interesting attempt has been with resonators, to bring up the response at the low end; but I think the solution is a larger parabola having a less steep response curve.

MR. CRABTREE: How do you focus the reflector, by trial and error? Also can you tell us something about your telephoto equipment?

MR. KELLOGG: The pictures were made with a 17-inch lens, the telephoto equipment on the motion picture camera. Focusing is difficult. Sound-waves are not as sharply focused as light-waves, and the simplest way we have found to focus the parabola is to aim it at the sun. Out in front, at the focal point, the parallel rays of the sun concentrate into a very hot spot. As the subject is closer than the sun, the focal point moves out a little bit, but that has merely the effect of broadening the spot, and in almost every instance it will cover the diaphragm very well. Experience shows that it is desirable to throw the concentrator slightly out of focus so as to have less high-frequency response.

We have a little telescope on the concentrator, placed right along the side. (The man in Fig. 4 is shown sighting through it.) At 5000 cps., which is about the average of bird songs, we get a gain of about 22 or 23 db., which is a very appreciable gain, I assure you. It is a very powerful instrument.

NOTES ON THE PROCEDURE FOR HANDLING HIGH-VOLUME RELEASE PRINTS*

JOHN K. HILLIARD**

Summary.—*Until such time as all theaters are equipped with new and modern improved equipment, methods must be pursued that will allow wide-power-range films to be reproduced to best advantage in theaters having equipment capable of such reproduction, and not, at the same time, penalize theaters having equipment incapable of handling the wider range. During the past year several major producing companies have made available to the theaters prints of two types: (1) The "Regular" release print with ordinary volume range; (2) "Hi-Range" and "Lo-Range" prints.*

The "Hi-Range" prints have a range of 50 db. The volume of the "Lo-Range" prints may correspond to that of the "Regular" prints, or may be recorded to play 3 or 4 db. above the particular studio's average. In other words, any production issued on "Regular" prints will be distributed completely on one type of print, while any production available on "Hi-Range" prints will be available also on "Lo-Range" prints as well. As more theaters become converted to equipment capable of the higher ranges the practice of issuing "Hi-Range" and "Lo-Range" prints will be rapidly extended.

Instructions are given for using the various kinds of prints in theaters, and curves show the recommended amplifier output in terms of theater area, cubical contents, and number of seats.

Since the addition of recorded sound to motion pictures there has been continual improvement in the quality of sound recording and sound reproduction which has been particularly marked within the past year.

The Research Council of the Academy of Motion Picture Arts & Sciences hopes by means of the work of its Committee on Standardization of Theater Sound Projection Equipment Characteristics to give to the exhibitor throughout the country a more intimate picture of the aims of the producers in attempting to obtain a more natural sound recording. As the quality of recorded sound is improved and its naturalness is increased, it is necessary, in order to obtain the

* Received October 7, 1937; presented at the Fall, 1937, Meeting at New York, N. Y.

** *Chairman*, Committee on Standardization of Theater Sound Projection Equipment Characteristics of the Research Council of the Academy of Motion Picture Arts & Sciences; Metro-Goldwyn-Mayer Studies, Culver City, Calif.

maximum benefit from these improved recordings, for the theater reproducing equipment to advance in step with the progress of the recording art.

Theater equipment that was considered adequate in the past is no longer capable of reproducing faithfully the current dialog, music, and sound effects now being recorded by the studios. Improvements in recording permit more faithful reproduction of the human voice as well as of vocal and instrumental music. Improvements in amplifiers permit a wider power range and allow an increased volume of sound on the film itself, and the theater reproducing apparatus must conse-

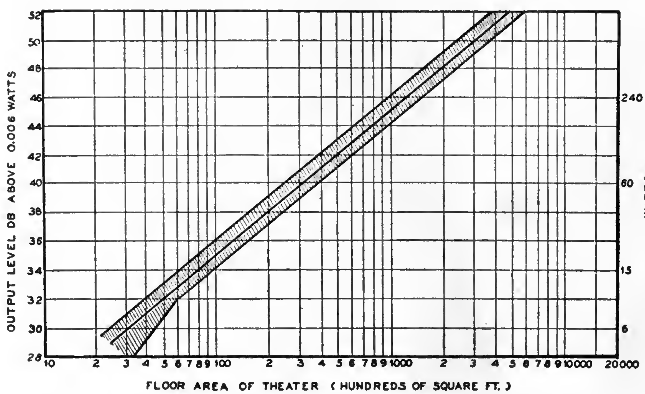


FIG. 1. Recommended amplifier output in electric watts in terms of the floor area of the theater.

quently be capable of transmitting this improved quality to the theater patrons.

Recent developments in the reproducing equipment have included the introduction of horns of new design which give far better quality than was formerly possible and more even and adequate distribution of sound throughout the theater auditorium. Improvements in the film-running mechanism have reduced flutter to a minimum, and increased amplifier power is now available for reproducing adequately and without distortion the wider power ranges now being recorded on the film.

It is recognized in the studios that until such time as all theaters are equipped with new and modern improved equipment, methods must be used that will allow the wider-power-range films to be reproduced to their best advantage in those theaters having equipment capable of this reproduction, and will not, at the same time, penalize those theaters that are fitted with reproducing equipment not capable of handling the wider volume range. During the past year several of the major companies have, in a limited number of releases, made available to the theaters two general types of prints: one type being the "Regular" release print with the ordinary volume range, and the other type, divided into two classifications according to the volume range recorded on the film, known as "Hi-Range" and "Lo-Range" prints.

The "Hi-Range" prints, requiring increased amplifier power in the reproducing equipment, and having an approximate sound intensity

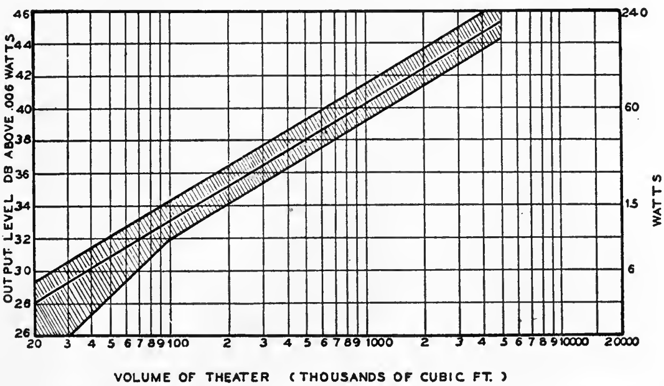


FIG. 2. Recommended amplifier output in electric watts in terms of the volume of the theater.

range of 50 db., produce intensity changes that closely approximate those occurring in nature. Musical passages so recorded and subsequently reproduced with adequate power, lend the added color and naturalness necessary to insure more complete enjoyment of the presentation.

Those productions released on "Hi-Range" prints will also be available on "Lo-Range" prints, the volume of which may correspond to the studio "Regular" prints, or may be recorded to play 3 or 4 db. above the particular studio's average (Figs. 2 and 3). In other words, any production issued on "Regular" prints will be distributed completely on one type of print, while any production available on "Hi-Range" prints will also necessarily be available on "Lo-Range" prints as well.

As more and more theaters are converted to the modern equipment capable of reproducing wider volume ranges, the practice of issuing "Hi-Range" and "Lo-Range" prints will undoubtedly be rapidly extended.

The success of such productions as *Maytime*, *One Hundred Men and a Girl*, and other similar musical productions released on "Hi-Range" prints, indicates that this type of release print has a definite place in the industry from a showmanship standpoint. Complete appreciation by the exhibitor of the technic required for their reproduction will insure still greater box-office success.

By means of improved technic in the studio, "Hi-Range" prints have a controlled balance of volume between dialog and music; that is, relative reproduction between the dialog and music has been predetermined by experienced showmen after careful consideration of the output level.

The sound volume reaching the ear of a patron from any given print projected at a certain fader setting depends upon the percentage modulation of the signal on the film. On "Regular" prints (projected at the average fader setting for any particular studio's product), both the dialog and music are given 100 per cent modulation a greater part of the time. This means that the output volume will be practically the same throughout the production.

In recording "Hi-Range" prints, however, most of the dialog passages are intentionally reduced in modulation so that the average dialog modulation rarely exceeds 50 per cent, while the music is recorded at 100 per cent modulation. This provides a volume differential between music and dialog of at least 6 db. "Hi-Range" prints do not necessarily provide *louder* sound, but an extended volume range that gives more dramatic value in the theater.

When such a print is projected, the fader must be raised at least 6 db. for proper dialog volume. To utilize this volume range on the film the theater must necessarily be provided with an amplifier output that is increased by approximately the same range.

Increased amplifier power is necessary since in the past the average theater installation has had only sufficient power to reproduce dialog satisfactorily.

In general, those theater installations equipped with modern loud speaker systems have sufficient amplifier power to reproduce adequately this higher volume range.

By observation of a number of houses it has been found that a theater containing up to 1000 seats requires from 10 to 15 watts of power, from either the original old standard horn systems or the more modern two-way loud speaker systems. Houses having from 1000 to 2000 seats require from 19 to 24 watts of power, and theaters with over 2000 seats require at least 48 watts. Houses equipped with the Electrical Research Products, Inc., three-way, wide-range system will require approximately the same power for the same seating capacity.

In order to simplify the determination of power necessary for theaters of various sizes to reproduce adequately the greater volume ranges now being recorded charts have been prepared as follows:

Fig. 1 shows the recommended amplifier power output in terms of

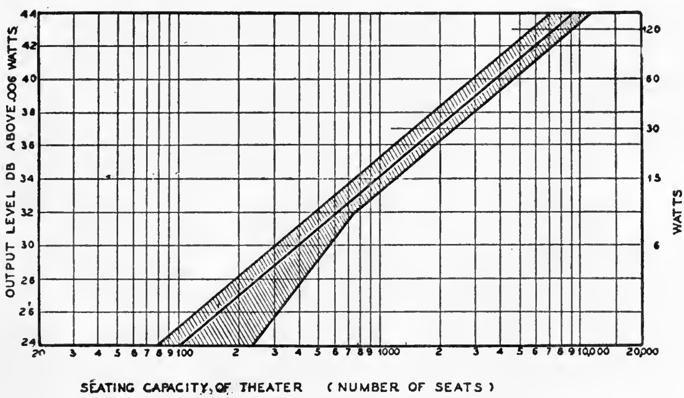


FIG. 3. Recommended amplifier output in electric watts in terms of the seating capacity of the theater.

the theater floor area; Fig. 2, in terms of the cubical contents of the theater; Fig. 3, in terms of the number of seats.

These curves indicate the necessary amplifier capacity to maintain high quality of sound reproduction, but since the required power is dependent partially upon the absorption and reverberation characteristics of the theater auditorium, deviation from these values may be required depending upon the variation of any particular theater from optimal reverberation conditions.

In reproducing a "Hi-Range" print, the theater manager and projectionist should follow the usual method of setting the fader for proper dialog volume, which will automatically insure proper reproduced volume level for any musical passages in the same production. If the volume level of the music is reduced to a point lower than that originally intended at the time of the recording, dialog passages would be too low for satisfactory reproduction.

If the equipment is not functioning properly or if there is insufficient power capacity, the higher-volume portions of the musical passages will be reproduced with harshness and distortion. In this type of reproduction, flutter (if present) due to poor motion of the film through the sound-gate will be particularly noticeable. When such prints are reproduced on the older types of theater systems the increase in amplification necessary to reproduce the high-volume passages properly will sometimes introduce objectionable hum and other system noises, which can usually be eliminated by careful adjustment of the system.

The use of the higher amplifier power necessary to reproduce these prints also requires that the distribution of sound throughout the theater be particularly uniform.

In order to assist the exhibitors, theater managers, and projectionists as well as the exchanges in identifying quickly the "Hi-Range" and "Lo-Range," as well as "Regular" prints, each of the major studios will commence immediately to label each print *Hi-Range* or *Lo-Range*, or *Regular*, and designate a general average fader setting at which the print should be projected—this information to be included in the Standard Release Print Leader on each reel of each production. *It is suggested that all theater projectionists carefully watch every print in order to take advantage of this additional information which should assist in increasing the showmanship value of recorded sound.*

ACADEMY STANDARD FADER SETTING INSTRUCTION LEADER

Editorial Note: The following paper represents a section of the Technical Bulletin of the Research Council of the Academy of Motion Picture Arts & Sciences as published on November 24, 1937. It is reprinted in this Journal to give it wider distribution among members of the Society of Motion Picture Engineers.

These Fader Setting Leader Instructions have been formally approved by the Academy Research Council but have not as yet received action by the Standards Committee of the Society of Motion Picture Engineers.

To aid the exhibitor further in the proper handling of "Hi-Range" prints the studios will, commencing about December 1, 1937, utilize that part of the Academy Research Council Standard Release Print Leader that has been designated for use for any pertinent information to be transmitted from studio to theater.

A portion of the specifications for the Standard Release Print Leader, indicating the location of this instructional information, is shown in Fig. 1, and details of the information to be known as *Standard Fader Setting Instructions* are illustrated in Fig. 2.

SPECIFICATIONS

The Standard Fader Setting Instruction Leader shall consist of 15 frames located as specified (Academy Research Council Standard Release Print Leader) in the synchronizing leader; the first frame shall designate the type of print; the second frame the type of reproducing equipment necessary to project the print; and the next nine frames the general fader setting specified in relation to an average fader setting for the particular product under consideration. The remaining frames may be used for whatever additional information the studio may wish to transmit to the theater.

This instruction leader will be of assistance to the exchanges in that it will facilitate the special handling required in the exchange for the various types of prints, by providing an easily noted means of identification for each type.

It should be noted that the designation "Regular" in the Standard Fader Setting Instruction Leader indicates that only one type of print has been issued on the particular production under consideration. Productions with prints designated as either "Hi-Range" or

ACADEMY RESEARCH COUNCIL STANDARD RELEASE PRINT LEADER SHOWING LOCATION OF STANDARD FADER SETTING INSTRUCTIONS

PROTECTIVE LEADER

Shall be either transparent or raw stock.
When the protective leader has been reduced to a length of six feet it is to be restored to a length of eight feet.

IDENTIFICATION LEADER (PART TITLE)

Shall contain 24 frames in each of which is plainly printed in black letters on white background: (*a*) type of print, (*b*) reel number (Arabic numeral not less than 1/4 of frame height), and (*c*) picture title.

SYNCHRONIZING LEADER

Shall consist of 20 frames ahead of Start mark, then 12 feet, including Start mark, to picture, opaque except as specified below: In the center of the first frame there shall be printed across the picture and sound-track area a white line 1/32 inch wide upon which is superimposed a diamond 1/8 inch high.

The next 15 frames may be used by the studio for sensitometric or other information. If not so used this leader shal be opaque.

The Start mark shall be the 21st frame, in which is printed START (inverted) in black letters on white background. The Academy camera aperture height of .631 inch shall be used in the photography of this frame, and all others between Start mark and beginning of picture.

From the Start mark to the picture the leader shall contain frame lines which do not cross sound-track area.

In the frames in which the numerals "6" and "9" appear, the words "six" and "nine" (also inverted) shall be placed immediately below the figure, to eliminate the possibility of misreading in the projection room due to the similarity between the inverted numerals.

Beginning 3 feet from the first frame of picture, each foot is to be plainly marked by a transparent frame containing an inverted black numeral at least 1/2 frame in height. Footage indicator numerals shall run consecutively from 3 to 11, inclusive. At a point exactly 20 frames ahead of the center of each footage numeral frame there shall be a diamond (white on black background) 1/8 inch high by 3/8 inch wide.

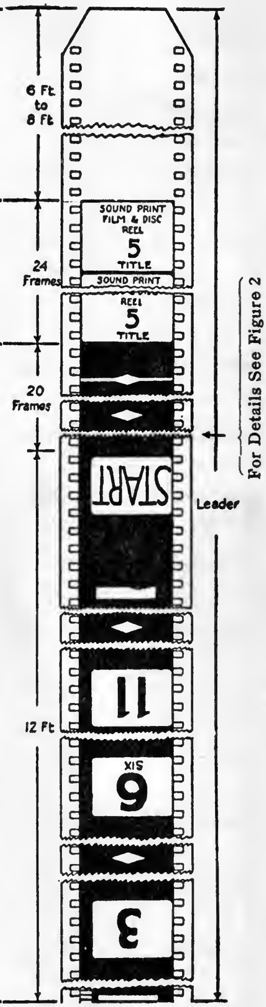


FIG. 1. Start of Picture

For specifications for motor and change-over cue location and reel-end leader see complete Academy Research Council Specifications for 35-mm. Motion Picture Release Prints in Standard 2000-ft. Lengths, published January 6, 1936.

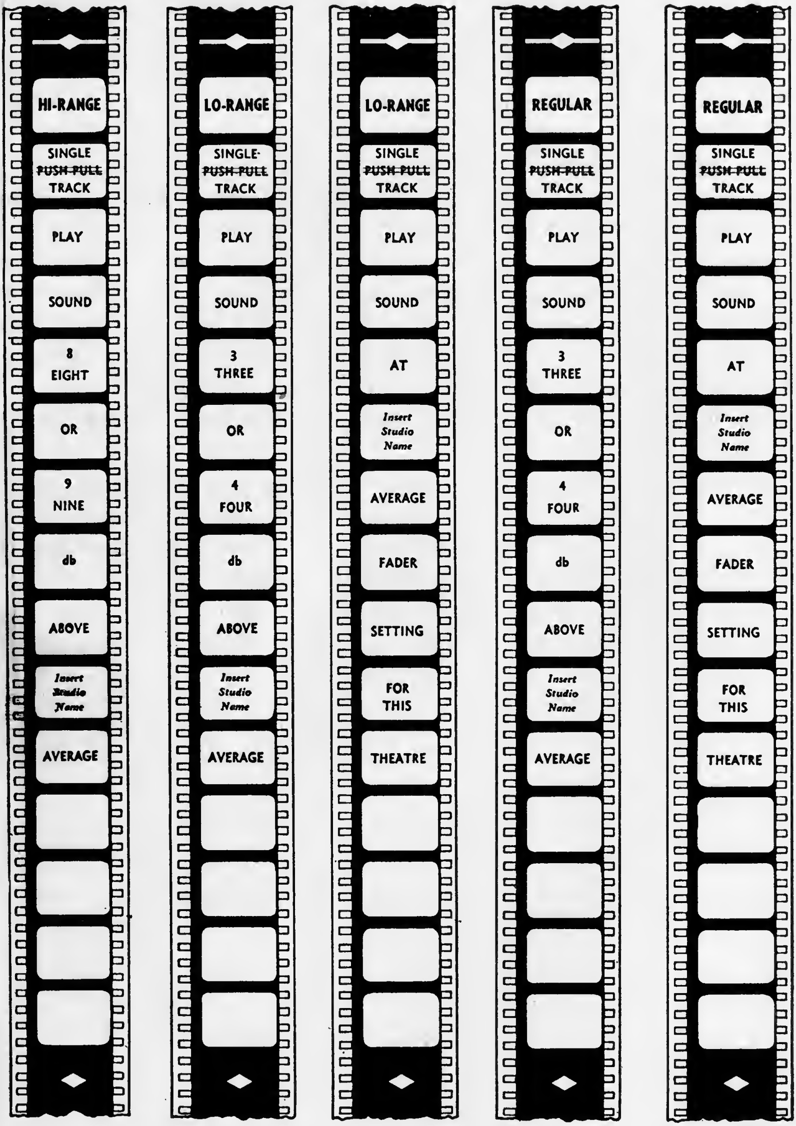


FIG. 2. Academy standard fader setting instructions.

"Lo-Range" will have been issued in both types of print, *i. e.*, all productions on "Hi-Range" prints necessarily will have been issued on "Lo-Range" prints as well.

This instruction leader will also enable the projectionist to identify prints that require "push-pull" reproducing systems as contrasted to prints requiring "single" systems.

In order to identify more plainly the "push-pull" or "single" system prints, it was decided to include both the terms "push-pull" and "single" on every leader, crossing out in the laboratory one or the other of these two to leave the appropriate term designating the type of sound-track on the print. Fig. 2 indicates the manner by which this was accomplished for leaders that would be included in prints containing sound-tracks for reproduction on a "single" system. For leaders to be included in prints containing "push-pull" tracks the word "single" would have been crossed out, leaving the word "push-pull" to indicate this type of track.

In order that the exhibitor may achieve the best results, the fader setting designated in this leader should be followed in general, inasmuch as the entire balance between the dialog and music throughout the reel will be chosen for each designated setting.

NEW MOTION PICTURE APPARATUS

During the Conventions of the Society, symposiums on new motion picture apparatus and materials are held, in which various manufacturers of equipment describe and demonstrate their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.

A MOBILE SOUND RECORDING CHANNEL*

L. T. GOLDSMITH AND B. F. RYAN**

The portable unit described herein is one of seven such units recently built for Warner Bros. Pictures, Inc., by RCA Manufacturing Company, and is aptly termed "a mobile sound recording channel," for, in contrast to the average location truck, nothing of the performance of a fixed studio channel has been sacrificed in achieving portability. The equipment is of the highest grade and is interchangeable with similar units in use in the fixed channels.

Fig. 1 shows the truck ready for recording, with the mixer case set up and the microphone connected. The body and cab are built on a standard four-speed, two-ton Ford chassis. The color scheme is red, blue, and white, with chromium strips to give the illusion of length. Actually, the wheel base is only 157 inches, and the overhang at the rear is small, so as to allow good maneuverability in woods and on mountain roads. All batteries are set low, resulting in a low center of gravity and good stability on curves and grades. The body is insulated with three inches of kapok, and the roof is painted with aluminum paint to reflect the heat of the sun.

Instead of a microphone boom, a two-sectioned jointed duralumin pole is provided to hold the microphone. This pole can be held by hand or mounted upon a lamp-stand, and has proved far superior to other types of boom on location. The microphone is insulated from the pole by rubber. Wind and rain screens are provided for the microphone so that recordings can be made under all but the severest conditions. Running shots, disk and film playbacks, and process projection work can all be handled as easily with this unit as with any fixed studio installation, so that it has actually proved itself a mobile recording channel.

Fig. 2 is a rear view, with the doors open. On the right are the large cable reels, operated by detachable handles from the inside of the truck. Sufficient cable is carried on the reels for recording at a distance of 1000 feet from the action. On the left is the plug panel for connections to the portable mixer and camera motors. All plugs are plainly marked and are poled so that it is impossible to

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received October 4, 1937.

** Warner Bros. Pictures, Inc., Burbank, Calif.

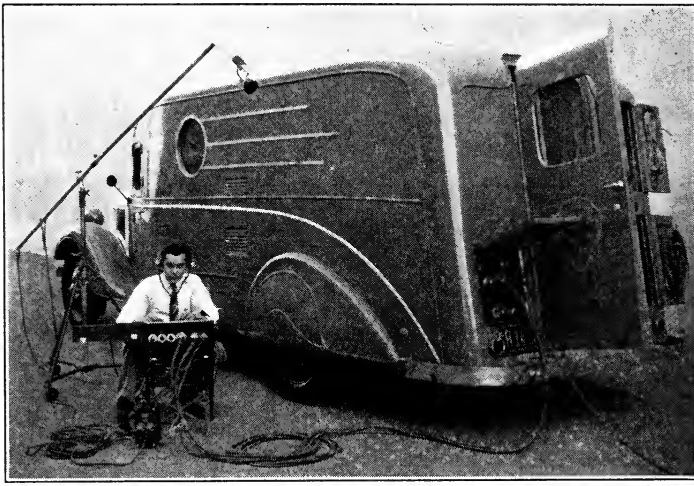


FIG. 1. Location truck set up for recording.

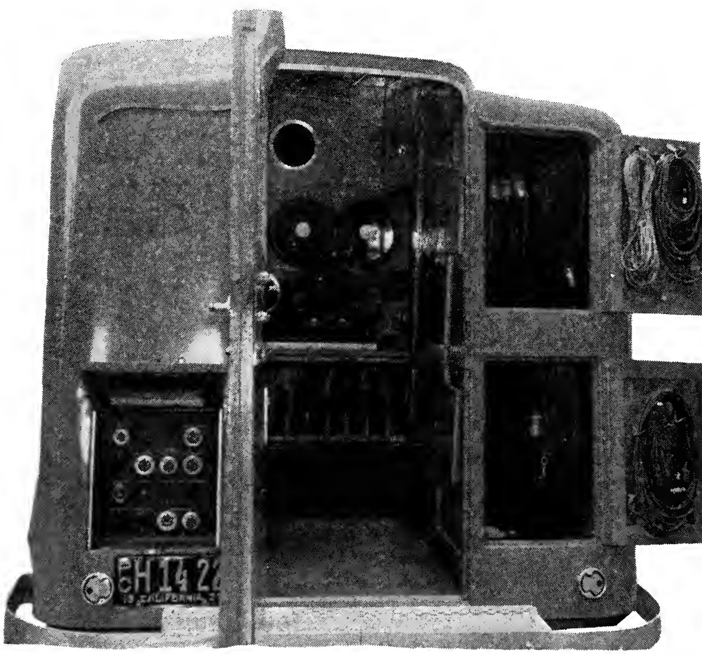


FIG. 2. Rear view of location truck.

FIG. 3. Interior of location truck.

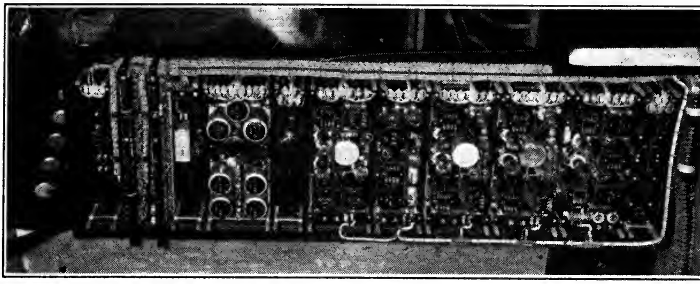


FIG. 4. Rear of amplifier rack.

make mistakes in connections. Despite the low height of the truck, the head room is six feet one inch. The top of the door follows the curve of the body, eliminating stooping when entering.

The body is divided into front and rear sections. Fig. 3 shows the interior of the rear compartment. On the left are the amplifier rack and the power control panel. In the center is the RCA ultraviolet light recording machine. Either

FIG. 5. Front compartment.

push-pull or standard bilateral shutter track may be made. The recording machine connections are brought to plugs so that machines for different types of recording can readily be substituted. Beneath the recorder is space for ten double film magazines. The compartment can be converted easily into a darkroom for loading and unloading magazines on location if desired.

The amplifier rack contains all the amplifiers, filters, and noise-reduction equipment necessary for recording. The rack is of duralumin, and the amplifier units are mounted on standard 19-inch aluminum panels finished in black alumilite. All input and output connections are brought out to jacks, to provide ease in testing and locating trouble. Each unit is individually fused in both high- and low-voltage circuits. A special airplane-type 250-volt dynamotor driven from the 110-volt motor battery supplies the amplifiers through appropriate filters, eliminating all "B" batteries. The noise-level for normal recording gain of the complete amplifier system, with all rotating equipment in operation, is 65 db. below 100 per cent modulation. This is considerably lower than the noise-level of many permanent installations.

The power control panel is alongside the recorder and contains all controls in addition to those on the machine needed by the recordist during operation. At the top are the charge-discharge meters and the 110-volt d-c. voltmeter. Below these are the charge-discharge switches and the two end-cell switches for an additional 6 or 12 volts when the service is unusually severe. In addition to the 110-volt motor battery, there is an 8-volt amplifier battery and a 14-volt recording lamp battery. The truck can be used for two full days and nights of recording without recharging batteries, and the battery capacities are so chosen that all batteries are discharged in approximately the same time. Below the switches are the a-c. and d-c. voltmeters for interlock voltage and plate voltage and a large size speed indicator. Along the bottom of the panel are the starting switches and the lights and fan switches. Lights are of the tubular type, recessed in the ceiling on each side of the recorder, and an exhaust fan in the ceiling provides ventilation in hot weather. The lights and fan can be switched from the 110-volt battery to a 110-volt a-c. circuit if the latter is available from an outside source.

FIG. 6. Mixer case.

Fig. 4 shows the amplifier rack swung out for servicing. The equipment covers have been removed so as to show the workmanlike job of wiring. The rack wiring is of the highest grade airplane type, No. 16 stranded wire, and is led to the rack in a length of flexible conduit. High- and low-level circuits are in separate forms on the rack and cross-talk is reduced to a negligible quantity. Only three types of standard RCA tubes are used throughout the entire recording system.

The heavy wiring to the power control panel prevents swinging this panel outward, as in the case of the amplifier rack. The service door is located at the rear of the panel on the left side of the body. All parts are stencilled and all wiring is in conduit and is color-coded. At the top is a work light and at the base are soldering iron outlets.

The front compartment of the truck, as shown in Fig. 5, contains all the rotating equipment and the small accessories used on the set. By locating such equipment forward, the stage helper need not disturb the recordist as he collects his mixer case, telephone set, microphones, *etc.*, and the recordist is left free to prepare his equipment for recording. The battery chargers are in the background. Auxiliary outlets are provided for the mixer case so that mixing can be done in the front compartment if desired. The windows can be lowered, and a ventilating

FIG. 7. Pre-amplifier and microphone.

fan and lights are provided. The same type of selsyn motor system is provided as is used in the studio. This has been found to be very desirable and allows playback and process projection equipment to be operated in synchronism with the cameras. The machine compartments are sound-proofed with lead and felt so that the truck is quiet enough to operate right on the set if desired.

Fig. 6 shows the mixer case. It is built of duralumin with a black alumilite finish, and is provided with a collapsible stand of the same material. Three mixing positions are available and facilities are provided to read and adjust heater and plate currents to the microphone pre-amplifiers. A high-speed extension volume indicator is supplemented by the latest type of high-quality monitoring head-phones. A telephone subset connects the mixer with the recordist and an extension connects with the stage helper at the microphone.

Fig. 7 shows the portable pre-amplifier and the type *630* microphone. The pre-amplifier has two stages of amplification and a gain of 48 db. It can be plugged into the line anywhere between the microphone and the mixer case. On long microphone runs it is used at the microphone, to raise the speech level well above line noised causes by lighting cables or electrical interference of any kind on the set. A radio-frequency filter is incorporated in the circuit to prevent radio pick-up when recording near broadcast antennas and aboard ships. Fig. 8 shows the pre-amplifier with the cover removed. The tube shelf may be opened for ease of servicing.

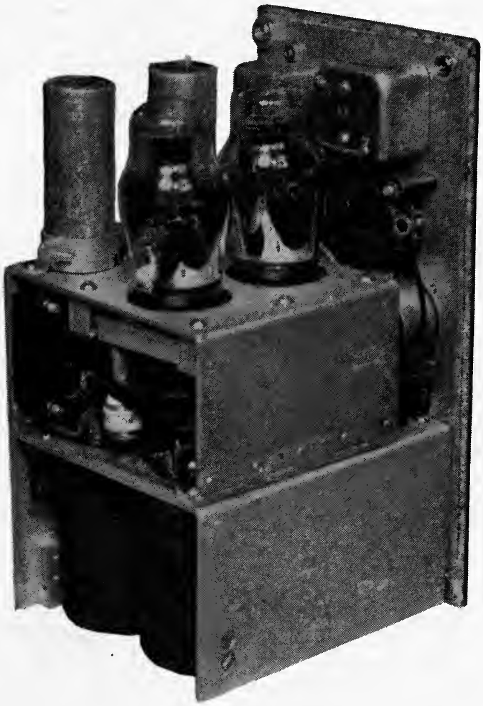


FIG. 8. Pre-amplifier, without case.

Fig. 9 is a block diagram of the recording circuit. For recording music, the frequency response is flat within ±1 db. from 40 to 9000 cps. For recording dialog the low end of the characteristic is reduced 6 db. at 100 cps. by a dialog equalizer in the pre-amplifier, the response is sharply cut off below 100 cps. by an 80-cycle high-pass filter, and the high end is always cut off at 9000 cps. by the 9000-cycle low-pass filter. Upward equalization is available by means of a high-frequency equalizer ahead of the recording amplifier. In general, a gradual 3-db. rise is used from 1000 to 7000 cps.

The mixer amplifier and recording amplifier are two-stage amplifiers, each having a gain of 50 db. Two units are used for ease of inserting filters and to render the equipment interchangeable with fixed-channel equipment in which the mixer amplifier is in a tea-wagon console on the stage and the recording amplifier in a central recording building. The overall harmonic distortion of the recording system is less than one per cent at an output of +22 db. above a zero power level of 6 milliwatts. This output level is 6 db. above 100 per cent modulation of the recording galvanometer.

The motor circuit consists of a 220-volt, 3-phase, 60-cycle, 1.75-kva. converter, driven by a 110-volt storage battery supplying interlock voltage to a 3-phase distributor driven by a $^1/_6$-hp. 110-volt d-c. motor. As many as eight cameras can be interlocked with the recording machine and distributor. Normally the motor

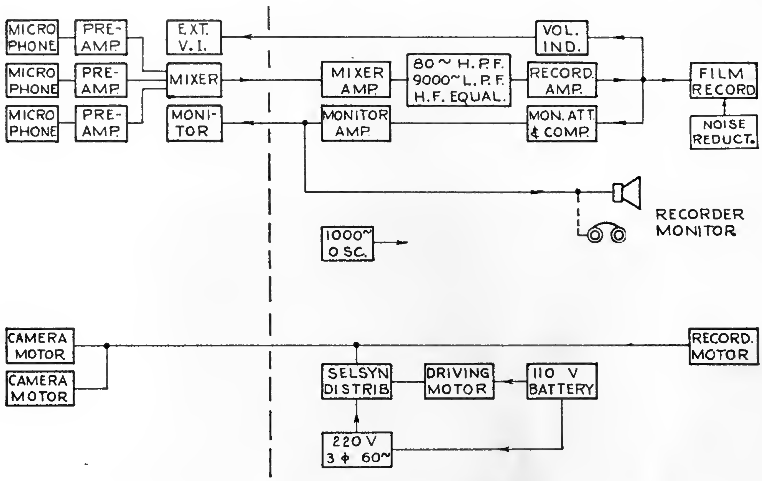


FIG. 9. Diagram of recording circuit.

speed is held at 1200 rpm. by a flywheel and butterfly type of control on the d-c. motor. The control can be cut out, however, and rheostats used to vary the speed from 900 to 1400 rpm. for undercranking or overcranking the cameras. A synchronizing circuit is provided that fogs the film in the camera and opens the bias circuit of the recorder when the system is up to speed. A limited power supply at 110-volts a-c. for playback and public-address amplifiers is available from the converter through a 3-phase 220/110-volt transformer.

A SIMPLIFIED DEVICE FOR CUEING MOTION PICTURE FILMS*

R. VINCENT**

Since the early days of silent pictures, the film measuring machine has been one of the tools of trade for the film cutter. The device here described is a modernized and improved form of the old familiar footage counter. Engineered to meet the exacting demands of musical conductor, re-recording mixer, commentators, and sound-effects men, it is a definite advance over previous devices. (Fig. 1.)

Simplicity has been the keynote in its construction. It consists of a three-place Veeder counter driven by a synchronous clock motor assembled so as to create a minimum of noise, the clock-face being illuminated from inside the case and in-

FIG. 1. Cueing device.

clined so as to be easily read. The associated electric stop-watch has the advantage over the hand-watch in that it has a much larger dial and may be started either manually or by plugging in on the a-c. projector or recording circuit so that timing begins with the start-marks on the film, before the picture appears on the screen. Of course, this is true also of the footage counter.

The case is of cast aluminum alloy and is so proportioned as to cause a minimum of resonance and sounding-board effect. The result is a compact and easily read device that may be used within a foot or two of the microphone, as is often necessary in connection with newsreel commentation.

---

*Presented at the Fall, 1937, Meeting at New York, N. Y.; received October 14, 1937.

** Reeves Sound Studios, Inc., New York, N. Y.

The applications of the counter seem to increase with use. Often the counters are used in pairs and sometimes even three's. Using the counters simultaneously saves many rehearsals and hundreds of feet of film.

A counter with stop-clock is usually preferred in the control room. A counter without the clock is ordinarily sufficient for a commentator, and when scoring from high-quality disk recordings a third counter is pressed into service.

A record or film may be started and run out to some predetermined length, say, 39 feet. The projector and recording machine then are started at, let us say, 15 feet. The mixer opens his controls, and if the cue sheet has been correctly prepared, the title music will begin exactly at the desired spot; and so on down through the reel. Often the commentator or the sound-effects must come in on a blind cue; the synchronized counter gives the correct instant for starting or stopping. Hands are left free, numbers are large and illuminated, and useless conversion from seconds to feet is eliminated.

In the cutting and review rooms this convenience is also valuable. Unlike the regular stop-watches which have an unhandy way of getting lost at critical moments, this is a piece of permanent equipment, always ready for instant use. Corrections, cuts, and inspections may be made directly in terms of feet from the beginning of the reel; or, when counter and clock combinations are used independently of each other, one may measure both the reel and the duration of a specific scene.

Simplicity, silence, and ruggedness are the important mechanical features of the device, and practical experience with the most exacting of cueing problems has been responsible for the present design.

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 copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Library of the U. S. Department of Agriculture, Washington, D. C.

American Cinematographer

18 (Nov., 1937), No. 11

Film Is Most Valuable in Television (p. 450). — H. R. LUBCKE

Ampro's Model *L* for All Houses (p. 473).

18 (Dec., 1937), No. 12

What 1937 Has Shown in Technical Progress in Motion Picture Making (p. 493).

Soviet Working in New Stereoscopic Pictures (p. 502). — V. SOLYEV

Walter Bell Completes 8-Mm. Reversal Machine (p. 519).

American Physics Teacher

5 (Dec., 1937), No. 6

Advanced Laboratory Experiments in Acoustics, Including a New Method for Measuring the Adsorption of Sound in Tubes (p. 252). — C. K. STEDMAN

Communications

17 (Nov., 1937), No. 11

Disk Recording—Record Processing (p. 24). — T. L. DOWEY

Educational Screen

16 (Nov., 1937), No. 9

Foreign Films for Educational Institutions (p. 289). — M. Z. MERCIER

Electronics

10 (Nov., 1937), No. 11

New Pictures by Wire (p. 12).

Phonograph Pick-Up Tracking Error *vs*. Distortion and Record Wear (p. 19). — B. OLNEY

Screens for Television Tubes (p. 31). — I. G. MALOFF AND D. W. EPSTEIN

International Photographer

9 (Nov., 1937), No. 10

Modern Backlot Magicians (p. 24). — C. JONES

New Continuous Projector (p. 27).
The Soundman's Book of Tables (p. 20) — J. N. A. HAWKINS
The Laboratory Book of Tables (p. 22). — D. K. ALLISON
(The last two are the first of a series of tables, to be published consecutively.)

International Projectionist

12 (Nov., 1937), No. 11

An Analysis of Imperfections Apparent on the Screen—II (p. 7). — A. C. SCHROEDER
Fundamentals of Sound Recording and Theater Reproduction—IV (p. 11) — F. T. JAMEY
Typical Troubles in Modern Sound Reproducing Units —*VI* (p. 20). — L. CHADBOURNE
An Outline of Tube Types Used in Modern Sound-Picture Amplifiers (p. 24). — W. STERLING
New Service Supply Units to Operate in the Theater Field (p. 27). — J. J. FINN

Kinematograph Weekly

249 (Nov. 18, 1937), No. 1596

Gevaert in the Color Field—in Association with True-Color (p. 52).

Kinotechnik

19 (Oct., 1937), No. 11

Die Reichsstelle für den Unterrichtsfilm (Teaching Films in Germany) (p. 254). — W. HELMBRECHT
Dynamik und Reintonwirkung der verschiedenen Schriftsysteme in Tonfilm (Dynamics and Pure Tone Effects of Different Stylus Systems for Sound-Films) (p. 255). — A. NARATH
Der Belichtungsmesser des Kameramannes (The Cameraman's Exposure Meter) (p. 259). — L. KUTZLEB
Anforderungen an Gluhlampen für den Bildwurf (Requirements for Incandescent Lamps for Projection) (p. 261). — O. HOPCKE

Movie Makers

12 (Dec., 1937), No. 12

Robot 35-Mm. (p. 621). — R. C. HOLSLAG
Sound Booth (p. 634).

Philips Technical Review

2 (Aug., 1937), No. 8

The Enlarged Projection of Television Pictures (p. 249). — M. WOLF

2 (Sept., 1937), No. 9

The Relationship between Fortissimo and Pianissimo (p. 266). — R. VERMEULEN

Photographic Journal

77 (Nov., 1937), No. 11

The Special Effects Department (p. 607). H. CHEVALIER

Photographische Industrie

35 (Nov. 24, 1937), No. 47

Fortschritte in der Fabrikation von Schmalfilmgeraten (Progress in the Manufacture of Substandard Film Apparatus) (p. 1269).

Technique Cinematographique

9 (Oct., 1937), No. 82

Vers le cinema stereoscopique de l'avenir (Motion Picture Stereoscopy of the Future) (p. 1019). V. SOLEF

Television

10 (Nov., 1937), No. 117

A New Idea for Large-Screen Pictures (p. 653).

The Design of the G.E.C. Television Receiver (p. 663). D. C. ESPLEY AND G. W. EDWARDS

SPRING, 1938, CONVENTION

WARDMAN PARK HOTEL
WASHINGTON, D. C.
APRIL 25th–28th, INCLUSIVE

Officers and Committees in Charge

W. C. KUNZMANN, *Convention Vice-President*
J. I. CRABTREE, *Editorial Vice-President*
G. E. MATTHEWS, *Chairman, Papers Committee*
W. WHITMORE, *Chairman, Publicity Committee*
E. R. GEIB, *Chairman, Membership Committee*
N. D. GOLDEN, *Chairman, Local Arrangements Committee*

Local Arrangements and Reception Committee

N. D. GOLDEN, *Chairman*

D. BENNETT
J. G. BRADLEY
H. T. COWLING
A. A. DETITTA
R. EVANS
N. GLASSER
C. L. GREGORY
N. C. HAEFELE
A. MUTO
R. F. NICHOLSON
W. K. PETTUS
J. A. PRATT
R. T. SCHLOSBERG
C. S. STODTER

Registration and Information

W. C. KUNZMANN, *Chairman*

E. R. GEIB
S. HARRIS
F. HOHMEISTER

Ladies' Reception Committee

MRS. R. EVANS, *Hostess*
assisted by

MRS. J. G. BRADLEY
MRS. H. T. COWLING
MRS. A. A. DETITTA
MRS. N. GLASSER
MRS. N. D. GOLDEN
MRS. S. B. RIDDICK
MRS. N. C. HAEFELE
MRS. A. MUTO
MRS. J. A. PRATT

Banquet Committee

R. EVANS, *Chairman*

J. G. BRADLEY
H. T. COWLING
A. A. DETITTA
N. GLASSER
N. D. GOLDEN
N. C. HAEFELE
W. C. KUNZMANN
A. MUTO

Publicity Committee

W. WHITMORE, *Chairman*

J. R. CAMERON	S. HARRIS	P. A. MCGUIRE
A. A. DETITTA	F. HEARON	A. MUTO
J. J. FINN	G. E. MATTHEWS	F. H. RICHARDSON

Convention Projection Committee

H. GRIFFIN, *Chairman*

N. C. HAEFELE	W. K. PETTUS	J. A. PRATT
W. HOLZ	J. FRANK, JR.	F. J. STORTY

Officers and Members of Washington Projectionist Local 224.

Membership Committee

E. R. GEIB, *Chairman*

J. G. BRADLEY	S. HARRIS
R. EVANS	J. A. PRATT

Hotel and Transportation Committee

J. G. BRADLEY, *Chairman*

D. BENNETT	C. A. LINDSTROM	R. T. SCHLOSBERG
F. HEARON	R. F. NICHOLSON	C. S. STODTER

Headquarters

The headquarters of the Convention will be the Wardman Park Hotel, where excellent accommodations are assured. A reception suite will be provided for the ladies, for whom also is to be arranged an interesting program of entertainment.

By special arrangement with the Hotel Management, special breakfast, luncheon, and dinner service will be provided on the Continental Room Terrace, for SMPE delegates only.

The following daily hotel rates, European plan, are guaranteed to SMPE delegates attending the Convention:

One person, room and bath	$ 3.50
Two persons, standard bed	5.00
Two persons, twin beds	6.00
Parlor suite, one person	9.00
Parlor suite, two persons	11.00

Room reservation cards will be mailed to the membership of the Society in the near future, and those who plan to attend the Spring Convention should return their cards promptly to the Wardman Park Hotel to be assured satisfactory accommodations. Local railroad ticket agents should be consulted with regard to trains and rates.

For those who will motor to the Convention ample free parking space is available on the Hotel grounds. For those who prefer parking in the Hotel garage, a special rate of 75 cents a day has been arranged.

Technical Sessions

An attractive and interesting program of technical papers is being assembled by the Papers Committee. All technical sessions, apparatus symposiums, and film programs will be held in the *Little Theatre* of the Hotel.

Apparatus Exhibit

An exhibit of newly developed motion picture apparatus will be held, to which all manufacturers of equipment are invited to contribute. No charge will be made for space. Information concerning the exhibit and reservations for space should be made by writing to the General Office of the Society.

Apparatus displayed should be newly designed or developed, or should have features of technical interest for the engineers attending the Convention.

Registration and Information

The Convention registration headquarters will be located at the entrance of the *Little Theatre*, where all the technical sessions will be held. The members of the Society and guests attending the Convention are expected to register and receive their badges and identification cards for admittance to special evening sessions. These cards will also be honored at several *de luxe* motion picture theaters in Washington during the four days of the Convention.

Informal Luncheon and Semi-Annual Banquet

The usual informal Luncheon will be held at noon of the opening day of the Convention, April 25th, in the Continental Room of the Hotel. On the evening of Wednesday, April 27th, will be held the Semi-Annual Banquet of the Society in the Continental Room of the Hotel at 8:00 P.M. Addresses will be delivered by prominent members of the industry, followed by dancing and other entertainment.

Motion Pictures

Delegates registering at the Convention will be supplied with complimentary passes to the following motion picture theaters in Washington during the dates of the Convention:

By courtesy of Mr. J. J. Payette: Warners' *Uptown* and *Earl* Theaters.
By courtesy of Mr. H. Meiken: *RKO Keith's* Theater.
By courtesy of Mr. C. Barron: Loew's *Capitol, Palace,* and *Columbia* Theaters.

Points of Interest

To list all the points of interest in and about Washington would require too much space, but among them may be mentioned the various governmental buildings, such as the Capitol, the White House, Library of Congress, Department of Commerce, U. S. Treasury, U. S. Bureau of Standards, Department of Justice, Archives Building; and other institutions such as the National Academy of Sciences, the Smithsonian Institution, George Washington University, Washington Cathedral, Georgetown University, *etc.* In addition may be included the Lincoln Memorial, the Washington Monument, Rock Creek Park, The Francis Scott Key Memorial Bridge, Arlington Memorial Bridge, the Potomac River, and Tidal Basin. Mt. Vernon, birthplace of Washington, is but a short distance away and many other side trips may be made conveniently *via* the many highways radiating from Washington.

Recreation

The Wardman Park Hotel management is arranging for golfing privileges for SMPE delegates at several courses in the neighborhood. Regulation tennis courts are located upon the Hotel property, and riding stables are within a short distance of the Hotel. Trips may be arranged to the many points of interest in and about Washington.

SOCIETY ANNOUNCEMENTS

BOARD OF GOVERNORS

The regular January meeting of the Board of Governors was held at the Hotel Pennsylvania, New York, N. Y., on January 14th. New members present at the meeting were E. A. Williford, Financial Vice-President, and R. E. Farnham, Governor. (A complete list of members of the Board of Governors will be found on the reverse of the Contents page of this issue.)

Messrs. W. C. Kunzmann and J. I. Crabtree reported on preliminary plans for the Washington Convention, to be held April 25th–28th, inclusive, at the Wardman Park Hotel. Some details of the Convention are given in the preceding section of this issue of the JOURNAL, and a complete program will be mailed to the membership in the near future. Detroit was selected for the Fall, 1938, Convention.

Mr. O. M. Glunt, retiring Financial Vice-President, reported very satisfactory fiscal conditions for the year 1937, and in presenting the budget for 1938, Mr. E. A. Williford, Financial Vice-President elect, prognosticated an equally successful year for 1938. The membership is continuing to grow, having reached an all-time high of nearly 1300 members.

The remainder of the Board meeting was concerned mainly with routine matters. The next meeting will be held at Washington, D. C., April 24th, the day preceding the opening of the Spring Convention.

MID-WEST SECTION

On January 18th, the Mid-West Section held its regular monthly meeting in the Engineering Building, Chicago, Ill., at which time Mr. A. F. Conto, formerly Chief Engineer of the Western Television Corp., presented a paper on the subject of "Trends in Television." The program was long and interesting, and the meeting was very well attended. The next meeting of the Section will be held on Tuesday, February 15th.

STANDARDS COMMITTEE

At a meeting held at the Office of the Society on January 7th, the work of reviewing the present standards of the Society was completed. The material is being set in type and proofs are being mailed to all the members of the Standards Committee, together with ballots for voting upon adoption of the revision.

The revision is based upon the previous edition of the Standards, published in November, 1934, and contains all the changes and additions that have evolved in the interim as a result of developments in the motion picture art. A few new drawings have been added in the 35-mm. and 16-mm. categories, as also a complete set of 8-mm. drawings. Quite a number of tolerances have been added that were lacking in the previous edition.

It is hoped that the voting upon the revision by the Standards Committee will be completed in time to publish the entire body of standards in the March issue of the JOURNAL, at which time comments from the membership of the Society will be solicited. If no objections arise, the Board of Governors will take action at their next meeting (April 24th) on adopting them as SMPE standards, after which they will be submitted to the Sectional Committee on Motion Pictures (ASA) for approval by the American Standards Association. Although a number of these standards have already been approved by the ASA, the complete body of standards will be re-submitted in view of the new plan of numbering and the single-sheet format.

PROJECTION PRACTICE COMMITTEE

At a meeting held at the Paramount Building, New York, N. Y., on January 20th, an agenda was established for the new year, and work continued on matters left unfinished from the previous year. Analysis of the theater survey charts is progressing, and it is anticipated that a report on the subject will be forthcoming at the approaching Washington Convention.

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 class 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 the President and Past-President shall be two years; of the Engineering, Editorial, Financial, and Convention Vice-Presidents, two years; and of the Executive Vice-President, Secretary, and Treasurer, one year. Of the Engineering, Editorial, Financial, and Convention Vice-Presidents, two shall be elected alternately each year or until their successors are chosen. The President shall not be immediately eligible to succeed himself in office.

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 five elected Governors. Two, and three, of the Governors shall be elected alternately each year to serve for two years.

---

* Corrected to January 1, 1938.

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, 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.

(*c*) An Active member is privileged to vote and to hold sectional office, and to have full privileges in all activities of the Society except that he may not be elected to a national office.

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 **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 shall be made on blank forms provided for the purpose, shall give a complete record of the applicant's education and experience.

Sec. 3.—(*a*) An **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*) Applicants for the grade of **Fellow** shall give as reference at least three Fellows in good standing. Applicants shall be elected to membership by the approval of at least three-fourths of the Board of Governors.

(*c*) Applicants for **Active** membership shall give as reference at least three members of Active or of higher grade in good standing. Applicants shall be elected to membership by the approval of at least three-fourths of the Board of Governors.

(*d*) Applicants for **Associate** membership shall give as reference at least one member of higher grade in good standing. Applicants shall be elected to membership by the approval of at least three-fourths of the Board of Governors.

By-Law II

Officers

Sec. 1.—An officer or governor shall be an Honorary member, a Fellow, or an Active member. After January 1, 1935, Active members shall not be eligible to hold national office in the Society.

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.

Sec. 2.—A majority of the Board of Governors shall constitute a quorum at regular 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 office, and to 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

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-tenth 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 V

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 4 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.

(*b*) The **engineering vice-president** shall appoint all technical committees. He shall be responsible for the general initiation, supervision, and coördination 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 VI

Elections

Sec. 1.—(*a*) All officers and five 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, having invited nominations from the Active, Fellow, and Honorary membership by letter form not less than forty days before the Board of Governors' meeting, shall nominate for each vacancy several suitable candidates. The secretary shall then notify these candidates of their nomination, in order of nomination, and request their consent to run for office. 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 also be provided on this letter ballot under each office, in which space the names of any Fellows 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.

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 the January 1st following their election.

(*b*) The first group of vice-presidents, *viz.*, the executive vice-president, engineering vice-president, editorial vice-president, financial vice-president, convention vice-president, and a fifth governor, shall be nominated by the Board of Governors at its first meeting after the ratification of the corresponding provisions of the Constitution; and the membership shall vote on the candidates in accordance with the procedure prescribed in these By-Laws for regular elections of officers so far as these may be applicable. The term of these vice-presidents shall be deemed to begin January 1, 1934.

By-Law VII

Dues and Indebtedness

Sec. 1.—The annual dues shall be twenty dollars ($20) for Fellows, ten dollars ($10) for Active members, and six dollars ($6) for Associate members, payable on or before January 1st of each year. Current or first year's dues for new members, dating from the notification of acceptance in the Society, shall be prorated on a monthly basis. Five dollars of these dues shall apply for annual subscription to the publication. No admission fee will be required in any grade of membership.

Sec. 2.—(*a*) Transfer of membership may be made effective at any time by payment of the pro rata dues for the current year.

(*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. All Honorary Members, Fellows, and Active Members in good standing, as defined in Sec. 5, may vote or otherwise participate in the meetings.

Sec. 4.—Members shall be considered delinquent whose dues remain unpaid for four months. Members who are in arrears of dues for 30 days after notice of such delinquency, mailed to their last address of record, shall have their names posted at the Society's headquarters, which shall be the General Office, and notices of such action mailed to them. Two months after becoming delinquent, members shall be dropped from the rolls if non-payment is continued.

Sec. 5.—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 Section 1 to 4, inclusive, of this By-Law VII, given above may be modified or rescinded by action of the Board of Governors.

By-Law VIII

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. In the printed emblem, the four-hole openings shall be orange, and the letters black, the remainder of the insignia being black and white. The Society's emblem may be worn by members only.

By-Law IX

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 X

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.

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 non-resident 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.

OFFICERS

Sec. 4.—Each Section shall nominate and elect a chairman, two managers, and a secretary-treasurer. The Section chairmen shall automatically become members of the Board of Governors of the General Society, and continue in that position for the duration of their terms as chairmen of the local Sections.

ELECTION OF OFFICERS

Sec. 5.—The officers of a Section shall be Active, Fellow, or Honorary members of the General Society. They shall be nominated and elected to sectional office under the method prescribed under By-Law VI, Section 1, for the nomination and election of officers of the General Society. The word *manager* shall be substituted for the word *governor*. All Section officers shall hold office for one year, or until their successors are chosen, except the Board of Managers, as hereinafter provided.

MANAGERS

Sec. 6.—The Board of Managers shall consist of the Section chairman, the Section past-chairman, the Section secretary-treasurer, and two Active, Fellow, or Honorary members, one of which last named shall be elected for a two-year term, and one for one year, and then one for two years each year thereafter. At the discretion of the Board of Governors, and with their written approval, this list of officers may be extended.

BUSINESS

Sec. 7.—The business of a Section shall be conducted by the Board of Managers.

EXPENSES

Sec. 8.—(*a*) As early as possible in the fiscal year, the secretary 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 secretary-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 by fixed annual dues, or by both.

(*f*) The secretary of the Society shall, unless otherwise arranged, supply to each Section all stationery and printing necessary for the conduct of its business.

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.

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 XI

Amendments

Sec. 1.—These By-Laws may be amended at any regular meeting of the Society by a two-thirds vote by ballot of the members present at the meeting, a quorum being present, either on the recommendation of the Board of Governors or by a recommendation of the Board of Governors signed by any ten members of Active or higher grade.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXX **MARCH, 1938** **Number 3**

CONTENTS

JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

Subscription to non-members, $8.00 per annum; to members, $5.00 per annum, included in their annual membership dues; single copies, $1.00. A discount on subscriptions or single copies of 15 per cent is allowed to accredited agencies. Order from the Society of Motion Picture Engineers, Inc., 20th and Northampton Sts., Easton, Pa., or Hotel Pennsylvania, New York, N. Y.

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

Publication Office, 20th & Northampton Sts., Easton, Pa.

General and Editorial Office, Hotel Pennsylvania, New York, N. Y.

West-Coast Office, Suite 226, Equitable Bldg., Hollywood, Calif.

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

REVISION OF SMPE STANDARDS PROPOSED FOR ADOPTION BY THE SOCIETY*

The following edition of the Standards of the Society of Motion Picture Engineers is based upon the previous edition, published in November, 1934, and contains all the revisions and additions that have evolved in the interim as a result of developments in the motion picture art. A few new drawings have been added in the 35-mm. and 16-mm. categories, as also a complete set of 8-mm. drawings. Quite a number of tolerances have been added, where lacking in the previous edition.

The complete body of standards herein contained have received initial approval by the Standards Committee, and comments from the membership of the Society are solicited. If no objections arise, the Board of Governors will take action at their next meeting on adopting them as SMPE standards, after which they will be submitted to the Sectional Committee on Motion Pictures (ASA) for approval by the American Standards Association. Although a number of these standards have already been approved by the ASA, the complete body of standards will be re-submitted in view of the new plan of numbering and the single-sheet format.

The early standardization activities of the Society have been described in an article entitled "A Historical Summary of Standardization in the Society of Motion Picture Engineers," published in the October, 1933, issue of the JOURNAL. Various editions of the standards promulgated by the Society have been published from time to time, the more comprehensive editions occurring in 1928, 1930, 1932, and 1934. In addition to publication in the JOURNAL, the standards were printed in the form of small booklets entitled *Dimensional Standards for Motion Picture Apparatus, and Recommended Practice.*

The issue published in November, 1934, was a revision of the edition published in May, 1930, and approved by the American Standards Association, September 20, 1930. Although some of the charts in the 1930 edition were superseded in the 1934 edition, the superseded charts were retained for purposes of reference, the original chart numbers remaining unchanged. Some of the changes involved new dimensions, whereas others involved merely a newer and clearer presentation of the data. The 1934 edition, therefore, contained all the 15 charts previously published in 1930, in addition to new charts, 16 to 32, inclusive.

During the period following the 1934 edition, considerable standardi-

* NOTE: Comments on any or all the subjects presented in this report are invited from the membership of the Society.

zation activity occurred throughout the world, particularly with respect to 16-mm. film and equipment. As a result of this activity, and also as a result of continuing development of the art, a need for substantial revision of many of the standards drawings was indicated, not only for the purpose of keeping step with the developments, but also for the purposes of clarifying the material and presenting the dimensional data in such fashion as to avoid all possibility of misinterpretation, to enhance their value in all other respects, and to devise a format that would admit of closer agreement with European standardization.

The present edition, therefore, is based upon the edition of 1934. Many of the charts have been redrawn, although for the most part the factual material has not been changed. The most important dimensional changes occur in the drawings of the sound-tracks, as is to be expected in view of the rapid changes being made in the art of sound recording. A number of new drawings have been added, referring particularly to those indicating the relation between the location of the sound-track, the emulsion surface of the film, and the direction of travel of the film. Also, tolerances have been added, where missing in the previous edition. However, no tolerances have been assigned to difference-dimensions, which in all cases have been calculated from the principal dimensions without considering tolerances.

In view of the Society's affiliation with the American Standards Association and the International Standards Association, and, according with the general practice in international standardization, the basic dimensions in the present revision of the standards have been referred to the metric system, the English equivalents being calculated to the appropriate number of decimal places. By so doing, the way is paved for much closer agreement in international standardization.

Up to the present time, all the standards adopted by the Society and approved by the American Standards Association have been approved by the latter organization as a unit body of standards, to which has been assigned the designation ASA-Z22. In view of the inflexibility of the arrangement, the present purpose is to submit the standards for adoption by the ASA in the form of single-sheet standards to each of which designation numbers will be assigned individually, thus permitting revision of any drawing or chart and its re-submission to the ASA without affecting the designations of the other charts. The designations will be numbered consecutively as approved by the ASA, and will, in addition, retain the project designation *Z22*. Thus, *Z22.12* refers to the twelfth standard in the *Z22* project of the *ASA*, which is the motion picture project.

In addition, however, an SMPE numbering scheme has been devised in order to include material that may not possibly be subject or amenable to national standardization through the ASA, and to supply a means of identification of SMPE standards prior to adoption by the ASA and assignment of designation numbers. Accordingly four categories have been established, referring principally to the widths of film in current use; and the letter *m*, referring to items not falling in those categories:

35-mm.
16-mm. (doubly perforated)
16-mm. (singly perforated)
8-mm.
m miscellaneous

The width designation is followed by the subject number in that category, which is again followed by the number of that particular drawing. The entire designation is preceded by the letters *DS* or *RP*, referring to *Dimensional Standards* or *Recommended Practice*, respectively. Thus *DS35-5-1* means the first drawing (not revision: the first revision would be the second drawing) of Dimensional Standard No. 5 in the 35-mm. category. In view of the fact that the number of revisions made prior to this edition of the standards is uncertain, all the drawings in this edition are designated 1, so that accurate track of future revisions may henceforth be kept. As a matter of record, however, the original dates of the standards, as far as they could be traced, are included on the drawings.

The entire standardization project is outlined in Table I, in which are shown the ASA "Z" numbers.

The following sections list the dimensional standards and recommended practices. Where changes from the previous standards have been made, these changes have been indicated.

DIMENSIONAL STANDARDS

35-Mm. (DS35)

DS35-1-1 (Z22.1) Cutting and Perforating Negative and Positive Raw Stock.—(1934 Chart 16) In dimensions *C* and *D*, the tolerances have been slightly widened.

Perforations.—The perforation shown is the standard SMPE perforation, adopted July 14, 1933, for both positive and negative film.

DS35-2-1 (*Z22.2*) *Sprockets.*—(1934 Chart 19) Revised drawing. No changes in data except rounding off decimal places.

DS35-3-1 (*Z22.3*) *Camera Aperture.*—(1934 Chart 24) Tolerances have been added; also the difference-dimensions *E*, *F*, and *G*, and the note below the table.

DS35-4-1 (*Z22.4*) *Projector Aperture.*—(1934 Chart 25) The dimension between picture frames has been omitted. Tolerances have been

TABLE I

Dwg. No.	Subject	35-Mm.	16-Mm. Double	16-Mm. Single	8-Mm.	Misc. (*m*)
			Dimensional Standards (DS)			
1	Cutting and perforating film	Z22.1	Z22.10	Z22.17	Z22.23	
2	Projector Sprockets	Z22.2	Z22.11		Z22.24	
3	Camera Aperture	Z22.3	Z22.12	Z22.18	Z22.25	
4	Projector Aperture	Z22.4	Z22.13	Z22.19	Z22.26	
5	Emulsion and Sound-Track Positions in Camera	Z22.5	Z22.14	Z22.20	Z22.27	
6	Emulsion and Sound-Track Positions in Projector	Z22.6	Z22.15	Z22.21	Z22.28	
7	Sound Records and Scanned Areas	Z22.7		Z22.22		
8	Reels	Z22.8	Z22.16	Z22.16	Z22.29	
9	Projection Lenses	Z22.9				
1	Unit of Photographic Intensity					Z22.30
2	Lantern Slides					Z22.31
			Recommended Practice (RP)			
1	Splices	Z22.32	Z22.37	Z22.38		
2	Release Print	Z22.33				
3	Screen Sizes	Z22.34				
4	Sound Transmission of Screens	Z22.35				
5	Projection Room Layouts	Z22.36				
1	Sensitometry					Z22.39
2	Photographic Density					Z22.40
3	Projection Screen Brightness					Z22.41
4	Nomenclature					Z22.42

added, as well as the difference-dimensions *D, E, F, G,* and *H*. *R* has been increased slightly, and the note beneath the table added.

> *Frame-Line.*—The center of the frame-line is midway between two successive perforations on each side of the film.

DS35-5-1 (Z22.5) Emulsion and Sound Record Positions in Camera (Negative).—New Drawing.

DS35-6-1 (Z22.6) Emulsion and Sound Record Positions in Projector (Positive).—New drawing.

DS35-7-1 (Z22.7) Sound Records and Scanned Area.—(1934 Chart 26) The width of the variable-width sound record has been increased from 0.71 to 0.76 inch, to correspond with present practice; also, tolerances have been added.

DS35-8-1 (Z22.8) Reels.—New drawing.

DS35-9-1 (Z22.9) Projection Lenses.—(*a*) No. 1 projection lens: External diameter of lens barrel 51.59 mm. ($2^1/_{32}$ inches); (*b*) No. 2 projection lens: External diameter of lens barrel 70.65 mm. ($2^{25}/_{32}$ inches). (No change from previous standard.)

16-Mm. Doubly Perforated (DS16d)

DS16d-1-1 (Z22.10) Cutting and Perforating Negative and Positive Raw Stock.—(1934 Chart 17) Tolerances for *C* and *D* have been increased to accord with European standards; also, *G* has been increased slightly.

DS16d-2-1 (Z22.11) Sprockets.—(1934 Charts, 20, 21, and 22) Revised drawing. No changes in data.

DS16d-3-1 (Z22.12) Camera Aperture.—(1934 Chart 11) The difference-dimensions *C, E,* and *F* have been added, as also the tolerances.

DS16d-4-1 (Z22.13) Projector Aperture.—(1934 Chart 11) Tolerances have been added, as also the difference-dimensions *C, D, E,* and *F.*

DS16d-5-1 (Z22.14) Emulsion Position in Camera (Negative).—New drawing.

DS16d-6-1 (Z22.15) Emulsion Position in Projector (Positive).—New drawing.

DS16d-8-1 (Z22.16) Reels.—New drawing.

16-Mm. Singly Perforated (DS16s)

DS16s-1-1 (Z22.17) Cutting and Perforating Negative and Positive Raw Stock.—New drawing, the dimensions given being the same as corresponding dimensions on *DS16d-1-1*. (See remarks under *DS16d-1-1*.)

ZS16s-2-1 Sprockets.—In preparation.

DS16s-3-1 (*Z22.18*) *Camera Aperture.*—(1934 Chart 28) Tolerances have been added, as also the difference-dimensions *C*, *E*, and *F*.

DS16s-4-1 (*Z22.19*) *Projector Aperture.*—(1934 Chart 29) Tolerances have been added, as also the difference-dimensions *C*, *D*, *E*, and *F*.

> *Frame-Line.*—The center of the frame-line shall pass through the center of a perforation on each side of the film.

DS16s-5-1 (*Z22.20*) *Emulsion and Sound Record Positions in Camera* (*Negative*).—New drawing. The distance between the center of the picture and the corresponding sound has been increased from 25 frames to 26 frames, in accordance with the action of the International Standards Association at the Budapest Conference in 1936.

DS16s-6-1 (*Z22.21*) *Emulsion and Sound Record Positions in Projector* (*Positive*).—New drawing. The distance between the center of the picture and the corresponding sound has been increased from 25 frames to 26 frames.

DS16s-7-1 (*Z22.22*) *Sound Records and Scanned Area.*—(1934 Chart 30) For the variable-width record, the width of the printed area has been decreased from 0.096 to 0.085 inch, and the width of the sound record has been increased from 0.060 to 0.064 inch.

For the variable-density record the width of the sound record has been increased from 0.080 to 0.085 inch.

The width of the scanned area has been increased from 0.065 to 0.074 inch. Also, tolerances have been added.

> *Film-track in Cameras and Projectors.*—A clearance of 0.13-mm. (0.005 inch) shall be allowed in designing the film-track in cameras and projectors.

DS16s-8-1 (*Z22.16*) *Reels.*—Same as *DS16d-8-1* (*Z22.16*).

8-Mm. (*Ds8*)

DS8-1-1 (*Z22.23*) *Cutting and Perforating Negative and Positive Raw Stock.*—New drawing.

DS8-2-1 (*Z22.24*) *Sprockets.*—New drawing.

DS8-3-1 (*Z22.25*) *Camera Aperture.*—New drawing.

DS8-4-1 (*Z22.26*) *Projector Aperture.*—New Drawing.

DS8-5-1 (*Z22.27*) *Emulsion Position in Camera* (*Negative*).—New drawing.

(*DS8-6-1*) (*Z22.28*) *Emulsion Position in Projector* (*Positive*).—New drawing.

DS8-8-1 (*Z22.29*) *Reels.*—New drawing.

Miscellaneous

DSm-1-1 (*Z22.30*) *Unit of Photographic Intensity.*—The unit of photographic intensity adopted by the International Congress of Photography in 1933 shall be adopted for negative materials. (No change from previous standard.)

DSm-2-1 (*Z22.31*) *Lantern Slides.*—The mat opening shall be 3.0 inches (76.20 mm.) wide by 2.35 inches (59.69 mm.) high. The thumb mark shall be located in the lower left-hand corner adjacent to the reader when the slide is held so that it can be read normally against the light. (No change from previous standard.)

RECOMMENDED PRACTICE

35-Mm. (*RP35*)

RP35-1-1 (*Z22.32*) *Film Splices, Negative and Positive.*—(1934 Chart 18) For the negative splices the dimension *B* in the 1934 edition was incorrect and is here corrected. Dimension *F* has been corrected accordingly. New dimensions *C*, *D*, and *E* have been added. For the regular positive and the full-hole positive splices, new dimensions *C*, *D*, and *F* have been added.

RP35-2-1 (*Z22.33*) *Release Prints.*—In course of revision.

RP35-3-1 (*Z22.34*) *Screen Sizes.*—Sizes of screens shall be in accordance with Table II.

The spacing of grommets shall be 6 inches, with 12 inches as a possible sub-standard. The ratio of width to height of screens shall be 4 to 3. (See *J. Soc. Mot. Pict. Eng.*, June, 1933, p. 510.)

The width of the screen should be equal to approximately $^1/_6$th the distance from the screen to the rear seats of the auditorium. The distance between the front row of seats and the screen should be approximately 0.87 foot for each foot of screen width.

RP35-4-1 (*Z22.35*) *Sound Transmission of Screens.*—A loss of 2.5 db. as given by the average response curve at 6000 cps. relative to the 1000-cycle response as recorded, is a desirable limiting value for existing types of sound equipment. Screens that meet this requirement are usually found to attenuate 4 db. at 10,000 cps. As to regularity of response, variations greater than ± 2 db. would not be tolerable.

No limits for regularity have been established for frequencies lower than 300 cps. (See *J. Soc. Mot. Pict. Eng.*, Sept., 1931, p. 446.)

RP35-5-1 (*Z22.36*) *Projection Room Plans.*—Complete plans for projection rooms are contained in the Report of the Projection Practice Committee published in *J. Soc. Mot. Pict. Eng.*, Oct., 1935, p. 341.

TABLE II

Screen Sizes

Size No. of Screen	Picture Width (Feet)	Picture Height, Feet	Inches	Size No. of Screen	Picture Width (Feet)	Picture Height, Feet	Inches
8	8	6	0	25	25	18	9
9	9	6	9	26	26	19	6
10	10	7	6	27	27	20	3
11	11	8	3	28	28	21	0
12	12	9	0	29	29	21	9
13	13	9	9	30	30	22	6
14	14	10	6	31	31	23	3
15	15	11	3	32	32	24	0
16	16	12	0	33	33	24	9
17	17	12	9	34	34	25	6
18	18	13	6	35	35	26	3
19	19	14	3	36	36	27	0
20	20	15	0	37	37	27	9
21	21	15	9	38	38	28	6
22	22	16	6	39	39	29	3
23	23	17	3	40	40	30	0
24	24	18	0				

Projection Lens Height.—The standard height from the floor to the center of the projection lens of a motion picture projector should be 48 inches.

Projection Angle.—Should not exceed 12 degrees.

Observation Port.—Should be 12 inches wide and 14 inches high, and the distance from the floor to the bottom of the openings shall be 48 inches. The bottom of the opening should be splayed 15 degrees downward. If the thickness of the projection room wall should exceed 12 inches, each side should be splayed 15 degrees.

Projection Lens Mounting.—The projection lens should be so mounted that the light from all parts of the aperture shall traverse an uninterrupted part of the entire surface of the lens.

Projection Lens Focal Length.—The focal length of motion picture projection lenses should increase in $^1/_4$-inch steps up to 8 inches, and in $^1/_2$-inch steps from 8 to 9 inches.

Projection Objectives, Focal Markings.—Projection objectives should have the equivalent focal length marked thereon in inches, quarters, and halves of an inch, or in decimals, with a plus (+) or minus (−) tolerance not to exceed 1 per cent of the designated focal length also marked by proper sign following the figure.

16-Mm. Doubly Perforated (RP16d)

RP16d-1-1 (Z22.37) Film Splices, Negative and Positive.—(1934 Chart 12) Several difference-dimensions have been added in order to render the drawing clearer.

16-Mm. Singly Perforated (RP16s)

RP16s-1-1 (Z22.38) Film Splices, Negative and Positive.—New drawing.

Miscellaneous

RPm-1-1 (Z22.39) Sensitometry.—The principle of non-intermittency shall be adopted as recommended practice in making sensitometric measurements.

RPm-2-1 (Z22.40) Photographic Density.—The integrating sphere shall be used as a primary instrument for the determination of photographic density. Photographic densities determined by means of this primary instrument shall be used as secondary or reference standards by means of which densitometers of other types may be calibrated.

RPm-3-1 (Z22.41) Projection Screen Brightness.—It is recommended that the brightness at the center of a screen for viewing motion pictures be between 7 and 14 foot-lamberts, when the projector is running with no film in the gate. (See *Bibliography:* Report of Projection Screen Brightness Committee.)

RPm-4-1 (Z22.42) Nomenclature.—A general glossary of technical terms used in the motion picture industry was published in *J. Soc. Mot. Pict. Eng.*, Nov., 1931, p. 819; a glossary of color photography in May, 1935, p. 432; and a supplementary color glossary in Aug., 1936, p. 164.

DEFINITIVE SPECIFICATIONS

Number of Teeth in Mesh.—The number of teeth in mesh with the film (commonly referred to as "teeth in contact") shall be the number of teeth in the arc of contact of the film with the drum of the sprocket when the pulling face of one tooth is at one end of the arc.

Safety Film.—The term "Safety Film," as applied to motion picture materials, shall refer to materials having a burning time greater than 10 seconds and falling into the following classes: (*a*) support coated with emulsion, (*b*) any other material upon which or in which an image can be produced, (*c*) the processed products of these materials, and (*d*) uncoated support that is or can be used for motion picture purposes in conjunction with the aforementioned classes of materials.

The burning time is defined as the time in seconds required for the complete combustion of a sample of the material 36 inches long, the determination being according to the procedure of the Underwriters Laboratory. This definition was designed specifically to define Safety Film in terms of the burning rate of the commercial product of any thickness or width used in practice. The test of burning time, therefore, shall be made with a sample of the material in question having a thickness and width at which the particular material is used in practice.

All 16- and 8-mm. film must be of the safety type.

E. K. CARVER, *Chairman*

P. ARNOLD	R. E. FARNHAM	N. F. OAKLEY
M. C. BATSEL	C. L. FARRAND	G. F. RACKETT
F. C. BADLEY	G. FREIDL, JR.	W. B. RAYTON
L. N. BUSCH	H. GRIFFIN	C. N. REIFSTECK
A. CHORINE	A. C. HARDY	H. RUBIN
A. COTTET	R. C. HUBBARD	O. SANDVIK
L. DE FEO	E. HUSE	H. B. SANTEE
A. C. DOWNES	C. L. LOOTENS	J. L. SPENCE
J. A. DUBRAY	K. F. MORGAN	J. VAN BREUKELEN
P. H. EVANS	T. NAGASE	I. D. WRATTEN

BIBLIOGRAPHY

(*All references are to J. Soc. Mot. Pict. Eng.*)

Reports of the Committee on Standards and Nomenclature:

XV (Aug., 1930), No. 2, p. 160.
Safety Code for Projection; Wide-Film Dimensions.

XV (Dec., 1930), No. 6, p. 818.
Projector and Camera Speeds; Standard Release Print; Screen Brightness; Negative Notching; Wide-Film Dimensions.

XVII (Sept., 1931), No. 3, p. 431.
Wide-Film Dimensions.

XVII (Nov., 1931), No. 5, p. 819.
Glossary of Technical Terms Used in the Motion Picture Industry.

XIX (Nov., 1932), No. 5, p. 477.
16-Mm. Standards.

XX (June, 1933), No. 6, p. 505.

XXII (Jan., 1934), No. 1, p. 17.

Standard SMPE Film Perforation; Unit of Photographic Intensity; Principle of Intermittency in Sensitometric Measurements.

XXIII (Nov., 1934), No. 5, p. 247.

Standards Adopted by the SMPE.

XXIV (Jan., 1935), No. 1, p. 16.

Stresa (Italy) Conference on 16-Mm. Standards.

XXV (July, 1935), No. 1, p. 97.

Report on Reichsfilmkammer at Berlin, April 25, 1935.

XXV (Aug., 1935), No. 2, p. 192.

XXV (Oct., 1935), No. 4, p. 370.

International Standards Association Questionnaire Regarding 16-Mm. Sound-Film Standards.

XXVI (Jan., 1936), No. 1, p. 18.

XXVI (May, 1936), No. 5, p. 597.

Great Britain Adopts SMPE 16-Mm. Standards.

XXVIII (Jan., 1937), No. 1, p. 21.

XXVIII (June, 1937), No. 6, p. 585.

16-Mm. Reduction Printing.

XXIX (Oct., 1937), No. 4, p. 376.

Report on Perforation Standards.

Reports of the Projection Practice Committee (Selected):

XVII (Aug., 1931), No. 2, p. 245.

Projection Room Lay-Outs.

XXI (Aug., 1933), No. 2, p. 89.

SMPE Standard Test Reels; Projector Optical Alignment.

XXII (March, 1934), No. 3, p. 173.

SMPE Standard Test Reels.

XXII (June, 1934), No. 6, p. 379.

Reel Lengths.

XXV (Oct., 1935), No. 4, p. 341.

Projection Room Lay-Outs (Revision).

XXIX (July, 1937), No. 1, p. 39.

Screen Brightness; Projector Apertures; Theater Survey; Screens.

XXIX (Dec., 1937), No. 6, p. 614.

Projector Apertures.

Reports of Projection Screen Brightness Committee:

XXV (Sept., 1935), No. 3, p. 269.

XXVI (May, 1936), No. 5, p. 489–579.

Symposium on Screen Brightness Problems.

XXVII (Aug., 1936), No. 2, p. 1.

Reports of the Sound Committee:

XXVI (Jan., 1936), No. 1, p. 21.

SMPE Primary and Secondary Frequency.
Reference Standards.

XXVIII (Jan., 1937), No. 1, p. 24.

Reports of Non-Theatrical Equipment Committee:

XXVII (Aug., 1936), No. 2, p. 161.
16-Mm. Screen Sizes and Illumination.

XXVIII (Jan., 1937), No. 1, p. 26.
16-Mm. Reels.

XXIX (July, 1937), No. 1, p. 57.

Reports of Color Committee:

XXIV (May, 1935), No. 5, p. 422.
A Glossary of Color Photography.

XXVII (Aug., 1936), No. 2, p. 164.
Supplementary Color Glossary.

XXIX (July, 1937), No. 1, p. 54.
Perforation Standards.

Reports of Committee on Laboratory Practice:

XXVI (April, 1936), No. 4, p. 345.
Descriptive Report on Current Methods and Practices.

Reports of the Projection Screens Committee:

XVII (Sept., 1931), No. 3, p. 437.
Acceptance Tests for Projection Screens.

XX (June, 1933), No. 6, p. 510.
Screen Sizes; Reflection Coefficients.

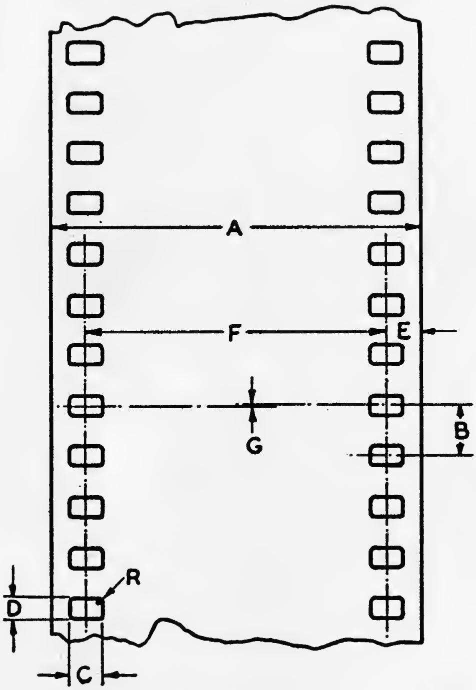
Miscellaneous:

XX (Feb., 1933), No. 2, p. 142.
Lantern Slides and Scientific Charts.

XXI (Oct., 1933), No. 4, p. 280.
Historical Summary of SMPE Standardization.

XXVIII (March, 1937), No. 3, p. 265.
Camera Synchronizing Systems.

ASA Z22.1 (Sept. 20, 1930)	AMERICAN STANDARD For 35 mm Film CUTTING AND PERFORATING NEGATIVE AND POSITIVE RAW STOCK	SMPE DS35-1-1 *Adopted* Original: prior to 1928 This revision: 1936



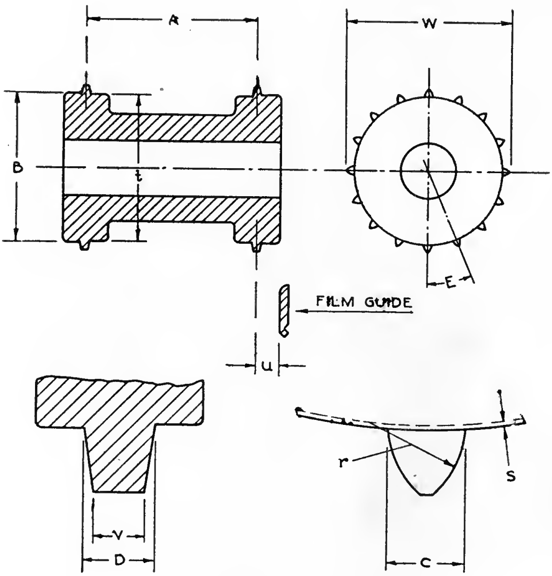
	Millimeters	*Inch Equivalents*
A	35.00 + 0.00 − 0.05	1.378 + 0.000 − 0.002
B	4.750 ± 0.013	0.1870 ± 0.0005
*C***	2.794 ± 0.01	0.1100 ± 0.0004
*D***	1.98 ± 0.01	0.0780 ± 0.0004
E	3.40 ± 0.05	0.134 ± 0.002
F	28.17 ± 0.05	1.109 ± 0.002
G	Not > 0.025	Not > 0.001
*L**	475.00 ± 0.38	18.700 ± 0.015
*R***	0.5	0.020

* *L* = the length of any 100 consecutive perforation intervals.

** This single style of perforation, known as the SMPE perforation, shall be used for all 35 mm. film. It is the same as the perforation known prior to July 14, 1933, as the standard positive perforation.

These dimensions and tolerances apply to the material immediately after cutting and perforating.

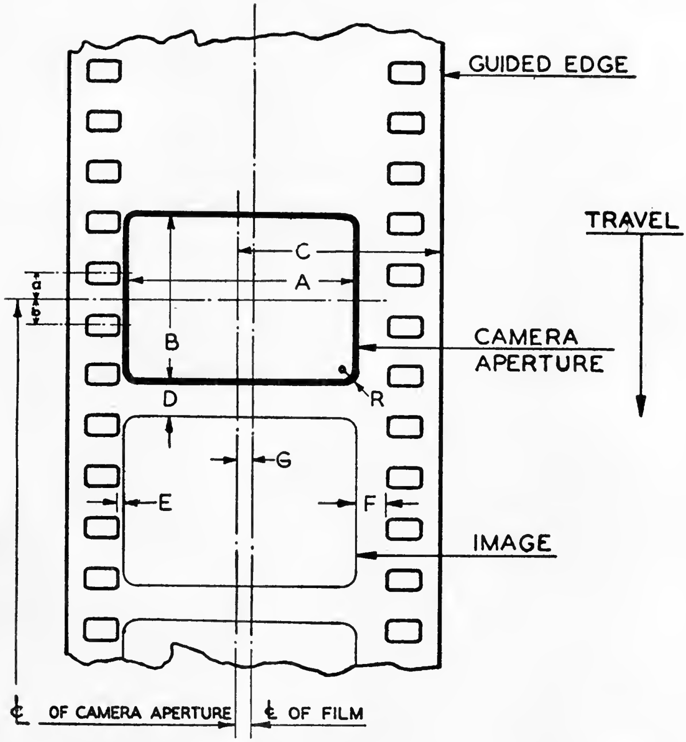
ASA Z22.2 (Sept. 20, 1930)	**AMERICAN STANDARD** **For 35 mm Film** **16-TOOTH PROJECTOR SPROCKETS**	**SMPE** **DS35-2-1**



	Feed Sprocket		*Intermittent Sprocket*		*Take-Up (Hold-back) Sprocket*	
	Millimeters	*Inch Equivalents*	*Millimeters*	*Inch Equivalents*	*Millimeters*	*Inch Equivalent*
A	27.36 ± 0.03	1.097 ± 0.001	27.86 ± 0.03	1.097 ± 0.001	27.86 ± 0.03	1.097 ± 0.001
B	24.00 ± 0.03	0.945 ± 0.001	24.00 ± 0.005	0.945 ± 0.0002	23.67 ± 0.03	0.932 ± 0.001
C	1.40 + 0.00 − 0.05	0.055 + 0.000 − 0.002	1.40 + 0.00 − 0.05	0.055 + 0.000 − 0.002	1.40 + 0.00 − 0.05	0.055 + 0.000 − 0.002
D	1.40 ± 0.00 − 0.05	0.055 + 0.000 − 0.002	1.40 + 0.00 − 0.05	0.055 + 0.000 − 0.002	1.40 + 0.00 − 0.05	0.055 + 0.000 − 0.002
E	22 Deg. 30 Min. ± 1.5 Min.		22 Deg. 30 Min. ± 0.75 Min.*		22 Deg. 30 Min. ± 1.5 Min.	
	Recommended Practice					
r	1.96	0.077	1.96	0.077	1.96	0.077
s	0.10	0.004	0.10	0.004	0.10	0.004
t	23.75	0.935	23.75	0.935	23.42	0.922
u	3.53	0.139	3.53	0.139	3.53	0.139
v	1.02	0.040	1.02	0.040	1.02	0.040
w	26.54	1.045	26.54	1.045	26.21	1.032

* The accumulated error between any two teeth not to exceed 4 minutes.

ASA Z22.3 *(Proposal)*	AMERICAN STANDARD For 35 mm Sound Film CAMERA APERTURE	SMPE DS35-3-1 *Adopted* Original; 1932 This revision: 1936

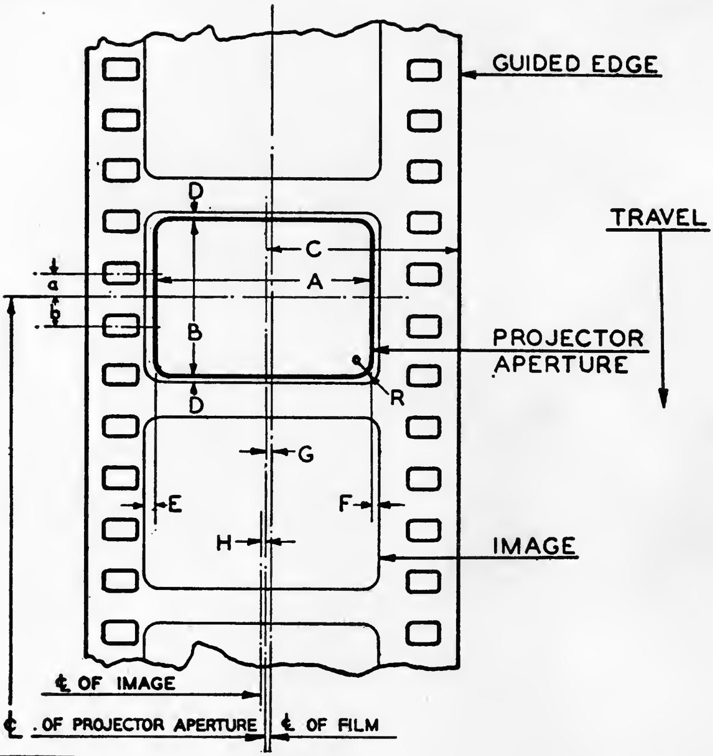


	Millimeters	*Inch Equivalents*
A	22.05 ± 0.05	0.868 ± 0.002
B	16.03 ± 0.05	0.631 ± 0.002
C	18.90 ± 0.05	0.744 ± 0.002
D	2.97	0.117
E	0.25	0.010
F	3.07	0.121
G	1.40	0.055
R	0.8 approx.	0.03 approx.
$a = b = \frac{1}{2}$ longitudinal perforation pitch.		

The aperture dimensions given, in combination with the projector aperture shown in *DS-35-4-1*, result in a screen picture having a height-to-width ratio of 3 × 4 when the projection angle is 14 degrees.

These dimensions and locations are shown relative to unshrunk raw stock.

ASA Z22.4 (*Proposal*)	AMERICAN STANDARD For 35 mm Sound Film — PROJECTOR APERTURE	SMPE DS35-4-1 *Adopted* Original: 1931 This revision: 1932



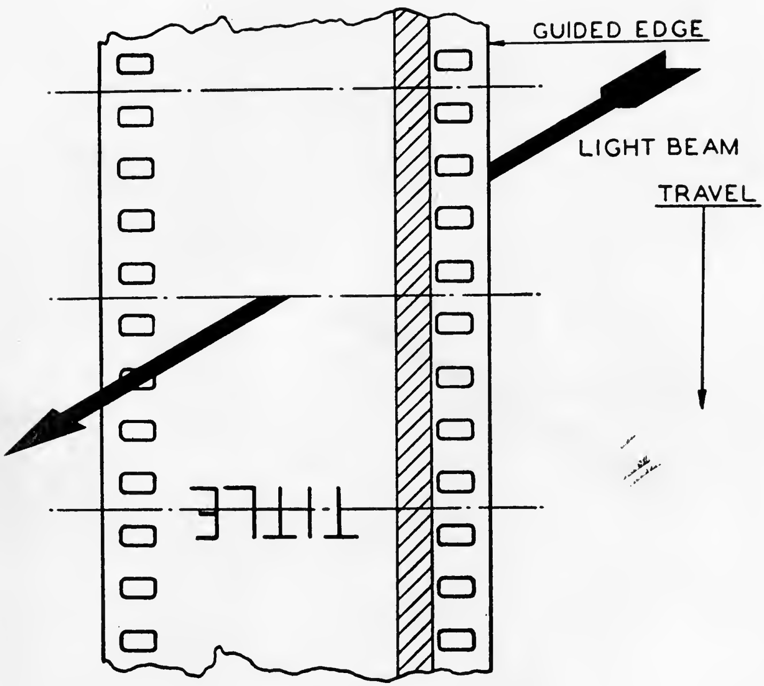
	Millimeters	*Inch Equivalents*
A	20.95 ± 0.05	0.825 ± 0.002
B	15.25 ± 0.05	0.600 ± 0.002
C	18.74 ± 0.05	0.738 ± 0.002
D	0.39	0.015
E	0.71	0.028
F	0.38	0.015
G	1.24	0.049
H	0.15	0.006
R	1.3 approx.	0.05 approx.

$a = b = \frac{1}{2}$ longitudinal perforation pitch.

The aperture dimensions given result in a screen picture having a height-to-width ratio of 3 × 4 when the projection angle is 14 degrees.

These dimensions and locations are shown relative to unshrunk raw stock.

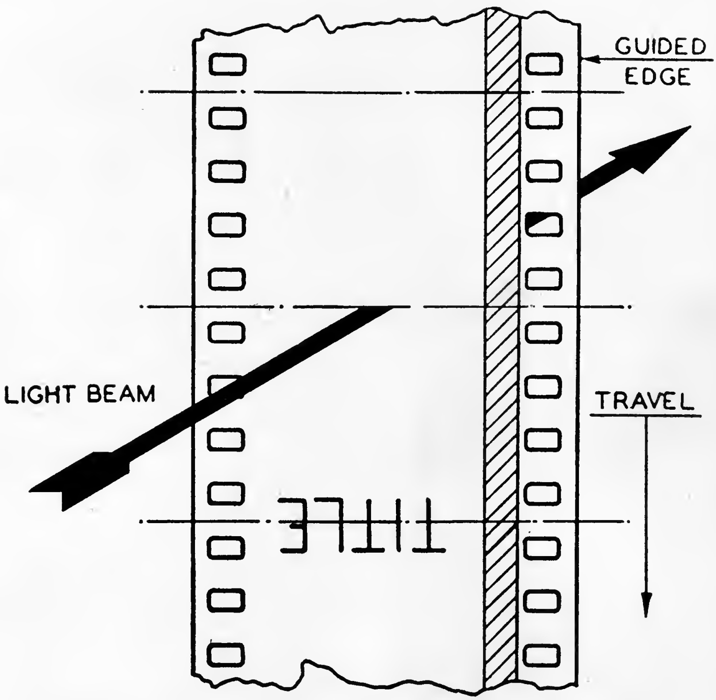
ASA Z22.5 (*Proposal*)	AMERICAN STANDARD For 35 mm Sound Film	SMPE DS35-5-1
	EMULSION AND SOUND RECORD POSITIONS IN CAMERA—NEGATIVE	*Adopted* Original: 1930 This revision: 1936



Drawing shows film as seen from inside the camera looking toward the camera lens.

(*1*) Emulsion position in camera: *toward the lens, except for special processes.*
(*2*) Speed: 24 frames per second.
(*3*) Distance between center of picture and corresponding sound: 20 frames.

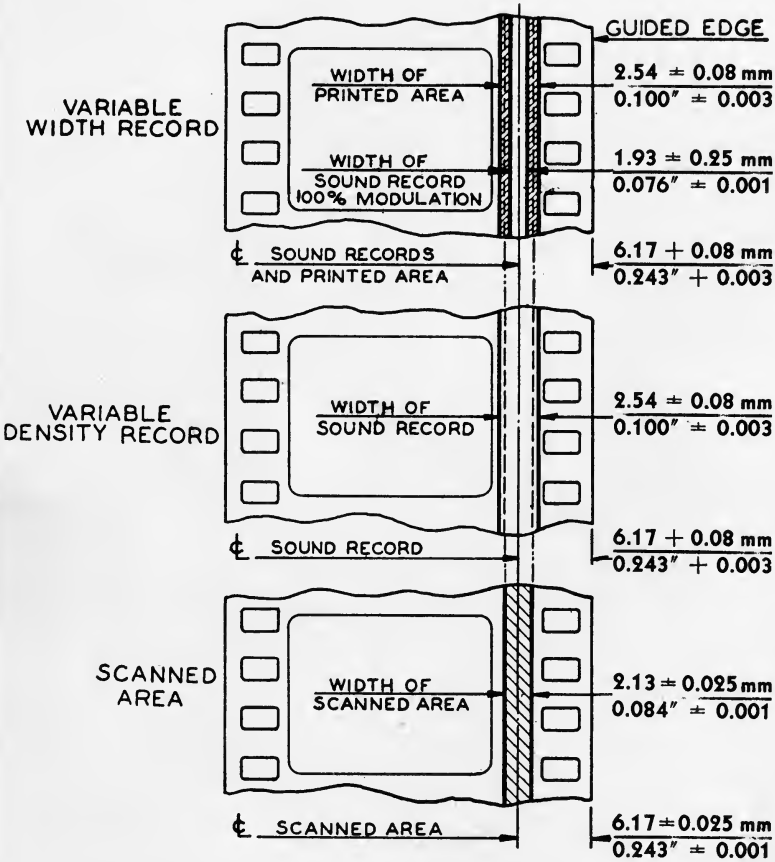
ASA Z22.6 (*Proposal*)	AMERICAN STANDARD For 35 mm Sound Film — EMULSION AND SOUND RECORD POSITIONS IN PROJECTOR—POSITIVE For Direct Front Projection	SMPE DS35-6-1 *Adopted* Original: 1930 This revision: 1936



Drawing shows film as seen from the light-source in the projector.

(*1*) Emulsion position in projector: *toward the light-source, except for special processes.*
(*2*) Speed: 24 frames per second.
(*3*) Distance between center of picture and corresponding sound: 20 frames.

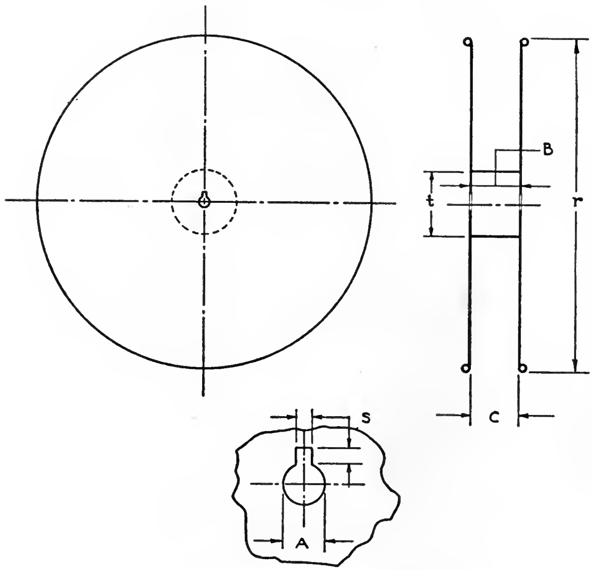
ASA Z22.7 *(Proposal)*	**AMERICAN STANDARD For 35 mm Sound Film**	**SMPE DS35-7-1 *Adopted***
	SOUND RECORDS AND SCANNED AREA	**Original: 1930 This revision: 1936**



When the push-pull type of sound record is used, the minimum separation between the two halves of the sound record shall be 0.152 mm. (0.006 inch). When the squeeze-track is used with the variable-density record, the width of the sound record shall be 1.93 mm. (0.076 inch).

These dimensions and locations are shown relative to unshrunk raw stock.

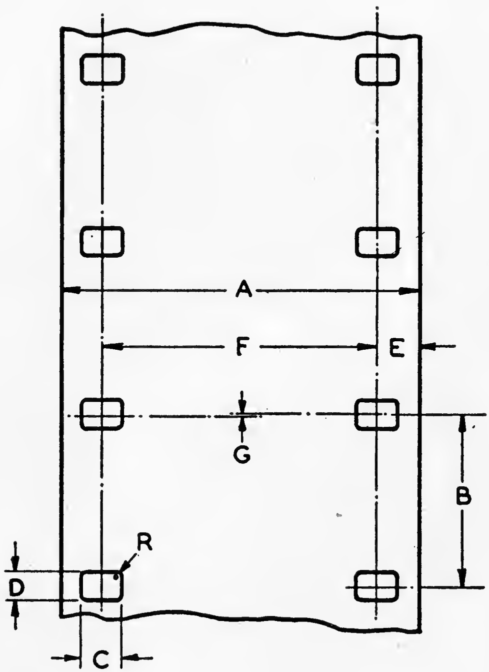
ASA Z22.8 (*Proposal*)	AMERICAN STANDARDS For 35 mm Film	SMPE DS35-8-1
	PROJECTION REELS	



Capacity	*300 Meters*	*1000 Feet*	*600 Meters*	*2000 Feet*
	Millimeters	*Inch Equivalents*	*Millimeters*	*Inch Equivalents*
A	8.3 Min.	0.328 Min.	8.3 Min.	0.328 Min.
*B**	40.1	1.58	40.1	1.58
C	38.1	1.50	38.1	1.50
Recommended Practice				
r	254.	10.0	368.0	14.5
s	3.17	0.125	3.17	0.125
t	50.8	2.0	101.6	4.0

* This dimension applies only within a radius of 0.5 inch from the axis of the reel.

ASA Z22.10 (Sept. 20, 1930)	AMERICAN STANDARD For 16 mm Silent Film	SMPE DS16*d*-1-1
	CUTTING AND PERFORATING NEGATIVE AND POSITIVE RAW STOCK	*Adopted* Original: prior to 1928 This revision: 1936

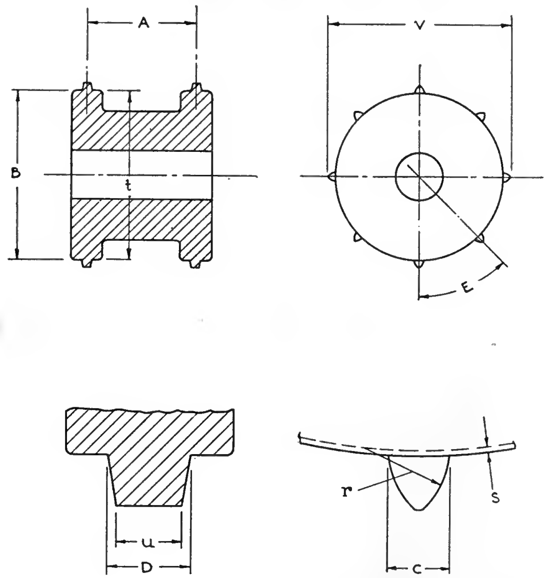


	Millimeters	*Inch Equivalents*
A	16.00 + 0.00 − 0.05	0.630 + 0.000 − 0.002
B	7.620 ± 0.013	0.3000 ± 0.0005
C	1.83 ± 0.01	0.0720 ± 0.0004
D	1.27 ± 0.01	0.0500 ± 0.0004
E	1.83 ± 0.05	0.072 ± 0.002
F	12.320 ± 0.025	0.485 ± 0.001
G	Not > 0.025	Not > 0.001
*L**	762.00 ± 0.76	30.0 ± 0.03
R	0.25	0.010

* *L* = the length of any 100 consecutive perforation intervals.

These dimensions and tolerances apply to the material immediately after cutting and perforating.

ASA Z22.11 (Aug. 28, 1935)	AMERICAN STANDARD For 16 mm Film	SMPE DS 16d-2-1
	PROJECTOR SPROCKETS	



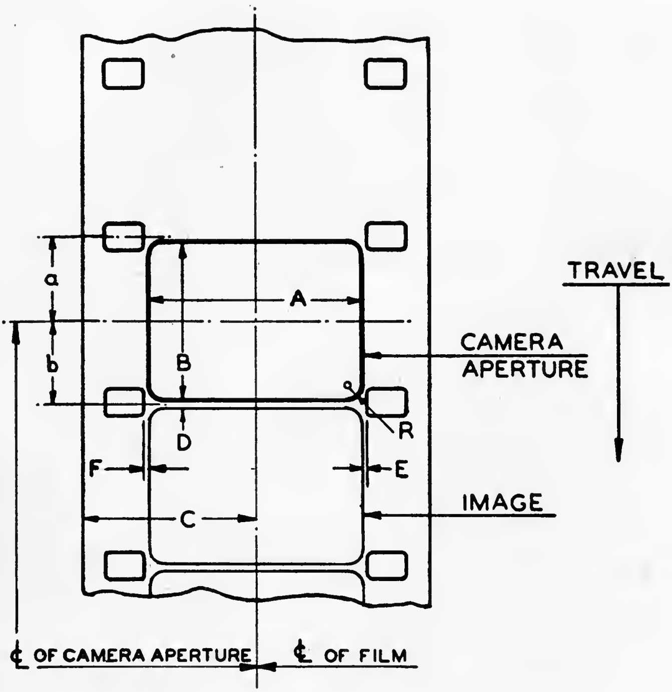
	N	B		E	Number of Teeth in Mesh: 3		4		5		6	
					C		C		C		C	
		Mm.	In.		Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
Feed	6	14.38	0.566	60°0′ ± 0.5′	1.02	0.040						
	8	19.23	0.757	45°0′ ± 0.5′	1.02	0.040	0.91	0.036				
	12	28.93	1.139	30°0′ ± 0.5′	1.02	0.040	0.91	0.036	0.79	0.031	0.69	0.027
	16	38.63	1.521	22°30′ ± 0.5′	1.02	0.040	0.91	0.036	0.79	0.031	0.69	0.027
Take-Up (Holdback)	6	14.15	0.557	60°0′ ± 0.5′	1.02	0.040						
	8	18.92	0.745	45°0′ ± 0.5′	1.02	0.040	0.91	0.036				
	12	28.50	1.122	30°0′ ± 0.5′	1.02	0.040	0.91	0.036	0.79	0.031	0.69	0.027
	16	38.05	1.498	22°30′ ± 0.5′	1.02	0.040	0.91	0.036	0.79	0.031	0.69	0.027
Combination	6	14.30	0.563	60°0′ ± 0.5′	1.09	0.043						
	8	19.13	0.753	45°0′ ± 0.5′	1.09	0.043	1.02	0.040				
	12	28.78	1.133	30°0′ ± 0.5′	1.09	0.043	1.02	0.040	0.94	0.037	0.86	0.034
	16	38.43	1.513	22°30′ ± 0.5′	1.09	0.043	1.02	0.040	0.94	0.037	0.86	0.034

		Millimeters	Inch Equivalents
For All Sprockets	A	12.22 + 0.05 − 0.00	0.481 + 0.002 − 0.000
	D	1.22 + 0.00 − 0.08	0.048 + 0.000 − 0.003
	r	1.27	0.050
	s	0.08	0.003
	t	B − 0.3, Max.	B − 0.01, Max.
	u	1.00	0.039
	v	B + 1.52, Max.	B + 0.060, Max.

Notes

N = Number of teeth on sprocket.
Tolerance for *B* and *C* +0.000 to −0.025 mm. or +0.000 to −0.001 in.
Dimensional standards indicated by capital letters
Recommended practice indicated by lower case letters.
Values of *C* are omitted in cases where the angle of wrap on the sprocket would exceed 180°.

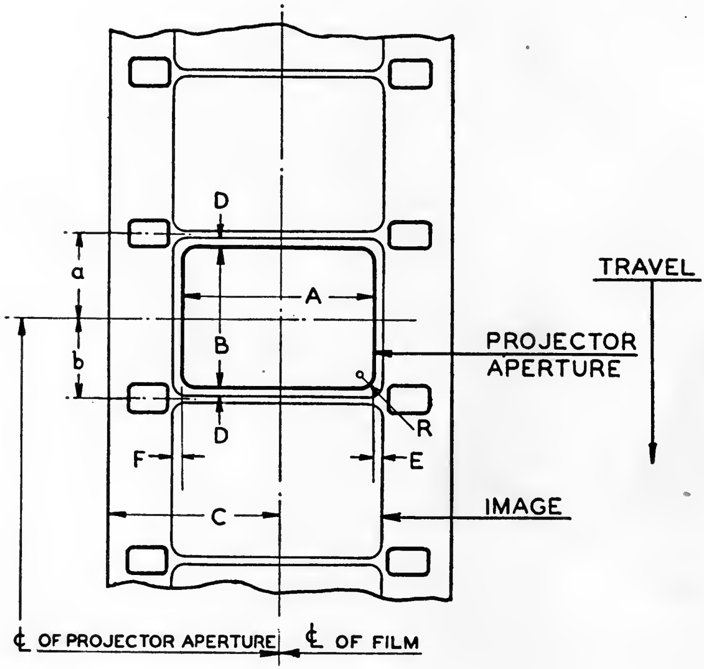
ASA Z22.12 (Sept. 20, 1930)	AMERICAN STANDARD For 16 mm Silent Film	SMPE DS16*d*-3-1
	CAMERA APERTURE	*Adopted* Original: 1930 This revision: 1936



	Millimeters	*Inch Equivalents*
A	10.41 ± 0.05	0.410 ± 0.002
B	7.47 ± 0.05	0.294 ± 0.002
C	8.00 ± 0.05	0.315 ± 0.002
D	0.15	0.006
E	0.05	0.002
F	0.05	0.002
R	0.5 approx.	0.02 approx.
$a = b = {}^1/_2$ longitudinal perforation pitch.		

These dimensions and locations are shown relative to unshrunk raw stock.

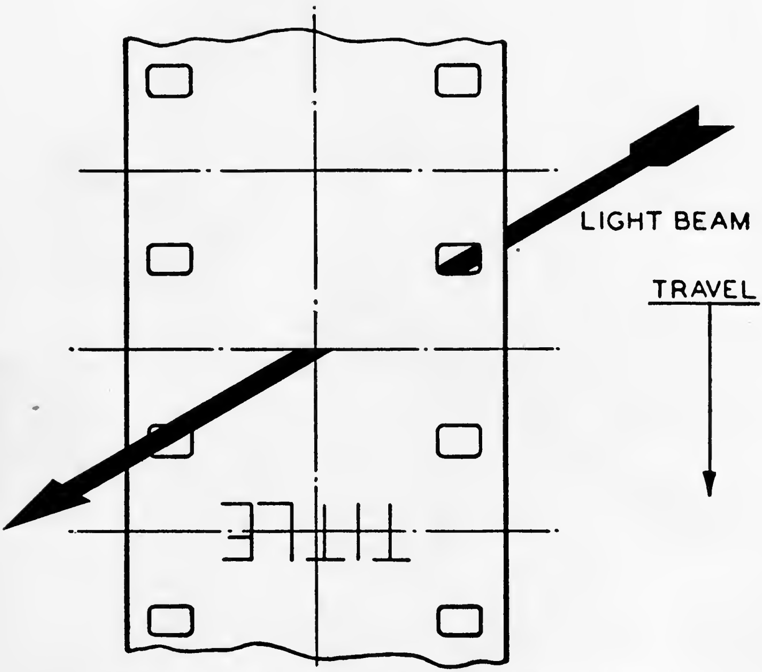
ASA Z22.13 (Sept. 20, 1930)	AMERICAN STANDARD For 16 mm Silent Film	SMPE DS16d-4-1
	PROJECTOR APERTURE	*Adopted* Original: 1930 This revision: 1936



	Millimeters	*Inch Equivalents*
A	9.65 ± 0.05	0.380 ± 0.002
B	7.21 ± 0.05	0.284 ± 0.002
C	8.00 ± 0.05	0.315 ± 0.002
D	0.13	0.005
E	0.38	0.015
F	0.38	0.015
R	0.5 approx.	0.02 approx.
$a = b = {}^1/_2$ longitudinal perforation pitch.		

These dimensions and locations are shown relative to unshrunk raw stock.

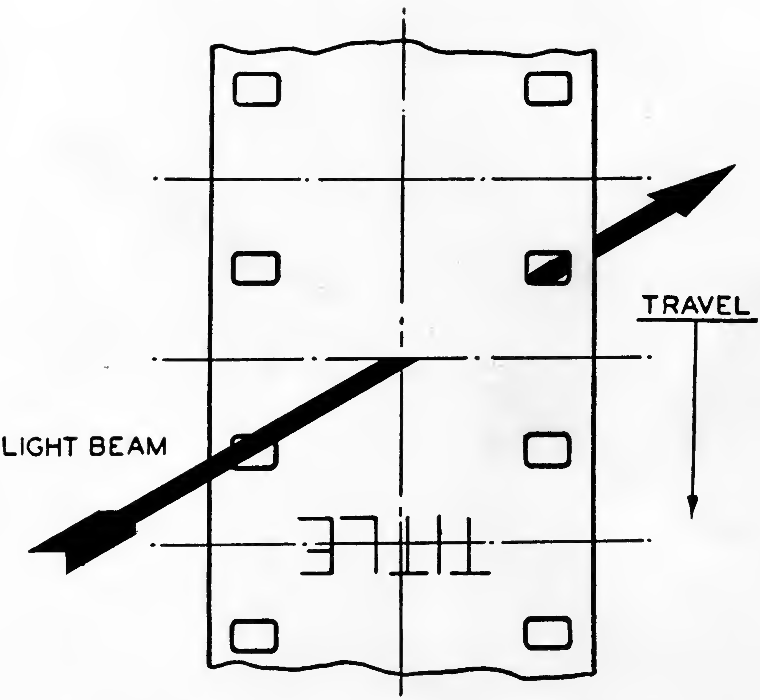
ASA Z22.14 *(Proposal)*	AMERICAN STANDARD For 16 mm Silent Film	SMPE DS16*d*-5-1 *Adopted*
	EMULSION POSITION IN CAMERA—NEGATIVE	Original: prior to 1928 This revision: 1936



Drawing shows film as seen from inside the camera looking toward the camera lens.

(*1*) Emulsion position in camera: *toward the lens, except for special processes.*
(*2*) Normal speed: 16 frames per second.

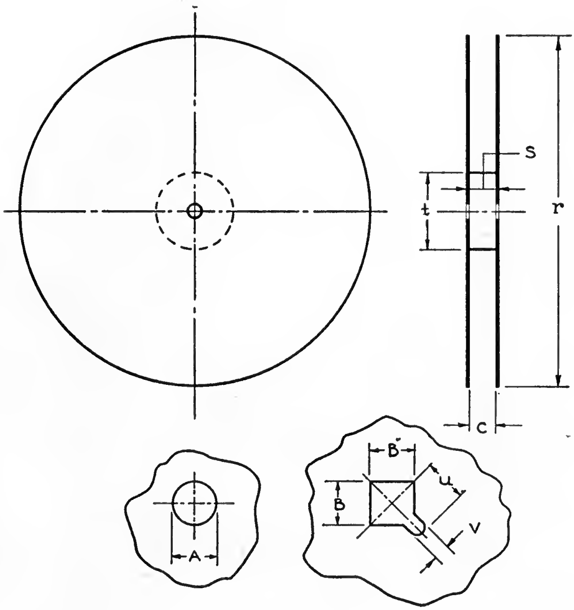
ASA Z22.15 (*Proposal*)	AMERICAN STANDARD For 16 mm Silent Film EMULSION POSITION IN PROJECTOR—POSITIVE For Direct Front Projection	SMPE DS16*d*-6-1 *Adopted* Original: prior to 1928 This revision: 1936



Drawing shows film as seen from the light-source in the projector.

(*1*) Emulsion position in projector: *toward the lens, except for special processes.*
(*2*) Normal speed: 16 frames per second.

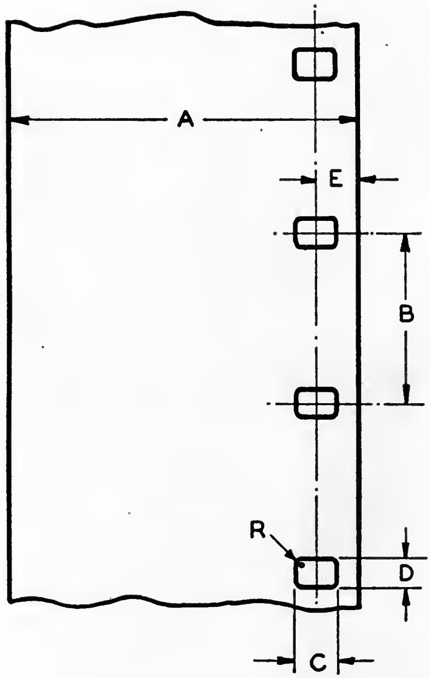
ASA Z22.16 (*Proposal*)	AMERICAN STANDARD For 16 mm Film — PROJECTION REELS	SMPE DS16-8-1



	120 Meters	*400 Feet*	*240 Meters*	*800 Feet*	*480 Met.*	*1600 Feet*
	Millimeters	*Inch Equivalents*	*Millimeters*	*Inch Equivalents*	*Millimeters*	*Inch Equivalents*
A	8.10 + 0.00 − 0.08	0.319 + 0.000 − 0.003	8.10 + 0.00 − 0.08	0.319 + 0.000 − 0.003	8.10 + 0.00 − 0.08	0.319 + 0.000 − 0.003
B	8.10 + 0.00 − 0.08	0.319 + 0.000 − 0.003	8.10 + 0.00 − 0.08	0.319 + 0.000 − 0.003	8.10 + 0.00 − 0.08	0.319 + 0.000 − 0.003
C	17.2 Min.	0.677 Min.	17.2 Min.	0.677 Min.	17.2 Min.	0.677 Min.
Recommended Practice						
r	177.8	7.00	250.8	9.87	355.6	14.00
s	19.23	0.757	19.63	0.773	21.92	0.863
t	37.85	1.490	37.85	1.490	117.48	4.625
u	7.94	0.312	7.94	0.312	7.94	0.312
v	3.17	0.125	3.17	0.125	3.17	0.125

NOTE: Center Spindle Holes—Either a combination of square and round holes or two square holes may be used.

ASA Z22.17 (Aug. 28, 1935)	AMERICAN STANDARD For 16 mm Sound Film CUTTING AND PERFORATING NEGATIVE AND POSITIVE RAW STOCK	SMPE DS16s-1-1 *Adopted* Original: 1932 This revision: 1936

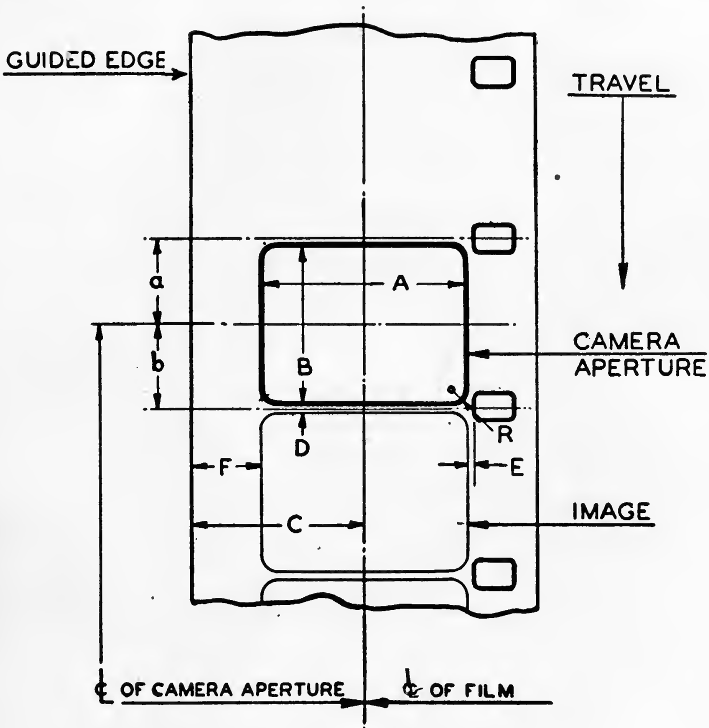


	Millimeters	*Inch Equivalents*
A	16.00 + 0.00 − 0.05	0.630 + 0.000 − 0.002
B	7.620 ± 0.013	0.3000 ± 0.0005
C	1.83 ± 0.01	0.0720 ± 0.0004
D	1.27 ± 0.01	0.0500 ± 0.0004
E	1.83 ± 0.05	0.072 ± 0.002
*L**	762.00 ± 0.76	30.00 ± 0.03
R	0.25	0.010

**L* = the length of any 100 consecutive perforation intervals.

These dimensions and tolerances apply to the material immediately after cutting and perforating.

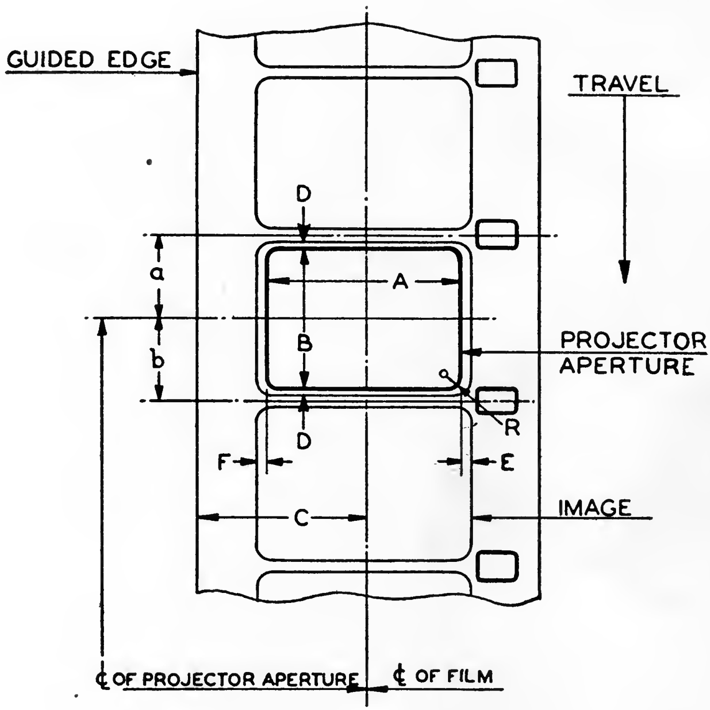
ASA Z22.18 (Aug. 28, 1935)	AMERICAN STANDARD For 16 mm Sound Film	SMPE DS16s-3-1
	CAMERA APERTURE	*Adopted* Original: 1932 This revision: 1936



	Millimeters	*Inch Equivalents*
A	10.41 ± 0.05	0.410 ± 0.002
B	7.47 ± 0.05	0.294 ± 0.002
C	8.00 ± 0.05	0.315 ± 0.002
D	0.15	0.006
E	0.05	0.002
F	2.79	0.110
R	0.5 approx.	0.02 approx.
$a = b = {}^1/_2$ longitudinal perforation pitch.		

These dimensions and locations are shown relative to unshrunk raw stock.

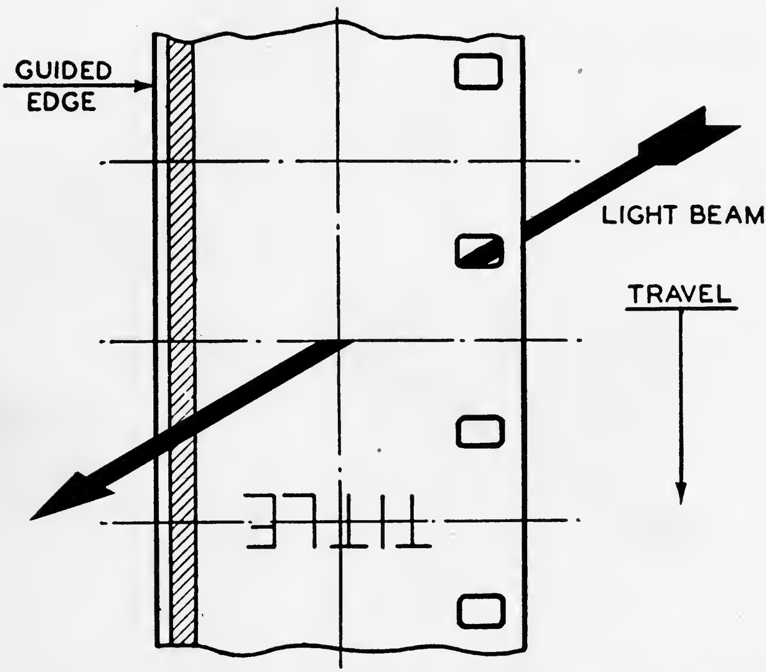
ASA Z22.19 (Aug. 28, 1935)	AMERICAN STANDARD For 16 mm Sound Film — PROJECTOR APERTURE	SMPE DS16s-4-1 *Adopted* Original: 1932 This revision: 1936



	Millimeters	*Inch Equivalents*
A	9.65 ± 0.05	0.380 ± 0.002
B	7.21 ± 0.05	0.284 ± 0.002
C	8.00 ± 0.05	0.315 ± 0.002
D	0.13	0.005
E	0.38	0.015
F	0.38	0.015
R	0.5 approx.	0.02 approx.
$a = b = {}^1/_2$ longitudinal perforation pitch.		

These dimensions and locations are shown relative to unshrunk raw stock.

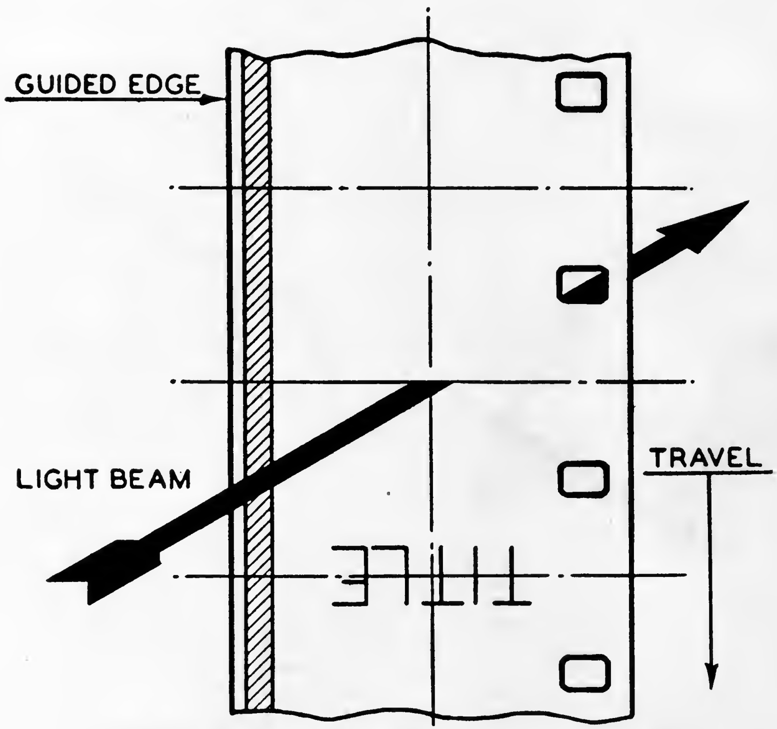
ASA Z22.20 (*Proposal*)	AMERICAN STANDARD For 16 mm Sound Film EMULSION AND SOUND RECORD POSITIONS IN CAMERA—NEGATIVE	SMPE DS16s-5-1 *Adopted* Original: 1932 This revision: 1936



Drawing shows film as seen from inside the camera looking toward the camera lens.

(*1*) Emulsion position in camera: *toward the lens, except for special processes.*
(*2*) Speed: 24 frames per second.
(*3*) Distance between center of picture and corresponding sound: 26 frames.

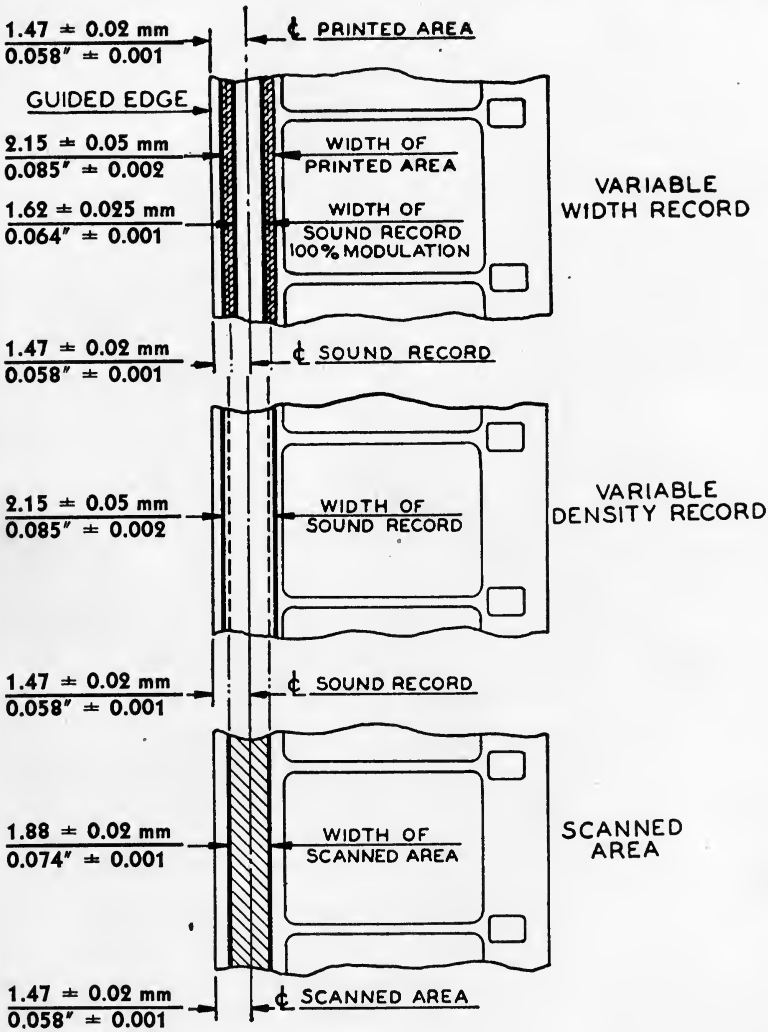
ASA Z22.21 *(Proposal)*	AMERICAN STANDARD For 16 mm Sound Film EMULSION AND SOUND RECORD POSITIONS IN PROJECTOR—POSITIVE For Direct Front Projection	SMPE DS16s-6-1 *Adopted* Original: 1932 This revision: 1936



Drawing shows film as seen from the light-source in the projector.

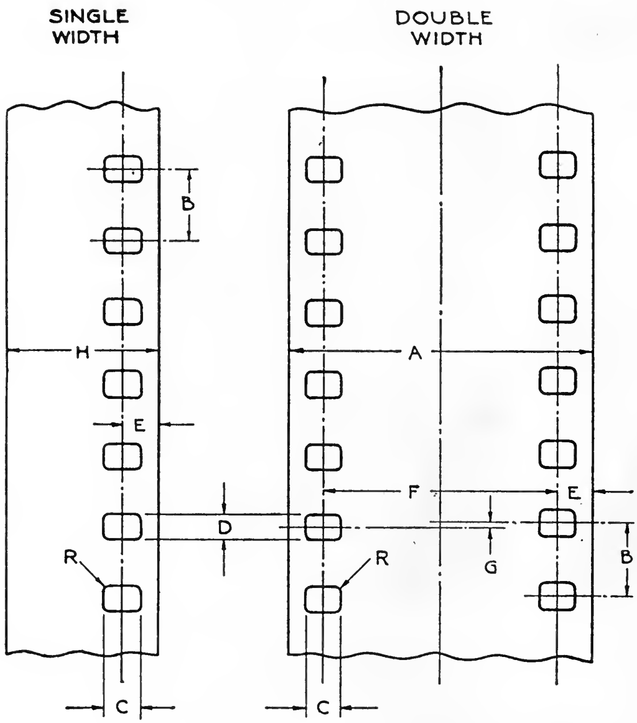
(*1*) Emulsion position in projector: *toward the lens, except for special processes.*
(*2*) Speed: 24 frames per second.
(*3*) Distance between center of picture and corresponding sound: 26 frames.

ASA	AMERICAN STANDARD	SMPE
Z22.22	For 16 mm Sound Film	DS16s-7-1
(Proposal)	SOUND RECORDS AND SCANNING AREA	*Adopted* Original: 1932 This revision: 1936



These dimensions and locations are shown relative to unshrunk raw stock.

ASA Z22.23 (*Proposal*)	AMERICAN STANDARD For 8 mm Film	SMPE DS8-1-1
	CUTTING AND PERFORATING NEGATIVE AND POSITIVE RAW STOCK	



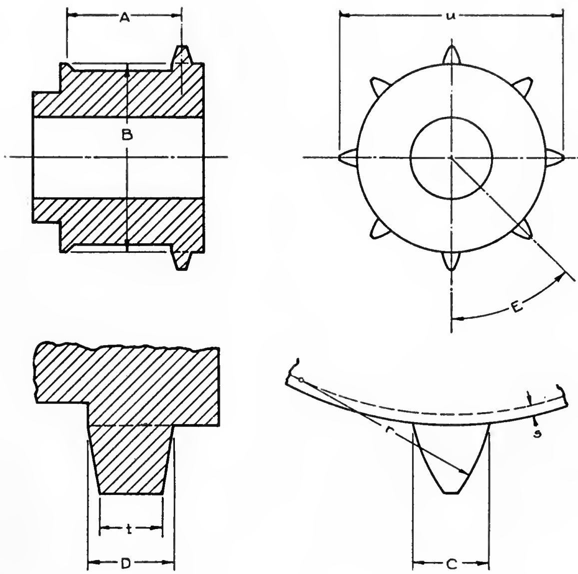
	Millimeters	*Inch Equivalents*
A	16.00 + 0.00 − 0.05	0.630 + 0.000 − 0.002
B	3.810 ± 0.013	0.150 ± 0.0005
C	1.83 ± 0.01	0.072 ± 0.0004
D	1.27 ± 0.01	0.0500 ± 0.0004
E	1.83 ± 0.05	0.072 ± 0.002
F	12.320 ± 0.025	0.485 ± 0.001
G	Not > 0.025	Not > 0.001
H	8.00 + 0.00 − 0.08	0.315 + 0.000 − 0.003
*L**	381.00 ± 0.38	15.000 ± 0.015
R	0.25	0.010

* *L* = the length of any 100 consecutive perforation intervals.

These dimensions and tolerances apply to the material immediately after cutting and perforating.

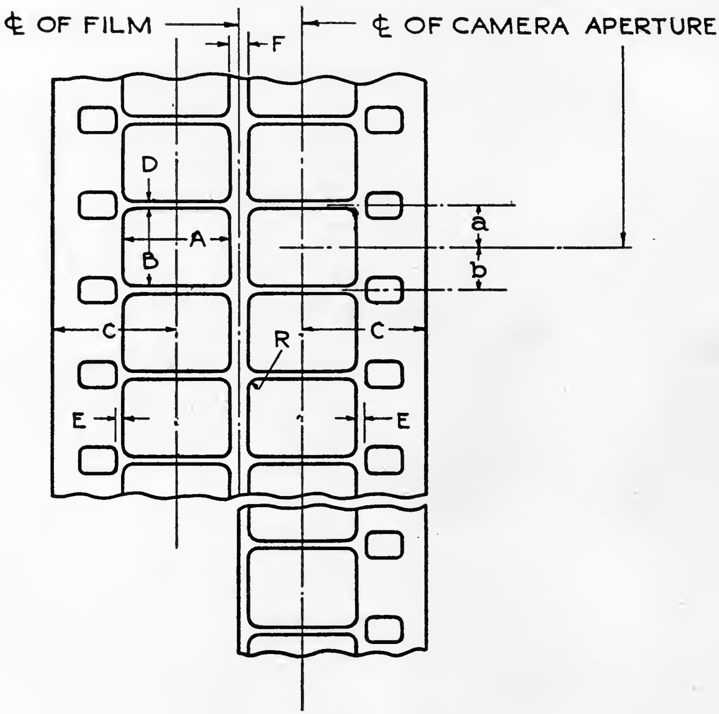
Film may be slit before or after processing.

ASA Z22.24 (*Proposal*)	AMERICAN STANDARD For 8 mm Film	SMPE DS8-2-1
	8-Tooth PROJECTOR SPROCKETS	



	Millimeters	*Inch Equivalents*
A	5.72 ± 0.03	0.225 ± 0.001
B	9.42 + 0.00 − 0.05	0.371 + 0.000 − 0.002
C	1.02 + 0.00 − 0.05	0.040 + 0.000 − 0.002
D	1.14 + 0.08 − 0.00	0.045 + 0.003 − 0.000
E	45°0′ ± 0.5′	
	Recommended Practice	
r	2.54	0.100
s	0.13	0.005
t	0.51	0.020
u	11.33	0.450

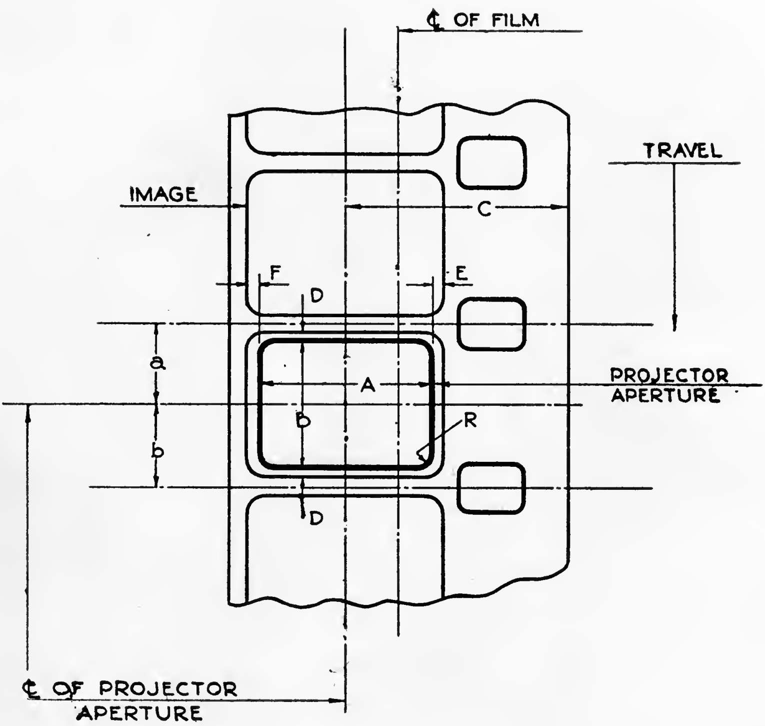
ASA Z22.25 (*Proposal*)	AMERICAN STANDARD For 8 mm Silent Film	SMPE DS8-3-1
	CAMERA APERTURE	



	Millimeters	*Inch Equivalents*
A	4.80 ± 0.03	0.189 ± 0.001
B	3.51 ± 0.03	0.138 ± 0.001
C	5.22 ± 0.05	0.205 ± 0.002
D	0.30	0.012
E	0.08	0.003
F	0.76	0.030
R	0.25	0.010

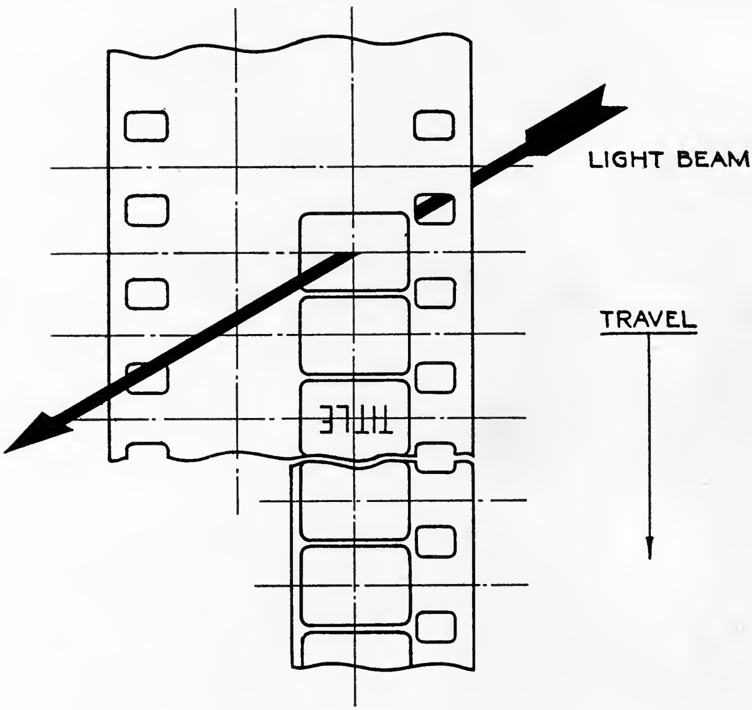
$a = b = {}^1/_2$ longitudinal perforation pitch.

ASA Z22.26 *(Proposal)*	**AMERICAN STANDARD** **For 8 mm Silent Film** **PROJECTOR APERTURE**	**SMPE** **DS8-4-1**



	Millimeters	*Inch Equivalents*
A	4.37 ± 0.03	0.172 ± 0.001
B	3.28 ± 0.03	0.129 ± 0.001
C	5.22 ± 0.05	0.2055 ± 0.002
D	0.11	0.004
E	0.21	0.008
F	0.21	0.008
R	0.25	0.010
$a = b = {}^1/_2$ longitudinal perforation pitch.		

ASA Z22.27 (*Proposal*)	AMERICAN STANDARD For 8 mm Silent Film EMULSION POSITION IN CAMERA-NEGATIVE	SMPE DS8-5-1

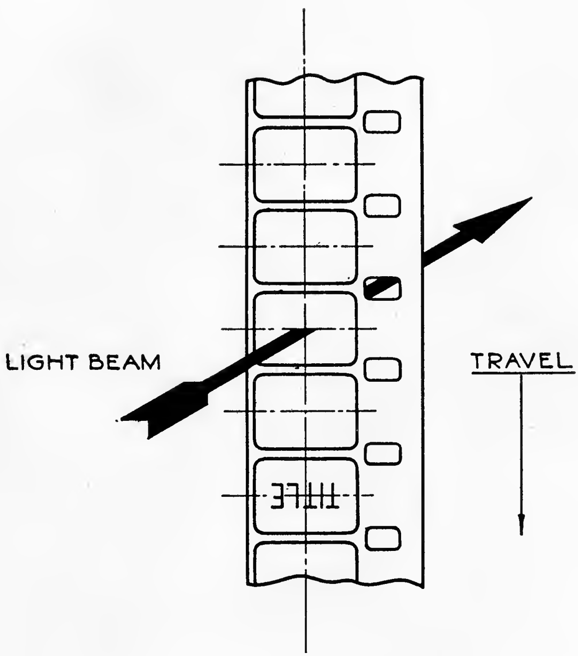


Drawing shows film from inside the camera, looking toward the camera lens.

(1) Emulsion position in camera: *toward the lens, except for special processes.*

(2) Normal speed: 16 frames per second.

ASA **Z22.28** ***(Proposal)***	**AMERICAN STANDARD** **For 8 mm Silent Film** **EMULSION POSITION IN PROJECTOR—POSITIVE** **For Direct Front Projection**	**SMPE** **DS8-6-1**

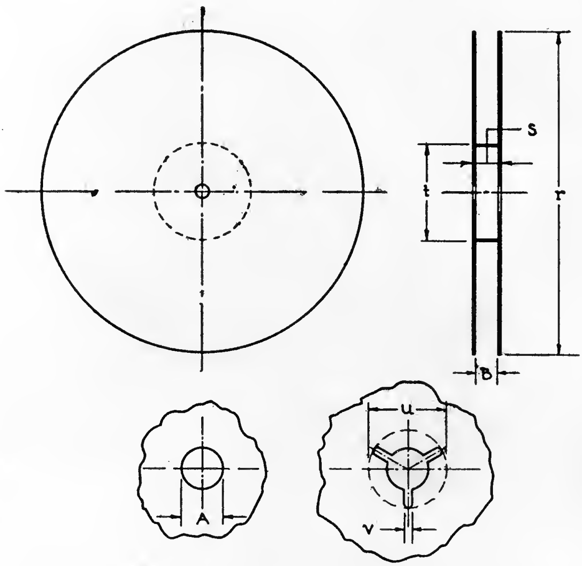


Drawing shows film as seen from the light-source in the projector.

(1) Emulsion position in projector: *toward the lens, except for special processes.*

(2) Normal speed: 16 frames per second.

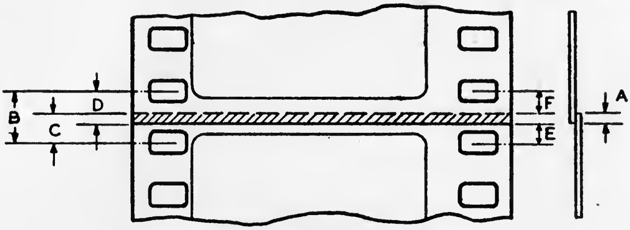
ASA Z22.29 (*Proposal*)	AMERICAN STANDARD For 8 mm Silent Film	SMPE DS8-8-1
	PROJECTION REELS	



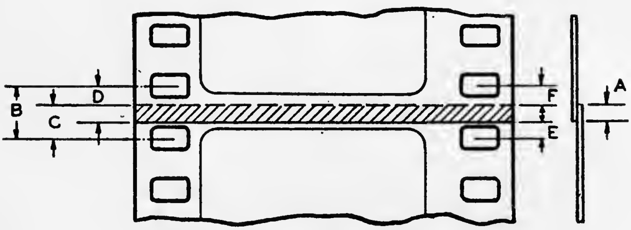
Capacity, 60 M. (200 Ft.)		
	Millimeters	*Inch Equivalents*
A	8.10 + 0.00 − 0.08	0.319 + 0.000 − 0.003
B	8.9 Min.	0.35 Min.
Recommended Practice		
r	127.0	5.00
s	10.5	0.41
t	37.8	1.49
u	16.0	0.63
v	1.6	0.06

Drive side of sprocket may have any desired odd number of driving slots, evenly spaced.

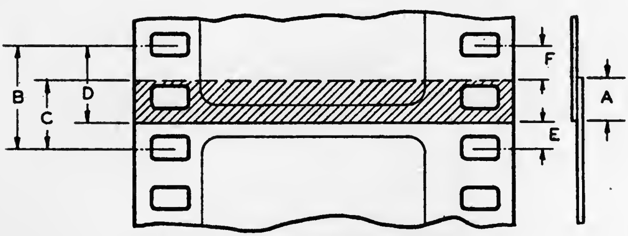
ASA Z22.32 (*Proposal*)	AMERICAN RECOMMENDED PRACTICE For 35 mm Sound Film	SMPE RP35-1-1
	FILM SPICES NEGATIVE AND POSITIVE	***Adopted*** Original: 1928 This revision: 1936



NEGATIVE SPLICE



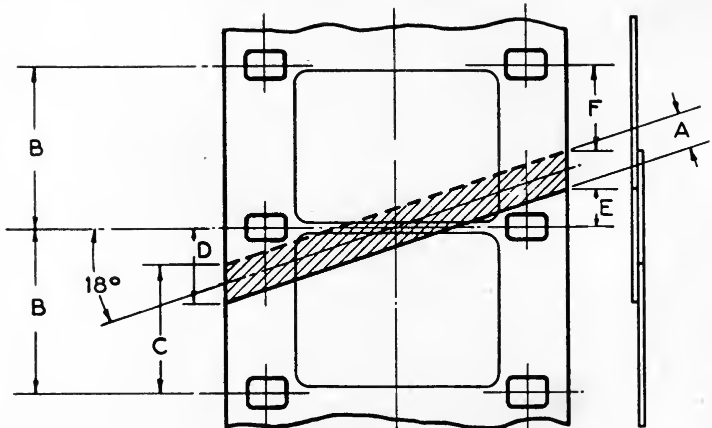
REGULAR POSITIVE SPLICE



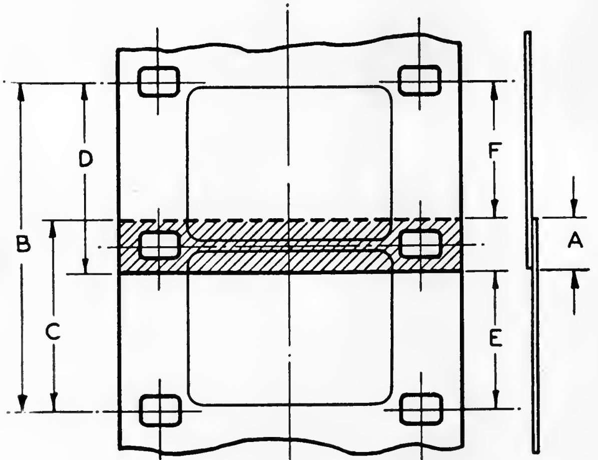
FULL HOLE POSITIVE SPLICE

	Negative		*Regular Positive*		*Full Hole Positive*	
	Mm.	*Inch Equiv.*	*Mm.*	*Inch Equiv.*	*Mm.*	*Inch Equiv.*
A	1.27	0.050	1.83	0.072	3.96	0.156
B	4.75	0.187	4.75	0.187	9.50	0.374
C	3.01	0.119	2.90	0.114	6.35	0.250
D	3.01	0.119	3.68	0.145	7.11	0.280
E	1.74	0.069	1.07	0.042	2.39	0.094
F	1.74	0.069	1.85	0.073	3.15	0.124

ASA Z22.37 (Sept. 20, 1930)	AMERICAN RECOMMENDED PRACTICE For 16 mm Silent Film	SMPE RP16*d*-1-1
	FILM SPICES NEGATIVE AND POSITIVE	*Adopted* Original: 1930 This revision: 1936



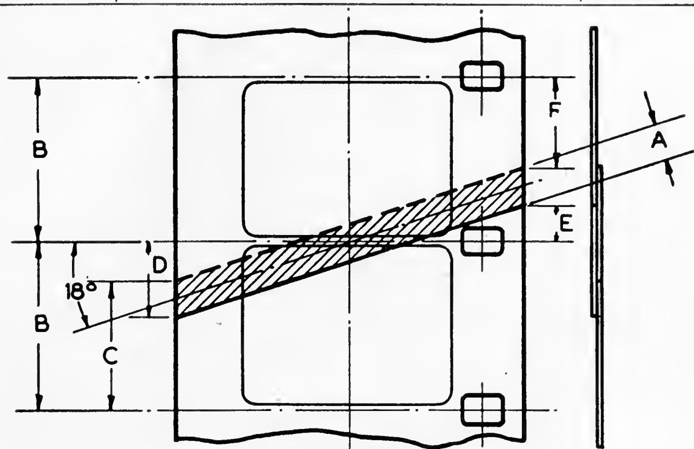
DIAGONAL SPLICE



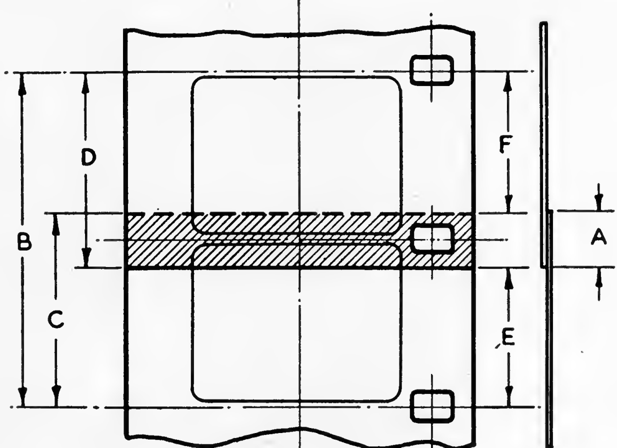
STRAIGHT SPLICE

	Diagonal		*Straight*	
	Mm.	*Inch Equiv.*	*Mm.*	*Inch Equiv.*
A	1.78	0.070	2.54	0.100
B	7.62	0.300	15.24	0.600
C	5.97	0.235	8.89	0.350
D	3.53	0.139	8.89	0.350
E	1.65	0.065	6.35	0.250
F	4.09	0.161	6.35	0.250

ASA Z22.38 (Aug. 28, 1935)	AMERICAN RECOMMENDED PRACTICE For 16 mm Sound Film	SMPE RP16s-1-1
	FILM SPLICES NEGATIVE AND POSITIVE	*Adopted* Original: 1932 This revision: 1936



DIAGONAL SPLICE



STRAIGHT SPLICE

	Diagonal		*Straight*	
	Mm.	*Inch Equiv.*	*Mm.*	*Inch Equiv.*
A	1.78	0.070	2.54	0.100
B	7.62	0.300	15.24	0.600
C	5.97	0.235	8.89	0.350
D	3.53	0.139	8.89	0.350
E	1.65	0.065	6.35	0.250
F	4.09	0.161	6.35	0.250

REPORT OF THE STANDARDS COMMITTEE*

Summary.—*Statement of the activities of the Standards Committee during the past six months, leading to completion of the revision of the SMPE standards published elsewhere in this issue of the Journal.*

There have been but two meetings of the Standards Committee since the last report was written. One of these was devoted to a final correction of a series of drawings that had been practically approved, and the second one dealt with the initial drafts of fourteen new drawings completed during the summer. These drawings covered 8-mm. film standards, a revision of the drawings for the 35-mm. and 16-mm. projection sprockets, and reels for 35-mm., 16-mm., and 8-mm. film.

35-Mm. and 16-Mm. Projection Sprockets.—In connection with the sprocket drawings, no essential changes in either design or dimensions have been suggested.

Projection Reels.—For the 35-mm. reels, both 1000- and 2000-ft. capacity, dimensions are being prepared. The 2000-ft. reel dimensions will agree essentially with the specifications proposed by the Academy, although only the basic dimensions will be given in the SMPE drawings.

In the case of the 16-mm. reels, objection has been raised toward standardizing the reel with the square hole on one side and the round hole on the other side, so that the present proposal by the Committee is to use two standards: the square-round combination to be used by those who wish to use it, and the square-square combination to be used by those who prefer that. The main objection to the square-round combination is that this feature is patented. At its last meeting, the Committee did not feel justified in standardizing exclusively on any patented feature of this sort.

For the 8-mm. reels, standards are being prepared only for the projection reels. The camera reels vary according as the manufacturer desires to use the double-width 8-mm. film in the camera and to slit after processing, or to use the single-width 8-mm. film the camera.

* Presented at the Fall, 1937, Meeting at New York, N. Y

Sound Records and Scanned Area, 35-Mm. Film.—A ballot was taken during the summer on the following proposal:

"In the case of the push-pull track, the space separating the two halves of the track shall be 0.15 mm. (0.006 inch) wide, and centered upon the center-line of the sound record."

Although the balloting was in favor of this proposal, there were enough objections to the 0.006-inch width to warrant going further into the matter, especially as there is some disagreement as to the actual practice used in the trade. Mr. J. O. Baker has been appointed a committee of one to investigate this problem thoroughly and to report back to the Committee. Anyone having definite ideas on the subject should communicate with the General Office of the society.

Perforation Dimensions.—The Committee has not forgotten the recommendation of its Sub-Committee on Perforation Size that the dimensions of the positive perforation be changed so as to coincide more closely with those of the old Bell & Howell perforation. Work was started last spring on a punch and die to be built in accordance with the specifications of Howell & Dubray. Owing to press of other work, and to the desire to have these dimensions as accurate as would be obtained in commercial work, special cams were designed and built, and the punches have been finished only within a few days. A thorough, practical test on film perforated with these dimensions is being undertaken by the Committee.

Standardization of Densitometers.—Owing to Dr. O. Sandvik's absence in Europe, no practical steps have been taken during the summer to prepare samples of film standardized by means of the integrating sphere for use in standardizing densitometers in the trade. The matter, however, will receive attention as soon as possible.

E. K. CARVER, *Chairman*

P. ARNOLD	R. E. FARNHAM	N. F. OAKLEY
M. C. BATSEL	C. L. FARRAND	G. F. RACKETT
F. C. BADGLEY	G. FRIEDL, JR.	W. B. RAYTON
L. N. BUSCH	H. GRIFFIN	C. N. REIFSTECK
A. CHORINE	A. C. HARDY	H. RUBIN
A. COTTET	R. C. HUBBARD	O. SANDVIK
L. DE FEO	E. HUSE	H. B. SANTEE
A. C. DOWNES	C. L. LOOTENS	J. L. SPENCE
J. A. DUBRAY	K. F. MORGAN	J. VAN BREUKELEN
P. H. EVANS	T. NAGASE	I. D. WRATTEN

REPORT OF THE STUDIO LIGHTING COMMITTEE*

Summary.—*A brief discussion of the new trends in studio set lighting—increased use of dolly shots; use of lamps above the set instead of on the floor; improvements in lens and reflector types of lamps; greater intensities required for color cinematography; lighting sets according to "key lights," with much less "general" lighting. The report concludes with a description of some of the new set lighting equipment.*

If we look back over the history of almost any art or science, whether it be sound recording and reproduction or motion picture photography or any similar activity, we can not help observing an interesting correlation between the advances in the art and the development of new devices or tools. It is frequently difficult to decide whether the development of the new tools is the cause or the result of the progress being made.

Advances in motion picture studio lighting during the past year or so provide an excellent example of this phenomenon. Here we have new types of lighting units, improvements in illuminants, the special requirements of lighting for color, new photographic emulsions, and the greater use of the moving-camera or "dolly" shot, all exerting their influence to bring on virtually a new era in the art of motion picture photography.

No doubt the dolly shot, which is a very definite contribution to the continuity and smoothness of action of the motion picture story, is one of the earlier influences. This form of camera operation makes the use of a multiplicity of floor-lighting units out of the question, and has put the lamps almost entirely upon the lamp-rails above the set. Because of the greater distances over which the light must be directed when the equipment is mounted overhead, the so-called "general lighting units," with their broad beam spreads and limited penetrating power, have almost entirely given way to spotlighting equipment with accurately controllable beam spreads.

With the greater emphasis toward "spots," their well-known shortcomings, such as low efficiency, spill light, non-uniform illumina-

---

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received October 8, 1937.

tion pattern, become intolerable. New spotlighting equipment, improved in these respects in both lens and reflector types, has already been discussed[1,2] or will be mentioned later in this report under the heading of new equipment.

The necessity of illumination intensities of 800 to 1000 foot-candles for the earlier Technicolor film emulsions caused the development of units of much higher power and efficiency, as, for example, the types *90* and *170* high-intensity arcs employing Fresnel lenses, so as not to increase unduly the number of units required. Paralleling the introduction of the big arcs, higher-powered and more efficient incandescent lamp units, giving uniform illumination patterns, have been made available. These employ improved 2000-, 5000-, and 10,000-watt lamps. Recently Fresnel lens spots of 500 and 1000 watts have been developed.

Thus the cameraman has the choice of a greater range of more adaptable lighting devices than ever before. At the same time, a smaller number of sources is required in lighting a given set, which has resulted in the use of strong highlights to accentuate the points of interest in the scene, sometimes called "key" lights. Often the remainder of the set is in comparative shadow.

The effect upon the art of lighting has been pronounced. Lighting has in many instances become one of the features of the picture, sometimes even obtrusive. Much of the excessive stylizing will doubtless prove to be a passing fad. Out of all the experimentation, however, new values are being introduced.

Tony Gaudio, one of the old-time cameramen, yet among the most progressive, has introduced a new technic, which he chooses to call "precision lighting." With the aid of the light-control features of the new spots he lights only the chief points of interest, leaving the remainder of the set at a relatively low level of illumination. As the actor moves about, other spots previously adjusted to cover the actor's movements are brought to full brilliancy by means of dimmers, and the lamps not then needed are gradually dimmed. This has the desirable effect of carrying the audience's attention with the actor at all times. It does, of course, call for unusual skill in direction, a high order of coördination among director, cameraman, and electrical staff, and ample rehearsal; but the result is an appealing and effective type of photography that will, no doubt, have its influence on all cameramen.[3]

Besides serving to focus the attention of the audience upon desired parts of the picture, the cameraman, with the aid of his lighting, endeavors to overcome the limitations of the two-dimensional picture in illustrating a three-dimensional scene. By backlighting he brings the actors into relief. In close-ups, modelling is achieved by several sources and by careful gradation of light-intensities across the faces. There are limitations to such technics beyond which the effect is an unnatural one.

With the advent of photography in color the idea prevailed that the lighting could be much flatter, since the color would provide the element of depth now supplied by the lighting. Furthermore, there seemed to be no alternative, because of the limited latitude of exposure of the photographic emulsions used in color work. The range of illumination intensity between highlights and shadows possible in black-and-white photography would result in over- or underexposure when applied to a color material. That was true with the earlier Technicolor emulsions, but recent improvements in both the material and its subsequent processing have greatly extended the lighting-contrast range of this particular color system. As a result, Technicolor cameramen are lighting with fully the same contrasts employed for black-and-white photography, with improved quality in the finished picture.

NEW SOURCES AND EQUIPMENTS

In discussing new studio lighting equipment the Committee is not in any sense duplicating the work of the Progress Committee,[4] but feels that it can render the industry a service in appraising the value of the new devices and discussing their effect upon studio lighting practice. It is interesting to observe that the new equipment to be discussed really represents refinements or extensions of equipment already in use in the direction of more accurate light control.

One manufacturer of lighting equipment during the past year has introduced a "Triple Five" studio spot. Recognizing the rather non-uniform field of illumination produced by parabolic-mirror reflector spots, particularly at the wider beam spreads, this firm has placed a specially designed Fresnel condensing lens at the front of the lamp to confine light that otherwise would become objectionable spill light within the angles of the beam from the parabolic mirror. The effect is a marked increase in efficiency of utilization and an improvement in quality, with the darker area in the center of the out-of-focus beam filled in. Since the lens adjustment necessary for a particular beam spread differs from that required with the parabolic mirror, the new lamp incorporates a differential leverage adjustment of such design that, as the lamp is moved into the mirror to gain a wider beam spread, the lens is moved toward the lamp at a somewhat different rate. Thus the beam of light coming from the lens at all times fills in the center of the spot produced by the parabolic mirror. This arrangement serves the double purpose of gaining a more uniformly illuminated field. The same firm also manufactures a compact 2-kw. lamp spot, employing the Fresnel type of condensing lens. In order to eliminate spill light from the risers of the lenses the risers have been blackened.

Another lighting equipment manufacturer, also of Hollywood, has added three units to his already rather complete line of incandescent and arc lighting equipment. One is the type *65* high-intensity arc spot. This lamp employs a 9-mm. high-intensity positive carbon and a $^5/_{16}$-inch diameter negative carrying a current of 65 amperes. The unit is considerably more compact than the type *120* and the 150-ampere arc spots. It employs a smaller Fresnel-type lens and is intended to be used in the more restricted locations where larger spots can not be employed. The same firm has also made available two smaller incandescent lamp spots, one known as the type *206 Solar Spot*, employing the 500-watt *G-30* bulb monoplane filament lamp with the new medium-bipost base; the other, type *208*, uses the 1000-watt *G-40* bulb medium-bipost base lamp. These spots are characterized by extreme compactness. They are intended primarily for close-ups in restricted localities where space is at a premium. These units are frequently mounted directly upon the camera blimp for use in connection with dolly or travelling shots. Lamps for the units are available in both the black-and-white and color-photography ratings.

The lamp manufacturers have introduced improvements in the efficiency of the 2000-watt *G-48* bulb lamp, the 5000-watt *G-64* bulb and the 10,000-watt *G-96* bulb lamps as employed for black-and-white photography. This is in answer to a demand from many cameramen for a whiter light and maximum output from these sources. Their observations in connection with color photography have suggested the advantages of lamps of higher efficiency for all types of production.

In addition to these changes, the lamp manufacturers have introduced a new group of lamps paralleling in most instances the black-and-white types and known as the *CP* line. They have been designed for a uniform color temperature of 3380°K, and include the familiar 2000-watt Movieflood in the *PS-52* bulb for use in general lighting equipment, a 2000-watt in the *G-48* bulb, a 5000-watt in the *G-64* bulb, and a 10,000-watt in the *G-96* bulb. The last three are fitted with the mogul bipost base. The unusual feature of these lamps, distinguishing them from any other group of lamps designed for a particular service, is that the color of the light is the same for all wattages. This is in deference to the very close color requirements of the Technicolor process. Thus, when used with the proper filter for color photography, the color is the same throughout the entire set, and, in addition, can be mixed with properly filtered arc light or with daylight. The effect of the improved lighting units upon the number of units employed for set lighting has been well discussed by Handley and Richardson.[5,6]

New Incandescent Lamp Filters.—At the Fall meeting of the Society in New York in 1934, the present chairman of the Studio Lighting Committee presented a paper[7] describing two relatively simple filters that permitted satisfactory Technicolor photography with incandescent lamps. These filters were not sufficiently accurate, however, to allow mixing or interchanging indiscriminately several different illuminants such as daylight, arcs, and incandescent lamps.

During the past year more precise filters have been produced by employing a medium-blue glass base and spraying it with an enamel made up principally of cobalt alumina. In the firing process, the cobalt alumina, which is blue, partially changes to cobalt silicate, which is purple; and by exact control of this feature the transmission characteristics of the filter are kept within very precise limits. The firing process also "tempers" or renders the glass non-shatterable.* These filters are now being used in regular Technicolor productions. Thus the Technicolor cameraman is provided with a range of lighting equipment fully as extensive as that available to the black-and-white cameraman.

Development in Other Sources.—A survey of developmental work now in progress on the gaseous conductor lamps shows no new types that have not already been covered in previous reports of this Committee and of the Progress Committee. The high-intensity, water-cooled capillary mercury arc still appears to have the best possibilities of

* Libbey-Owens-Ford *Vitrolux.*

this type of illuminant for motion picture work. At present lamps of about 1000-watt rating are being manufactured experimentally, having efficiencies of the order of 60 or more lumens per watt and a source brightness of the order of 250,000 candles per square-inch and higher. Before such sources can be used for motion picture work, however, there still remain the problems connected with liquid cooling, and cyclic variation of the light with the current frequency, since high voltages are involved. The light quality of the present lamp is also not entirely suitable, particularly for color work, but improvements are being made in this direction.

In the allied branches of studio lighting, such as power production, wiring methods, *etc.*, there appears to have been little change in the past year. Mole-Richardson, Inc., has made available three up-to-date portable, gasoline-driven power plants rated at about 1400 amperes each, employing d-c. generators developed especially to meet the load-speed characteristics of the gasoline engine and incorporating high-speed voltage-control devices to prevent overshooting the voltage should part of the load be switched off. The housing surrounding the engine and the exhaust have been carefully designed to render them so nearly noiseless that they may be stationed within 200 feet of the microphone.

R. E. FARNHAM, *Chairman*

W. C. KUNZMANN   V. E. MILLER   E. C. RICHARDSON
J. H. KURLANDER   M. W. PALMER   F. WALLER
G. F. RACKETT

REFERENCES

[1] RICHARDSON, E. C.: "A Wide-Range Spotlamp for Use with 2000-Watt Lamps," *J. Soc. Mot. Pict. Eng.*, **XXVI** (Jan., 1936), No. 1, p. 95.

[2] RICHARDSON, E. C.: "Recent Developments in High-Intensity Arc Spotlamps for Motion Picture Production," *J. Soc. Mot. Pict. Eng.*, **XXVIII** (Feb., 1937), No. 2, p. 206.

[3] GAUDIO, G.: "A New Viewpoint on the Lighting of Motion Pictures," *J. Soc. Mot. Pict. Eng.*, **XXIX** (Aug., 1937), No. 2, p. 157.

[4] Report of the Progress Committee, *J. Soc. Mot. Pict. Eng.*, **XXIX** (July, 1937), No. 1, p. 3.

[5] HANDLEY, C. W.: "The Advanced Technic of Technicolor Lighting," *J. Soc. Mot. Pict. Eng.*, **XXIX** (Aug., 1937), No. 2, p. 169.

[6] RICHARDSON, E. C.: "Recent Developments in Motion Picture Lighting," *J. Soc. Mot. Pict. Eng.*, **XXIX** (Aug., 1937), No. 2, p. 178.

[7] FARNHAM, R. E.: "Recent Developments in the Use of Mazda Lamps for Color Motion Picture Photography," *J. Soc. Mot. Pict. Eng.*, **XXIV** (June, 1935), No. 6, p. 487.

REPORT OF THE COMMITTEE ON PRESERVATION OF FILM*

Summary.—*A statement of recent activities of the Committee, and a proposed program of future work.*

The Committee met at the Hotel Pennsylvania, New York, N. Y., on October 13, 1937. Members in attendance were J. G. Bradley, *Chairman*, J. I. Crabtree, A. S. Dickinson, T. Ramsaye, and J. E. Abbott. Substitutes attending were K. Famulener for W. A. Schmidt and C. A. Lindstrom for R. Evans. Mr. Bradley substituted for C. L. Gregory. V. B. Sease and M. E. Gillette were represented by written submissions setting forth their views on problems before the Committee.

The Chairman made a brief report on related work being done at Washington, summarized briefly as follows: (*1*) The National Archives storage cabinets, previously approved by the Committee, have been installed, and field tests with other types of cabinet are being made; (*2*) the research work at the Bureau of Standards on preservation of records has been resumed; and (*3*) the Federal Fire Council has become increasingly active in an effort to minimize fire hazards.

It was pointed out that emphasis is shifting (temporarily, at least) from a consideration of preservation in terms of deterioration to a consideration of preservation in terms of film fires and film handling. This shift does not represent lack of interest in the problems of deterioration, nor does it indicate that the work in that field has been completed. It is based rather upon the fact that a very large quantity of nitrocellulose material in Federal custody has been discovered recently, lacking adequate fire protection. It is also the result of increasing interest on the part of corporate and private collectors in preserving this type of record. Adding momentum to this shift have been some recent and rather extensive film fires. It was agreed that the Committee should take cognizance of the fire problem as

*Presented at the Fall, 1937, Meeting at New York, N. Y.; received October 27, 1937.

falling in the field of preservation, and render all possible service to those seeking help.

The need for additional funds with which to carry on this work was mentioned, and various means for meeting the emergency were discussed. It was the consensus of opinion that, while certain private individuals and non-Federal agencies might be expected to contribute nominally, the U. S. Government should finance this work, being the most representative agency of all the people.

The Chairman submitted a proposed work program to cover future activities of the Committee, which had been the subject of correspondence between him and the individual members. This program follows:

(*1*) The effects of projection heat and light upon films.

(*2*) Continued investigation of the use of acetate film base for long-time storage.

(*3*) Investigation of other film base materials not in current use.

(*4*) A safe yet economical plan for long-time storage.

(*5*) A study of the handling and winding of film—roll winding under dust-free conditions.

(*6*) Standardized physical and chemical tests to determine condition of films received for storage.

(*7*) Chemical and physical treatment for restoration of faded images, deteriorated emulsion, and decomposing base.

(*8*) Specifications for processing film for long-time storage.

(*9*) A study of printers for old shrunken film.

(*10*) Definition of terms: a glossary.

The proposed program was discussed at length and was finally adopted as a general guide, with the recommendation that it be made sufficiently flexible to meet current and local situations. The discussion also enlarged the scope of some of the foregoing items and limited the scope of others. For example, it was suggested that the Committee should continue its study of nitrocellulose film for the reason that for a long time to come it will be necessary to handle that type of material. As to a study of new materials for film bases, the view was expressed that the practical aspects of this properly belonged in the field of commercial enterprise rather than in the experimental field as found in the laboratory; and that much experimentation lies ahead of any successful effort to gain wide acceptance of a new base—all modified by market conditions, sales resistance, cost of materials, *etc.* The best service the laboratory can render in this regard is to examine specimens submitted to it and give out its unbiased findings. A study of emulsions, projection light and heat, storage and preservation, handling, restoration of faded images (when practicable), chemical tests, printers for old film, and a standardized glossary were emphasized.

The question was asked whether the Committee should act as a review board or whether it (or its individual members) should participate actively in certain phases of research. Mr. Crabtree expressed the view, shared generally by other members and substitutes present, that while some of the members represented institutions having facilities for doing research work, others did not; and, furthermore, that the final stamp of approval by the National Bureau of Standards would give general acceptance to the work not given to commercial institutions or private individuals. Hence it was agreed that the Committee should continue to act largely in an advisory capacity to the Bureau, except for the following division of labor among members of the Committee:

(*1*) Mr. Crabtree agreed, with the help of Messrs. Sease and Schmidt, to assume the leadership in the matter of handling film as set out in item *5* of the work program.

(*2*) Mr. Bradley agreed, with the help of Mr. Dickinson, to take over the work of storage and fire control as set out in item *4*.

(*3*) Item *9*, a study of printers, was assigned to Messrs. Gregory and Abbott.

(*4*) The matter of a standardized glossary as outlined in item *10* was assigned to Messrs. Gregory and Ramsaye.

It was agreed that all other items in the program not covered by these special assignments were to be left to the Chairman, with the help of Messrs. Gillette and Evans, with recommendations that the final work be cleared through the National Bureau of Standards. The Committee pledged its support to this work, and the members present representing manufacturers with research facilities extended this pledge to include the use of these facilities by the Bureau's technical workers.

J. G. BRADLEY, *Chairman*

J. E. ABBOTT	R. EVANS	T. RAMSAYE
J. I. CRABTREE	M. E. GILLETTE	V. B. SEASE
A. S. DICKINSON	C. L. GREGORY	W. A. SCHMIDT

CHANGING ASPECTS OF THE FILM-STORAGE PROBLEM*

JOHN G. BRADLEY**

Summary.—*The volume of film being used for permanent record purposes is rapidly increasing. This includes principally the documentary type of motion pictures. However, better entertainment pictures are being produced which can reasonably be expected to live just as a good book lives. Increased volume of documentary records and increased interest in permanency demands planned storage, both in terms of preservation and in terms of fire hazard. The principle of unit isolation is the basis for storage at The National Archives. Spread of film fire can be prevented by (1) insulation and (2) use of a cooling agent. Among cooling agents tested, water was found effective and economical. Cascade type of shelving holds out great promise.*

Three changing aspects of the film-storage problem seem pertinent to this discussion. Two of these are offered as evidence of the problem, and one (the third) as a possible solution. The first is the increased use of photographic material, and the second is the increased interest in permanency.

(I) INCREASED USE OF PHOTOGRAPHIC MATERIAL

Not only are present users of film increasing their output but the number of users is increasing rapidly. Reference is made here to institutions making photographic records of the documentary type. For example, recent surveys have located nearly 1500 depositories of photographic records in federal custody alone. Some of these are large and some are quite small, but 282 of them have either 5000 or more still negatives or 10,000 feet or more of motion pictures. The total volume will perhaps exceed 600 tons of material.

Various governmental agencies are engaged in making aerial maps, and hope some day to photograph every square mile of the United States. The Bureau of the Census is engaged in microfilming its enormous census records. The National Archives is giving serious

*Presented at the Spring, 1937, Meeting at Hollywood, Calif.; received May 13, 1937, revised November 4, 1937.

** *Chief*, Division of Motion Pictures and Sound Recordings, The National Archives, Washington, D. C.

thought to the same technic as a method of ultimately reducing the millions of records in its custody. When the committee in charge of the film preservation work,[1] done at the National Bureau of Standards, announced that this type of record could be expected to last a long time, interest in the production of such records by libraries, schools, and commercial firms was greatly stimulated. These are a few of the many examples that could be cited if further evidence seemed necessary, but it is reasonable to expect that the coming years will develop both new uses and new users of this very effective type of record.

(II) INCREASED INTEREST IN PERMANENCY

It is evident that some of the increased use of photographic material is based upon an interest in permanency, but this is not the sole factor. The production of entertainment pictures, educational or instructional pictures, or of documentary pictures for other purposes, may be entirely divorced from any thought of permanency. On the other hand, the interest in permanency seems to have its own foundation, and to be the result of a natural trend.

Individuals and industries are a great deal alike in many respects. Youth offers one interest and mature years offer another. A young man taking his first job is interested (or should be) in making good at his work. If married, he builds a house as a shelter, buys clothes to cover his back, and eats simple food. In brief, he is a utilitarian. A little later he is interested in gaining recognition and making money. When his money is made and he has leisure, he takes up golf, buys etchings, and writes his memoirs. When a young industry starts out it is interested in hard work and in making good. Neither its policy nor its product has received general recognition. Perhaps both its capital and credit are limited. The basement or the old warehouse will do for quarters. It is interested in making the product and selling it, in beating last year's quota, in making money and lots of it. In brief, it is highly utilitarian and this is as it should be. Later, when it has made its money, cultural interests may find a place in its activities.

The trend on the part of the motion picture industry in this direction seems well defined. Both the number and percentage of motion pictures dealing with artistic and cultural subjects are increasing. Classical literature is being drawn upon heavily as source material. The services of scholars are being enlisted to authenticate data. Scientists, musicians, and eminent authorities in various fields are being called to Hollywood just as the engineer was called when sound was introduced. That this trend may rest upon profit motives is not exactly pertinent to this discussion. In any event, the time has come when we may expect a good picture to live just as we expect a good book to live; for which we should be grateful.

Aside from the hope that good entertainment motion pictures as produced by the industry may be preserved, there remains a very genuine and legitimate interest in preserving photographic records for legal, historical, educational, and governmental reasons. Land and other property claims continue sometimes over several generations. Veterans' claims and claims under the new social security legislation will continue for a long time to come. For example, Harvard University wishes to preserve the motion pictures it took at its tercentenary celebration so that they can be shown a hundred years hence. The Wanamaker heirs are making definite plans to perpetuate the valuable collection of American Indian motion pictures as a memorial to Rodman Wanamaker. People from all over the world—from Australia to Russia—have made personal calls at The National Archives, and others have written, asking how they can keep their film. And finally there is the great body of newsreels which few will dispute should be preserved.

If this increased volume represents a fixed trend, and if the interest in preservation is genuine and permanent, then greater emphasis must be given to planned storage. No longer will the cellar or the abandoned garage be good enough. One is reminded here of automobile parking; when there were few cars and traffic was light, any place along the curb was good enough; there was no problem. Now auto parking must be reckoned with, and photographic film, particularly nitrocellulose film, demands basic planning.

(III) PLANNED STORAGE—SUGGESTED SOLUTION

Although our research at The National Archives on storage *in terms of preservation*, to which members of the Society of Motion Picture Engineers and others have made valuable contributions, is far from complete, we have learned a few things, and collected and coalesced other things already known, most of which had been presented in previous papers. Recently we have been giving considerable attention to storage *in terms of fire-control*. That work is also unfinished but certain preliminary results may prove interesting or even helpful.

In our plans for film-fire control unit isolation is emphasized above everything else. This principle, of course, is not new; we merely have adapted it to certain variations. But let us review the matter

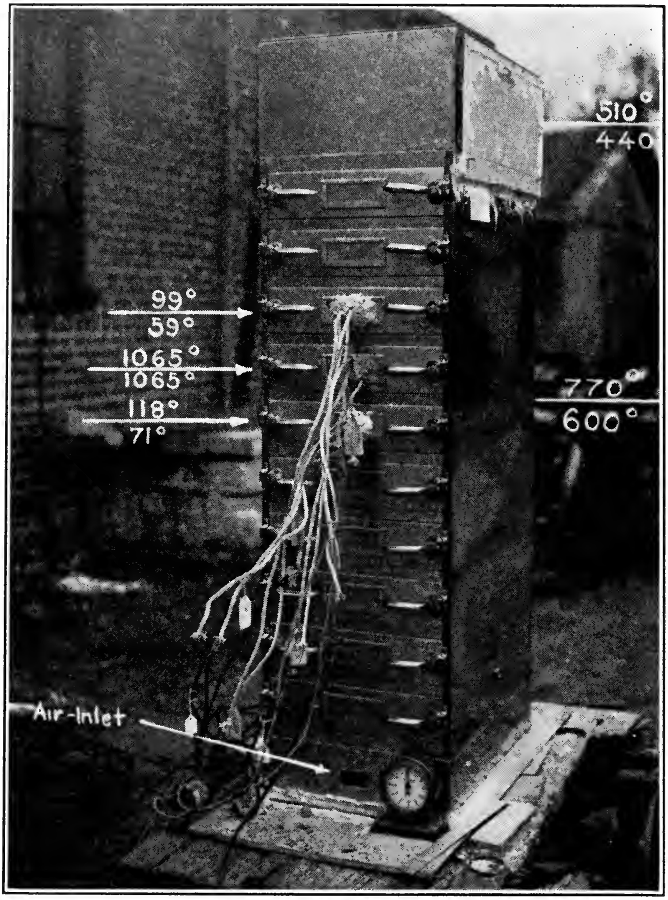


FIG. 1. The National Archives film-storage cabinet set up for fire test. Figures above the arrows indicate temperatures (Fahr.) obtained without the container; figures below the arrows, with the container.

for a moment. A vault of 750 cubic-feet, holding approximately 5000 pounds of nitrocellulose film on open racks, is generally accepted as the maximum. An intermediate step is an enclosed cabinet in which approximately 100 pounds (more or less) is the average unit of isolation. Finally, there is the compartment or pigeon-hole, with 5 pounds as the unit of isolation. This latter form of storage was reported by Crabtree and Ives[2] some time ago. The National Archives has adopted this principle for its more valuable motion pictures, but has gone considerably further in the matter of insulation.

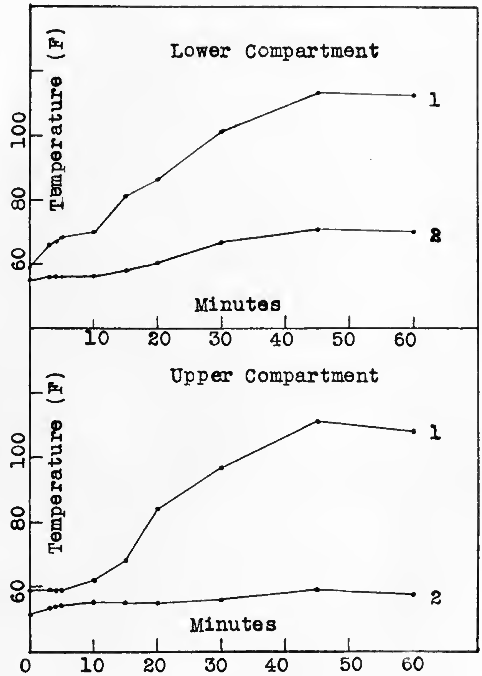


FIG. 2. Time-temperature curves of fire test of motion picture film cabinet.
Lower compartment: Curve *1*, on top of can. Curve *2*, inside can on top of film.
Upper compartment: Curve *1*, under can. Curve *2*, inside can on top of film.

Although the design of this cabinet has been reported,[1] the fire test was not made until recently.

Fire Test on Insulated Cabinet.—(See Fig. 1.) The test was made with one unit of a sample cabinet furnished by the General Fireproofing Company of Youngstown, Ohio, under their contract with the Procurement Division of the Treasury Department for The National Archives. The unit consisted of ten horizontal-drawer compartments and a vertical flue, a base section, and a top section. The cabinet was fabricated from corrosion resistant steel throughout, and all walls, drawer-fronts, and spaces between compartments were insulated. The insulation was approximately 1 inch thick, leaving a $12^1/_2 \times 12^3/_{16}$-inch compartment (inside measurements) $2^1/_2$ inches high, and a $12^1/_2 \times 4$-inch flue in the rear. The drawer heads were of the icebox type and were held in place under pressure. A gravity flap with breather ports[1] separated the compartment from the flue.

In the preparation of the fire test, the base section was laid in a bed of plaster on a flat piece of plaster board. Rebates between the sections were filled with putty (Alumilastic, consistency "C") before fitting the sections together.

Three full reels of old nitrate film were placed in the special vented containers developed by The National Archives[3] and located in compartments *6*, *7*, and *8*, reading from the bottom drawer as number *1*. An ignition coil, connected to a source of current, was placed around the outer edge of the reel in compartment *7*. Thermocouples for measuring temperatures were located in all three drawers.

The outside temperature was approximately 51°F. Fumes were noted issuing from the top of the cabinet 10 seconds after electric contact was made, and were soon seen in large volume. After $2^1/_2$ minutes the fumes began to decrease in volume and practically ceased at 4 minutes.

Tests were made both with the container and without the container. Maximum temperatures (Fahr.) developed were as follows, as shown also in Fig. 1. (the first figures given are those obtained when the container was used):

Compartment *6*	71– 118
Compartment *7*	1065–1065
Compartment *8*	59– 99
In flue opposite compartment *7*	600– 770
In flue top of cabinet	440– 510

It will be noted that the use of the container materially reduced the temperatures in all instances but it was satisfactory to note that the temperatures, even without the use of the can, were greatly below the danger point. (See Fig. 2.)

In view of some very valuable motion pictures placed in our custody, we feel that the expense of a limited number of these cabinets is justified. Nevertheless, we realize the need for less expensive storage for future expansion, yet storage that would be safe from fire hazards.

Consequently we have been experimenting with an alternative wherein a cooling agent is the protective factor rather than insulation.

Carbon Dioxide as Cooling Agent.—Our first tests were conducted with carbon dioxide. An enclosed cabinet, approximately 14 inches square and 8 feet high, holding 29 containers stored horizontally, was used. This was constructed of 1-inch pine board. At the top two $3^1/_2$-inch horns, leading from a tank of carbon dioxide through a $^3/_8$-inch hose, were installed, directing the discharge downward into the cabinet. Three adjacent reels of nitrocellulose film were used, the middle one being connected with a heater coil for ignition purposes and the upper and lower ones connected with thermocouples for the purpose of reading temperatures. The final tests were conducted at the National Bureau of Standards the early part of April of this year.

A total of 15 tests were made, with variations in the number of containers, the type of container, the amount of carbon dioxide, the kind of actuating agent used, and types of shelves between containers. Naturally, these shelves can not be solid since there must be a quick and easy spread of the cooling agent but, in some of the experiments, asbestos plates were placed under the containers. These plates materially decreased the hazard. The National Archives container,[3] being of heavier metal, showed a distinct advantage over the commercial "tin" can.

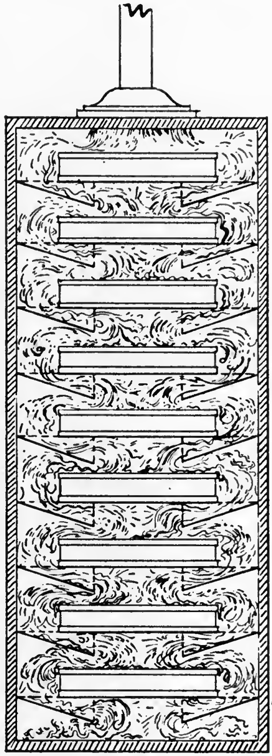


FIG. 3. Artist's conception of "cascade" film-storage cabinet of The National Archives (not drawn to scale).

Eight pounds was the minimum of carbon dioxide used and 51 pounds was the maximum. Although spread of fire was prevented in some of the tests with as little as 17 pounds of carbon dioxide, the resulting temperature in the adjacent containers was higher than that considered good practice for preservation purposes. Approximately 25 pounds applied within 15 or 20 seconds after ignition is considered the minimum safety margin from a fire standpoint for minimum losses, and from a preservation standpoint a greater supply is recommended.

Test with Water as Cooling Agent.—The National Archives has carried on independent experiments with water as a cooling agent, and hopes shortly to finish these tests at the National Bureau of Standards for final measurements.

The first of these tests involved local application of water. A wooden cabinet having a capacity of 9 containers stored horizontally was used. In the rear of the cabinet a water-pipe 1 inch in diameter

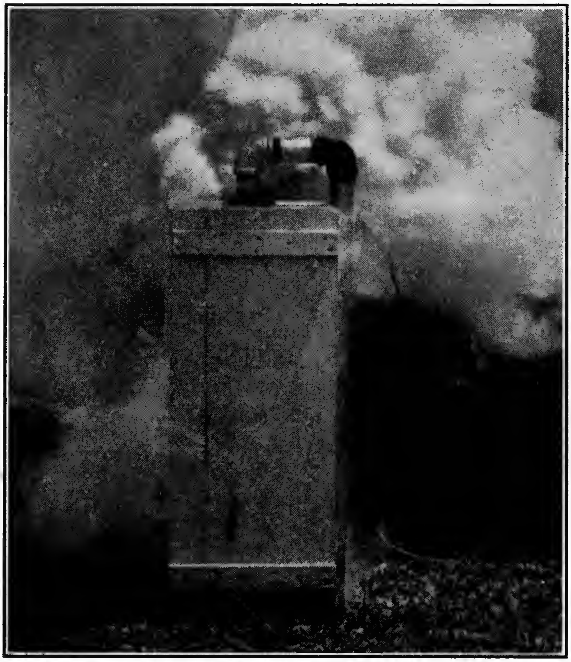


FIG. 4. Showing progress of film fire 20 seconds after ignition. Note volume of smoke given off by one reel of nitrocellulose film.

was placed vertically, with slits cut in the sides so that water would be sprayed horizontally on the top of each container. Three adjacent containers, each filled with nitrocellulose film, were used with empty containers to fill in the other spaces. A heater coil was used to ignite the film in the middle container but no temperature readings were made. In less than 5 seconds after the electric current was turned on smoke was visible and the water was turned on manually immediately

Three minutes from the time of ignition the water was turned off and the film was examined. Only the middle reel had burned.

The experiment was repeated several times successfully up to 17 seconds' lapse before applying the water. After a lapse of 29 seconds, however, before turning on the water, one additional reel was lost. It should be noted that a fusible link having a melting point of 165°F was used, the link being placed directly in the rear of the middle container. This link was connected to a visible weight, the dropping of which was a signal for turning on the water. Although this scheme is quite effective and has much to commend it, further experiment has

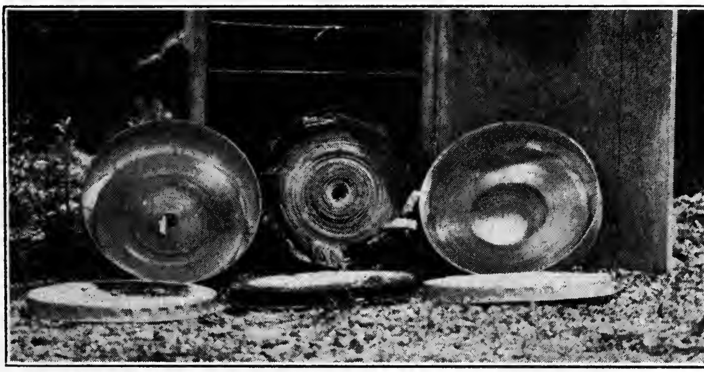


FIG. 5. Showing condition of three adjacent reels of nitrate film after test with "cascade" film-storage cabinet. The ignited reel was between the other two. Cooling agent operated 20 seconds after ignition.

been discontinued (for the time being, at least) in favor of other schemes that appear to be less complicated.

Our final tests with water, now in progress, are being made with what we call a "cascade" type of shelf within an enclosed cabinet. This cabinet can be either portable or can be in the form of installed stacks separated by partitions plus a door. We definitely recommend the door, however, for at least two reasons: (*1*) to guard against the combustion's taking the form of a flame and (*2*) to direct the heat from the burning film upward to the actuating agent.

This cabinet, as before, calls for horizontal storage and a flue in the rear for the escape of heat and fumes. A thermostat or sprinkler-head is placed in the path of this escaping heat. The water supply is placed directly over and leading into the cabinet. On being released it falls on the first can, cascades to the sides, falls to the next shelf, drains toward the middle where there is a large hole, falls to the next can below it, and this movement of the water is repeated until every can in the cabinet is covered with a sheet of water. (Figs. 3, 4, 5, and 6.)

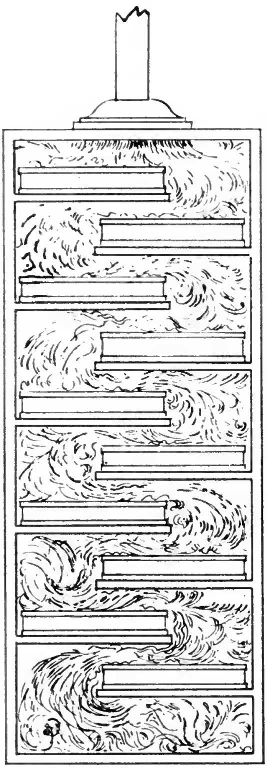


FIG. 6. Showing another design of "cascade" film-storage cabinet, on which experiments are being made.

One other provision is necessary, and that is that there must be ridges both on the top of the shelf and the bottom. The ridges on the top create troughs for the water to flow in, and the ridges on the bottom serve to prevent the lid of the can below from coming up and closing the hole. The shelves are gently sloping toward the center.

Preliminary field tests with this "cascade" type of cabinet have been very successful and the design holds great promise as an effective and economical method of storage. We hope to conclude our experiments in this regard shortly. It is believed, however, that in a unit cabinet holding 20 containers, not more than 2 reels (10 per cent for the stack or cabinet and a negligible percentage for the vault) will ever be lost—perhaps only one, if the actuating agent is arranged to operate within 15 to 20 seconds.

Other Considerations.—Two other fundamental considerations remain in planned storage. The first is based upon the need for keeping the film at low temperatures. This consists of a tempering unit wherein the film is brought out in sealed containers and left to stand while the temperature gradually rises by induction or radiation. Thus condensation of moisture is prevented. This is not a complicated device and further comment seems unnecessary.

The second consideration is what we call a re-humidifier, with which the moisture content of film, particularly of cellulose acetate film, can be restored so as to prevent brittleness. This can be accomplished in several ways, but two methods are offered in illustration. First, an accumulator device may be used for blowing moist air across the surface of the film while the latter is being slowly wound. Again, the film may be wound upon a fluted apron and placed in an inclosed cabinet wherein moist air is blown across its surface. There are possibly other methods equally effective but whatever scheme is used, the surface of the film should be exposed.

In closing permit me to recall a metaphor used in my paper "Motion Pictures as Government Archives."[1] I referred to motion pictures as an awkward youth with a bad reputation with whom nice little boys were not supposed to play, and who occasionally went on a spree and smashed the furniture. Well, it looks as if this young man were growing up. No longer is it in order for him to sleep on the old sofa in the same room with Pappy and Mammy but he needs must have a room all his own. We simply have to plan for him. Not only has he outgrown all his old clothes, not only is he still as strong as an ox and as mean as the devil when he breaks loose, but he is altogether worthy of our affection and admiration.

REFERENCES

[1] BRADLEY, J. G.: "Motion Pictures as Government Archives," *J. Soc. Mot. Pict. Eng.*, **XXVII** (June, 1936), No. 6, p. 655.

[2] CRABTREE, J. I., AND IVES, C. E.: "The Storage of Valuable Motion Picture Film," *J. Soc. Mot. Pict. Eng.*, **XV** (Sept., 1930), No. 3, p. 289.

[3] Report of the Committee on Film Preservation, *J. Soc. Mot. Pict. Eng.*, **XXVII** (Aug., 1936), No. 2, p. 147.

A short demonstration film was projected, showing burning tests of film in cabinets designed by The National Archives and described in the paper.

DISCUSSION

MR. KERSHNER: What is being done with regard to lengthening the life of film?

MR. BRADLEY: Our study of preservatives, coatings, and impregnating methods has not been completed. I understand, however, that a study of the problem is being made in Hollywood under the sponsorship of the Academy Research Council. Perhaps the Council will have some announcements to make on that soon.

The gases of combustion are composed of oxides of nitrogen, carbon monoxide, carbon dioxide, hydrogen, methane, and traces of hydrogen cyanide.

MR. LUBCKE: Do the gases kill by suffocation, or is the action a corrosive one?

MR. BRADLEY: It is a corrosive action, and frequently very rapid. In the Cleveland Clinic fire the bodies of several persons were found sitting in chairs without having moved. Others lived for several weeks.

MR. ENSIGN: Was there any indication of explosion during the time the film was burning?

MR. BRADLEY: The gases will not generally explode unless they are confined. That is why we use vented cans. Two important considerations should be emphasized: (*1*) Protection of property in preventing a spread of the fire. This is accomplished by observing the principle of unit isolation, letting the affected unit burn out, and venting the fumes to the exterior; (*2*) protection of human life and health. We do not ask our employees to fight film fires; the risks are too great. Exhaust fans should be provided to clean the room of residual smoke, and gas masks should be kept handy for emergencies such as rescue work. In brief, ninety-nine per cent of the film fire control work should be done before the fire occurs.

NOTE: Mr. Bradley gave an oral summary of his paper at the Fall Convention at New York, October 11, 1937, for the benefit of the Eastern members who did not attend the Spring Convention at Hollywood. After his talk, the following discussion ensued:

MR. RICHARDSON: As I understand it, the silver that forms the photographic image is permanent. How long will it last?

MR. BRADLEY: I do not know. We believe that the acetate base will last 100 years or more if properly kept; but our experiments have not covered emulsions as such.

MR. RICHARDSON: Would it not be possible to take a series of pictures on glass strips of convenient length? It would seem that they would last very much longer than on ordinary film. Another point: please extend your remarks on the injurious effects of the gases. That is an important subject in projection rooms.

MR. CRABTREE: Film that is decomposing but not burning gives off oxides of nitrogen, and when these gases come into contact with moisture in the lungs, nitric acid is produced, which is poisonous and very irritating.

MR. RICHARDSON: We have had a great many film fires in which the projectionists certainly must have breathed some of the gas. Can we get any definite information as to how far that would not be very dangerous?

MR. CRABTREE: If the projectionist inhales gases from burning film, that is not nearly so dangerous as inhaling gases from film that is rapidly decomposing but not burning with a flame. The film in Cleveland, of which Mr. Bradley speaks, was heated and gave off toxic gases, and much of the film was not burning. If the products of decomposition ignite, the resulting gases are not as dangerous, although it is not desirable to breathe them.

MR. KENDE: In slow-burning of acetate film, are any toxic gases given off at all?

MR. BRADLEY: They are quite objectionable and are not good for the health, but are not as poisonous as the nitrate fumes. We do not know the conditions under which the combustion of film will take the form of flame or the form of smoke. Members of the Committee witnessed a demonstration at the Bureau of Standards a couple of years ago in which we burned nitrate film in a can, mainly to test the can. In one instance the combustion took the form of a huge cloud of smoke, and in the next instance it took the form of flame, under apparently the same conditions. If we could always get the burning to take the form of flame, the danger would not be so great. I do not believe projectionists or anyone else should be asked to fight film fires. We ask our people to run and let the film burn out.

MR. HOVER: There are no records showing the number who may have been injured by inhaling the fumes, mainly because the medical profession was not aware that they were so toxic. There are quite a number of records that show that projectionists had inhaled fumes and about two weeks later were found dead.

I believe it is only in the last two years, due to research started in New York by one of the medical associations, that these conditions have been fully appreciated. There is no way of telling how many projectionists have inhaled the fumes and died as a result, when their deaths were blamed on heart failure and various other things.

Regarding the film fire in Cleveland, I was recently informed that one of the casualties in that case was a man driving a car. He drove through a cloud of the smoke, and his car crashed into a pole less than a block away. He was dead when they took him out of the car, due to having inhaled the gas.

MR. RICHARDSON: For many years I have fought for ventilation systems in projection rooms that would remove smoke and gases as fast as they are formed.

MR. CRABTREE: In the event of fire, a fan could be started immediately to remove the decomposition fumes, but it would not be necessary to ventilate the room to such an extent during normal times.

MR. GREENE: Possibly there is some need also for specific education on the subject among our craft. I have never heard a projectionist speak of the possibilities of film fire but he says, characteristically, "Brother, when she pops, I am gone." I have known of only one who did that. There is something, I do not know just what it is, that impels the projectionist to stay there and fight the fire.

MR. CRABTREE: In attempting to preserve valuable films we should not rely too much upon a water supply. I can imagine instances where the water supply might be shut off just at the time when the film was subjected to dangerous conditions. We should try to design the vaults so as to be effective even in the absence of water.

MR. BRADLEY: I probably did not make myself clear on that. We should use insulation, and add the cooling agent as an additional feature. Insulation is fundamental.

MR. CRABTREE: Some of the fires that have happened in recent years have stressed the importance of three things: (*1*) That the vault walls should be sufficiently resistant, (*2*) that the vents should be large enough in cross-sectional area and no longer than necessary, since additional length incurs additional resistance, and (*3*) vents should be properly located with respect to their surroundings. The decomposition products of the film are explosive, and if conditions are such as to produce a detonative mixture the explosive force is quite considerable. The vent size should be adequate to reduce the explosion pressure and the walls sufficiently strong to resist this pressure. Baffles of massive construction and of fire resistant material carried outward from the building roof or walls would also be helpful. That being the case, I do not think there would be much danger of the fire's being transmitted from one vault to another, as has happened in some of the cases mentioned.

In Rochester we have been experimenting with a vault that would be, perhaps, a happy medium between a very expensive vault and the standard Underwriters' vault. The cost of the National Archives vault is probably ten times that of a standard vault, is it not?

MR. BRADLEY: Our cabinets for the more valuable Archival films are quite expensive, figured in terms of original cost, but in view of their long life we do not feel that the cost is out of proportion.

MR. CRABTREE: In the vault in question the cans have embossings on each side so as to provide adequate air space between adjacent cans. Air is an excellent heat insulator. The can is fitted with a vent so that decomposition gases can escape; and if the gases become blow-torches, they blow in the direction of the sprinkler. With such a vault, one must depend upon water. If the water supply did fail, however, I do not think the heat would transfer to other cans; and perhaps not more than one or two cans of film would be lost. This type of vault, of course, is not as foolproof as the one that Mr. Bradley has described, but I think it is much more satisfactory than the standard Underwriters' vault, which is concerned merely with the protection of property external to the vault. Apparently the Underwriters were not very much concerned about the film inside the vault.

There is no doubt that if a can of film in the conventional vault does happen to catch fire, the water from the sprinklers will have access to the remaining cans and the film will be ruined. The proposed modification, we hope, will prevent access of water; and insure that decomposition will not progress beyond the can in which it originates.

The objection to Mr. Richardson's scheme of using glass plates is, of course, the space that would be required and the difficulty of registering successive pictures. There would have to be registration marks on the glass slides so that they could be copied onto motion picture film. If you needed ten feet of film, that would mean 160 glass slides. I think some thought should be given to the suggestion, however. Mr. Bradley stated that the film in the safety vault may reasonably be expected to last perhaps fifty or a hundred years. Methods of duplicating films have been improved greatly in the past few years, and assuming that we shall make still further progress, I think we can assume that within the next fifty years we shall be able to duplicate those films, let us say, 99 per cent perfectly.

MR. KENDE: Mr. Bradley has indicated that the life of acetate base films is definitely longer than that of the nitrate base. Of course, we all know that nitrate base films are the more dangerous. Is there any hope that the safety base will make its entrance into professional work in the near future?

MR. CARVER: Progress is being made all the time in the manufacture of acetate film. At present it is not as good as nitrate film as regards quality and strength, that is, it is not as good for a short time. The cost is greater, and the demand from the trade is not very great.

Not many actual facts are in sight to indicate that these difficulties may be overcome; but when we consider that nitrate film has been manufactured for a great many years and acetate film only for a few years, we know that improvements are bound to come. That is about as much as I can safely say.

MR. BRADLEY: Considerable thought has been given to putting photographic images on material other than film. There is an experimental process in Germany of putting the images on aluminum. In the field of microphotography there is experimentation on photographing a whole book on one sheet of glass 8 × 10 inches. But that would not be motion pictures, just still photography; that is why I did not bring up the subject before.

I have a piece of nitrate film that was produced by the Eastman Kodak Company in 1901, which makes it 36 years old. It has suffered a great deal of punishment in being carried about and handled, but it is still in almost perfect condition. That is why I say that even nitrate film, handled properly and cared for on the principle of good housekeeping, can be expected to last fifty or a hundred years. I regard the present form of film as basic. If we can continue our researches on what we have, I feel that it would be better than trying to go off into glass or bronze or gold or some of these other things. We have considerable promise that cellulose film will last several centuries.

THE PRACTICE OF PROJECTION*

ALFRED N. GOLDSMITH**

***Summary.**—Correct engineering design of theater sound and projection equipment depends upon close contact between the engineers and the projectionists. The position of the projectionist in the industry is stressed, since the motion picture performance is placed before the audience by him.*

It is natural that there should be a Projectionists' Session at any important convention of the Society of Motion Picture Engineers. For one thing, a motion picture engineer can not be truly qualified in his profession if he does not know of the status of projection and of the problems in that field that still await solution. The engineer can not hope to learn of these problems from his inner consciousness or work out their practical answers by a feat of imagination. It is only by being in close contact with the projectionists who are skilled in the practice of their art and who daily encounter the problems in question that the engineer can be guided aright and can hope to produce workable equipment and methods that will advance the art of projection. Solely by close and continuous coöperation between the skilled projectionists and engineers can apparatus be produced that will stand the harsh test of everyday wear and tear.

But this is only a small part of the reason for a Projectionists' Session at an SMPE convention. As has been correctly pointed out, projection of the motion picture and reproduction of the related sound constitute the "neck of the bottle." The motion picture industry has gone to enormous pains to produce an appealing and valuable product. Vast studios having the most modern equipment have been built. The most popular stories and the most successful plays are purchased for motion picture adaptation at figures that truly approach "colossal." Stars of the first magnitude are selected as the chief players, and at rates that are truly "awe-inspiring." Large groups of writers, re-writers, and specialists in the literary polishing of the

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received August 23, 1937.

** New York, N. Y.

script bend their efforts to producing the best results on the set. Cameramen, sound recordists, electricians, make-up men, wardrobe mistresses, carpenters, painters, and a host of others form an army under the command of the most capable directors. Editors and cutting-room experts toil through weary months to produce the smoothest and most appealing film. Elaborate sales and distribution systems carry the films to every corner of the land. A myriad of sparkling and attractive theaters with bright lights blazing in the lobbies and the names of the stars and the play in twinkling lights overhead attract the audience. A whole branch of the advertising industry is devoted to acquainting the public with the romance of the film presentation. Comfortably upholstered chairs, spick and span ushers, air-conditioned theaters, and other instances of efficient management are added to complete the attractiveness of the theater.

And now we finally reach the merchandise—if so prosaic a name may be used—that it is proposed to sell. And this merchandise is nothing more than foot-lamberts from the screen and acoustic watts from the loud speakers. These are the neck of the bottle, and it is for these that the audience pays—or does not pay. And these all important elements in the motion picture industry—the sole and final reasons for its existence—are under the care of the projectionists. If the engineers have provided proper equipment in the projection room, the projectionist then determines the quality and reliability of the performance. He is really the physical impresario of the motion picture presentation. Failure of equipment or incorrect handling can annul all that has gone before.

The aim of the projectionist is to produce pictures that are sharper, steadier, and (within limits) brighter than heretofore. Much can be said in detail relative to each of these requirements. Nevertheless, broadly, they cover the field. At the same time, more perfect and realistic sound reproduction is also the aim of the projectionist.

Many elements in the field of projection are in a state of evolution—illuminating sources, projection room equipment and routine, color projection, and many other developments.

It is clear enough why there should be a Projectionists' Session at any SMPE convention. Indeed, it would be difficult to pick any element in a convention that was more necessary than this session, which, like those that have preceded it, will contribute to the pleasure of future theater audiences and the prosperity of the industry that the engineers and projectionists alike will serve.

GRADING PROJECTIONISTS*

G. P. BARBER**

***Summary.**—Advanced methods of licensing projectionists in the Province of Alberta are described, with some comments on the apparent benefits derived from the process. Becoming a first-class projectionist requires a licensed apprenticeship of at least twelve months, followed by one year as third-class and, later, one year as second-class projectionist before taking final examination for a first-class license. Each period, except apprenticeship, is preceded by a thorough examination.*

The purpose of theater regulations in the Province of Alberta (Canada) is to give public protection against panic or serious mishap in the event of film fires in projection rooms. That purpose has been developed to include general precautions covering width of aisles, door spacing, seating arrangement and fire-prevention measures within the auditorium, or that total enclosure that is known as a theater.

As film fires occur chiefly in the projection room, any measure that tends to confine or limit such fires to the projection room is considered as treating the danger at its source. This paper, however, will not consider details of construction, or projectors and equipment, but will deal with the importance of licensing and progressively grading the persons who work in projection rooms and who are in charge of projection equipment during the time the theater is open to the public.

Over a period of several years Alberta has been privileged, with the friendly assistance of its exhibitors and projectionists, to build up a system of issuing certificates to projectionists that it is believed represents a major factor in fire prevention. In addition, the life of current prints is prolonged under competent handling, and prints are less subject to premature mutilation than would be the case if novices were employed in place of the trained and experienced men.

---

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received September 1, 1937.

** *Chief Inspector of Theaters,* Province of Alberta, Edmonton, Alberta, Canada.

A person wishing to take up projection work in Alberta is required to obtain an apprentice license. The application for such license is in the form of an affidavit, and must be signed by three persons, namely, the proposed apprentice, the manager or owner of the theater, and the projectionist under whom the apprenticeship is to be served. The object of this threefold preliminary is to establish the good faith of the application; to insure that the owner of the equipment has consented to let his property be used; to guarantee that a projectionist is willing to act as teacher or instructor; and to start a genuine record of the apprenticeship so that the required projection room service may be readily traced when the apprentice is ready for his initial examination.

The apprenticeship must cover a period of at least twelve months, with not less than three hundred hours of actual projection room instruction on standard 35-mm. equipment. Examinations are held quarterly, and assuming that the apprentice has fulfilled the requirements as to length of time and hours of training, he may sit for the initial third-class examination. All examinations are written, but the examiner may test the ability of the prospective applicants on their own equipment from time to time while on inspection work in connection with the theater.

The successful apprentice in the initial examination is granted a third-class certificate, which enables him to hold a position as assistant in small theaters and so to continue the next period of twelve months together with at least another five hundred hours of actual projection room experience. His next examination, which is for second-class, is advanced in both theory and practice over his initial attempt and is intended to represent the next higher standard attainable with the normal growth and development of the progressing candidate. If successful, he is given a second-class certificate, on which the same period of twelve months is again required but with not less than six hundred hours of additional projection room experience in a second-class theater before he may sit for first-class examination.

Applicants coming from places outside the Province of Alberta are required to furnish proof of their experience as projectionists before examinations will be granted. This proof may be in the form of letters from former employers, or the original license if such license was required in the territory in which they claim to have been employed.

Examination fees are fifteen dollars for third-class; twenty dollars for second-class; and twenty-five dollars for first-class. These fees cover the issuance of certificates but are forfeited should the candidate fail to pass the examinations. The casual observer might be inclined to call these fees excessive, but a little reflection will show that they induce a more serious attitude of mind on the part of prospective candidates than is the case when the financial consideration is negligible. The examination is primarily designed to prove the candidates' understanding of projection room practice in its various phases, and a certificate is intended to certify that the holder thereof is familiar with the work that his employer expects him to perform. The fee is likely to deter the trifler, but it lends incentive to the serious-minded candidate in the study of real projection problems.

Theaters are graded according to seating capacity. A place with five hundred or more seats requires two first-class projectionists, one for each projector. Two second-class men are required in theaters with less than five hundred but more than three hundred and fifty; below three hundred and fifty seats, one second-class man in charge with a third-class assistant. Apprentices are not employed in place of licensed projectionists and not more than one apprentice is allowed to each theater at any time.

Certificates are issued as from January 1st of each year, and expire on the 31st of December of the year of issue. First- and second-class certificates are renewable without re-examination, but holders of third-class certificates have the option of trying for second-class or rewriting for third-class, as that class is not renewable. This policy has been adopted as tending to urge the beginner to reach the higher grades.

Question papers are changed and modernized from year to year, and no candidate receives the identical paper twice. Questions are arranged numerically under the general headings of mechanics, optics, electricity, and safety. There are thirty questions in the third-class examinations; fifty in the second-class; and seventy in the first-class. The percentage required to pass is 60 for third-, and 80 for second- and first-class.

Should a candidate be dissatisfied with the markings of the examiner, provision is made for a Board of Appeal, consisting of a representative of the Government, a representative of the exhibitors, and a representative of the licensed projectionists. The findings of this Board are binding upon both the candidate and the examiner alike;

there is no higher appeal. While there have been many failures in past years, especially in the lower grades, the percentage of appeals has been almost nil, as the sincere candidate is fully aware of his shortcomings immediately the examination is completed; and as the whole procedure is obviously not to trick or hinder but to encourage and educate the applicant right from the early stages, the entire system builds up a spirit of confidence not only in the methods followed but also within the candidate himself, which makes for friendly cooperation among all concerned.

Generally speaking, the system of licensing is of benefit all around. Those supplying films are assured that reasonable care will be taken of their prints, since the men to whom they are entrusted are experienced and have "grown up" in the work of projection. Every projectionist must sign a complete film report for every item on the program (feature, comedy, and shorts) at the end of custody of each run of pictures. A copy of this report is sent to the Department and one to the film exchange. A third copy is retained for projection room records. We thus have accurate knowledge of the condition in which the film was received at any particular theater, the number of times it was projected, who projected it and what, if any, trouble was encountered.

Exhibitors now depend upon the licensing system in selecting projectionists, and projectionists are protected from the "fly-by-night machine operator" who usually may be depended upon to leave behind him a lot of trouble for the projectionist to clean up.

It is believed that our examination fees are effective in compelling study. No candidate likes to fail, but to fail and lose money in addition makes the sensation doubly painful, since he not only gets nowhere but he foots the bill for the experience. Then there is the matter of three examinations, third-class, second-class and finally first-class. If he is to "arrive" at all he soon comes to the conclusion that study, assimilation, and practice are essential to his progress.

Our biggest problem has been to combat the argument that such restrictions are not enforced or even suggested in other places, *etc. etc.* That is why we welcome symposiums such as are presented at SMPE conventions. We feel that if similar systems could be established throughout this whole continent there would be better prints, better all-round projection, and considerably less willful, careless, and useless waste.

It has been the wish in this paper to outline briefly a system of licensing that has for its main objective the purposeful conscientious study and application of projection knowledge on the part of those who spend the greater part of their working hours in projection rooms, and who are charged with the responsibility of putting the picture on the screen. These men, known as projectionists, can either make or mar the work of film producers and their staffs. It is believed, therefore, that aside from the public safety angle any prevention of waste in the form of mutilated prints is worthy of the best consideration of Governments, examiners, and the serious-minded throughout the entire industry.

DISCUSSION

MR. RICHARDSON: This paper is one of the most important that have come before this body, and I wish to emphasize that it is a government paper. Although the candidates have to put up a considerable sum, the man who puts up $10, $15, or $25, knowing that its return is contingent upon his passing the examination, is not going to take much chance on passing. He gets busy and really studies. That is the important point of this paper.

MR. KESSLER: For the past thirty years as a member of Local 306, and, prior to that, Auxiliary 35, I know it to be a fact that the examinations we formerly took on Park Row (New York) and the examinations that are taken today are given in the same old-fashioned way. Nothing has been improved. It would be a good idea if the engineers of today would take it upon themselves to go down and show the City Department how to examine projectionists.

MR. MCGUIRE: When examinations were introduced by the Government some years ago in Canada there was considerable opposition. They were, however, taken by the men who passed them with flying colors and everyone was very much pleased with the results.

MR. HOVER: I believe a number of members here are familiar with the stumbling block of the system. If our engineers and projectionists could find a way of rooting out politics from the examining boards, there would be no trouble.

MR. FISHER: I was a member of the Board of Examiners of my city for six years. One day our mayor said, "We have twenty-five or thirty janitors in our schools; they all must have licenses to run motion picture machines."

The corporation counsel was told by the mayor to see what he could do about removing from the law of the State the clause that requires that applicants serve apprenticeships, so that the janitors in the schools could run the motion picture machines because the Board of Education could not afford the cost of projectionists.

The following day I happened to go into one of the schools containing an assembly hall with five hundred little children in it. The picture machine was set up at the back of the hall—no booth; four or five reels of film on a chair, not even in tin boxes; and cable running from the machine the whole length of the hall, over which some little child might stumble and probably start a nice fire. I stopped the show, and later the principal went to the mayor's office and asked that I be put off the examining board because he could not run pictures that would endanger the lives of all those children in the assembly hall.

I do not doubt that there are similar situations all over the state, but it is pretty bad that we have to put up with such things.

MR. RICHARDSON: One bad feature of projection examinations, aside from politics, is that our laws take cognizance of practically only one thing, so far as concerns examinations, and that is fire hazard. No attention is paid to the hazard to eyesight, to the ability to put an image on the screen in such a way that there will be a minimum of eye-strain; and yet the shows increase in length until now they are three hours long. The law pays no attention to the quality of projection.

MR. FINN: I question the necessity for the distinction made in the paper between, say, a 600-seat theater and a 750-seat theater, from which it would appear that the need for good projection is not so pressing in the former as in the latter.

Canadian procedure makes quite a point of examining the applicant on what they call "his own equipment." That permits a man to be a fine projectionist in one theater and probably a very bad one in another house with different equipment.

MR. GREENE: The great majority of us have probably long since reached the limit of patience with law-making and law-enforcing bodies; we no longer expect anything of them, and are content if we can just keep them from doing too much harm. All the more it becomes the obligation of each local to assume as its own duty and responsibility that of safeguarding the public, and to insure the excellence of the performance they place before the public. They would be quite satisfied if through their own efforts they were able to do that without too much interference from politics. Fortunately there is an increasing proportion of union members who are not primarily interested in politics, either inside or outside their own organizations.

MR. EDWARDS: About three years ago the Projection Practice Committee spent considerable time on an inquiry from officials in Canada regarding projectionists' examinations. I have not heard of the results of examinations taken directly under our suggestion, but I do believe that under the examination as suggested at the time anyone who went up for examination, first of all, could not assume that the examiner did not know his business.

Our problem is to try to draft an examination or make suggestions for an examination for the people who are supposed to do the examining; in other words, to teach the examiners their business. Not all examiners need teaching; we have present a gentleman who is an inspector in Connecticut, where I know that the examinations are fair and strict, and the general proceeding one that should be welcomed by projectionists everywhere.

COÖPERATION AS THE KEYNOTE OF PROJECTION SERVICE*

T. P. HOVER**

Summary.—*Engineers as a group are backward in dealing with problems involving the human element. They would rather deal with things than persons. They can not be blamed for this, however, because most engineering problems are solved by definite formulas and procedures, while problems dealing with the human element seldom follow expected paths. The human element is a vital consideration in the successful operation of a theater that requires that sound and projection equipment be maintained in first-class condition at all times.*

Plans and ideas that have aided in maintaining high standards of projection in Lima (Ohio) are presented. Since the city is more than 150 miles from the nearest parts-supply company, a well-planned system of mutual coöperation is of the greatest importance in order to prevent shut-downs with attendant loss of money and good-will. Success over a period of ten years recommends the plans to the consideration of other protectionists' organizations that are more or less isolated from repair and emergency engineering facilities.

Many changes have occurred in the motion picture industry since the arrival of the first practicable projectors. However, two outstanding objectives remain unchanged and are of vital interest to the exhibition branch of the industry. The most important is that projection equipment be maintained at the very highest efficiency at all times. Almost of equal importance is the fact that such maintenance should be carried on at a price within reason.

Methods of solving these problems when motion pictures were in their infancy differed somewhat from those of the present day. A breakdown of the single projector meant long weeks of waiting for repair parts, which only too often did not even resemble the originals and sometimes never did arrive. Manufacturers of equipment were not entirely to blame, for if they attempted to "sell" the idea of parts or repair service, the suggestion was often greeted with the attitude that perhaps the machine was not so good in the first place if provision had to be made for its repair.

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received November 7, 1937.

** Warner's Ohio Theater, Lima, Ohio.

The simplicity of design and construction of many of the older types of projectors often assisted the ingenious projectionist. In 1926 the author was called upon to check over a Powers projector to which had been applied successfully repair parts from a lawn mower, a sewing machine, a gas engine, an alarm clock, and a revolver. The great precision of modern equipment has definitely obviated these haphazard sources of repair parts. High-speed communication and transportation have been of great assistance to the exhibitor. Standardization of parts and whole-hearted coöperation from equipment manufacturers have also been helpful factors.

One of the most serious causes of annoyance and loss of revenue to the exhibitor is the class of trouble broadly referred to as "breakdown." No equipment is free from the likelihood of breakdown, and the only remedy is a maintenance plan that will reduce the probability of its occurring and a carefully planned repair program that will bring back into operation the affected equipment with the least expenditure of time and money. So much has been said and done on the subject of maintenance and service that they will not be discussed here further, but the problem of emergency repairs will be given considerable attention.

Approximately fifty cities in the United States have supply depots and theatrical repair shops giving 24-hour service. Emergency repairs in those cities resolve themselves largely into procuring and installing damaged parts, which can usually be done in less than an hour. For theaters located even short distances from repair facilities, an entirely different problem appears. Telephone or telegraph may instantly connect the exhibitor with the nearest available source of repairs, but the transportation of the parts, which even at best may take from four to twenty-four hours, is an important item. A solution of this problem has been worked out in Lima (Ohio) by the projectionist members of the local Union. The average city of any fair size has facilities within it for making almost any repair that may be necessary to keep the picture on the screen until the proper parts arrive from the factory or a serviceman can bring them. In order to be available at a moment's notice, these emergency facilities must be properly recognized and coördinated. The keynote of the system must be coöperation between the exhibitor, the projectionist, and the holder of such facilities. The projectionist who will devote a small part of his time to "selling" his fellow townsmen on the idea that his work of projecting pictures is a profession entailing scientific knowledge and accuracy will find that he has driven an entering wedge into his problem.

The most important prerequisite of emergency service is the possession of the proper testing equipment and tools. Through careful planning within our organization, members seldom buy equipment of types already held by other members. Ten members of an organization each buying a $100 amplifier analyzer and test kit, will have available only $100 worth of test apparatus in the event of an emergency; but the same ten members, with proper planning, can have available a full $1000 worth of modern equipment ranging from tube-tester, oscilloscope, vacuum-tube voltmeters, all the way to complicated vibration analyzers. The fact that some of the larger chains have made available to their engineers a quantity of laboratory testing equipment is ample proof that the investment is justified. Our own group, through careful buying, has available almost $5000 worth of precision equipment. Included in the equipment are a number of complete portable amplifiers, which, in the event of a breakdown could be immediately hooked up to any projection room in the city. It should not be thought that this equipment has been purchased for exclusive use in projection rooms, for the income available from such equipment when so used would not justify the expenditure. For instance, the projectionist may add to his income by renting out public address systems, which have been constructed to handle practically any photocell input. Such equipment obviously, is available also for emergency service work. The availability of this equipment means that any amplifier or loud speaker breakdown can be completely remedied in less than thirty minutes.

In the event of minor amplifier repairs, such as of defective resistors or condensers, a local radio parts company provides day or night service in return for our permitting them to mention in their advertisements the theaters that use their brands of vacuum tubes. Those who have attempted to arouse a parts supplier at night in order to get an elusive amplifier part, can readily appreciate the importance of reliable day and night service.

Mechanical troubles offer the possibility of the most extended shut-downs. While a reasonable quantity of spare projector parts is usually carried, breakdowns often occur in which gears are damaged or shafts bent in such a way that factory replacement is almost necessary. Records of ten years of mechanical breakdowns have shown that 95 per cent of such breakdowns are the result of using cheap, mismatched, or so-called bootleg repair parts.

Our organization has effected a coöperative tie-up with a local company specializing in the manufacture and repair of motors. All regular motor repair work of the theaters is done by this one company. In return, a machine and electrical shop that is a veritable mechanic's paradise is open to the use of our members. This company also maintains a research department and has portable welding and brazing equipment and a portable power and lighting unit, which is

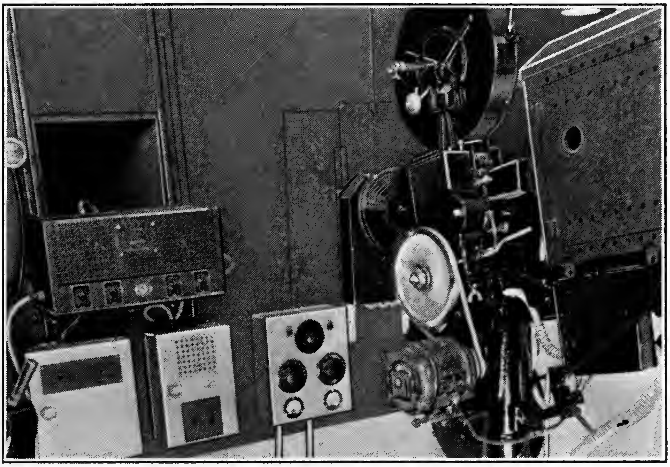


FIG. 1. Experimental projection room maintained by local projectionists.

also at the disposal of our members. As the shop runs 24 hours a day, its facilities are always available.

Recently the main drive gear of one of the projectors was ripped out due to the "freezing" of a misfit shutter shaft. A telephone call revealed that to obtain the nearest replacement part would require an automobile trip of almost eight hours, or high-speed railroad shipment of six hours. The breakdown occurred at 5:30 P.M., and one projector continued the show. A collection of gears from obsolete miscellaneous projection equipment was assembled and taken to the machine shop. Two and a half hours later, after multiple grinding, brazing, turning, and boring operations, the disabled projector was again in service. The replacement gear was so nearly identical to the original that the new gear, which subsequently arrived, has been held as a spare, and the emergency gear has never been removed. A point of interest is that the entire cost incident to rebuilding the gear was less than the factory cost of the new one.

Almost every projectionist envisions a projection room where he can try out new ideas, uninterrupted by the routine of theater operation. Twenty years ago our organization moved to make this dream a reality. Sponsored by the local high-school principal and the student council, members of our group designed and supervised the construction of a modern projection room in the high-school auditorium. Under the supervision of the author and Professors

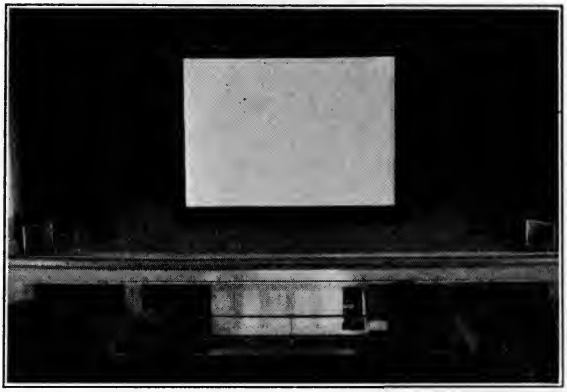


FIG. 2. Screen and amplifier in local high-school auditorium, supervised by local projectionists.

R. E. Offenhauer and H. W. Leach, visual instruction pioneers, this projection equipment has played an important part in the educational program of the high-school system. The equipment and the auditorium have been available to our membership at any time. An elaborate physics and chemistry laboratory, and an industrial arts department, as well as a fair technical library, are also open to our members.

While the depression slowed up our activities, the interest of the student body has been responsible for the installation of a sound system which has been completed for use during the present year. This system was entirely constructed by projectionists and is one of the most elaborate in any school in the country. Fig. 1 shows the projectors and the photocell amplifier used in this installation.

Voice reinforcement, radio and non-synchronous equipment are available. Hard-of-hearing aids are being installed for the benefit of those so afflicted. Fig. 2 shows the auditorium stage with the microphones, speakers, and amplifier cabinet located in the orchestra pit. It would be almost impossible to list all the original ideas that have been developed in this projection room, and special work has been conducted in practically every branch of projection.

One of the most important benefits derived from our coöperative tie-up with the school system is that the students, and through them their parents, realize that our projectionists' organization is an

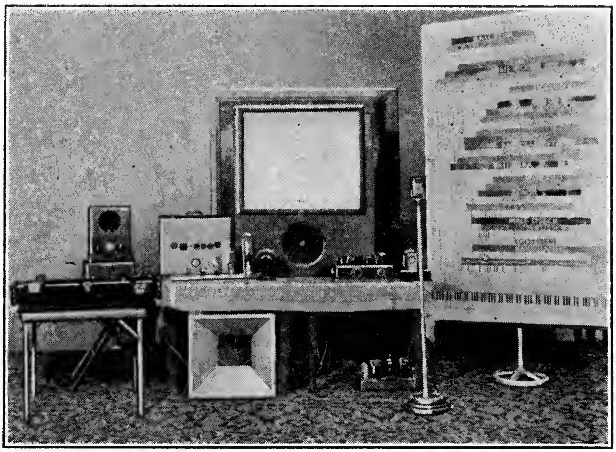


FIG. 3. Demonstration equipment for lecture: "Giving the Movies Their Voice."

important civic asset. Our members are welcomed as guest instructors in both the public and parochial schools. Their knowledge of the physical sciences permits them to aid the teachers in presenting practical experiments and demonstrations. This works a twofold benefit, creating interest in our profession among students and teachers, and stimulating interest in modern education among our own members.

A contact committee carefully handles matters of publicity dealing with projection. This committee makes no attempt to promote either theaters or pictures, and never permits itself to be used for ballyhoo purposes. Its activities are apparently without end. Physicians and surgeons request their assistance in enlarging x-ray films and microscope slides by projection. A breakdown in the local broadcasting station brought a quick call for assistance. The police department has contacted us for the use of ultraviolet equipment, and a number of churches and schools keep 16-mm. film records of their most important activities. The camera work is always assigned to our members. We find that our offers of cooperation and assistance usually surprise our fellow townsmen. Too often the policy of exhibitors has been to contact fellow business men only when they have wanted something.

Recently a prominent industrialist suggested that there was probably considerable romance behind the scenes in projecting pictures, particularly since the subject has always been a closed book to the public. As a result of the idea we assembled and staged a series of demonstrations entitled "Giving the Movies a Voice." Fig. 3 shows some of the sound equipment used in this lecture. Originally intended for the benefit of one of our luncheon clubs, the demonstration has been given in three local high-school auditoriums and before many service and luncheon clubs. Its popularity has brought many attempts to book the demonstration as a standard lyceum act. As a builder of good will, we consider it invaluable. The main idea that we have attempted to carry out in our organization is to give 100 per cent projection service to the theaters and, by selling our organization to the city at large, to gain their cooperation wherever we may need it.

Our service activities do not represent a commercial or moneymaking project. We have no wish or intention to operate in competition to regularly organized service, supply, and repair agencies. Our activities are planned for the express purpose of keeping the picture on the screen as far as possible regardless of equipment and current supply failures, and to do so at reasonable cost. The following case histories are ample proof of the time saved by our emergency service system.

CASE HISTORIES

Case	Trouble	Off Sceen	Nearest Service
1	Main drive gear stripped	8 min.	4 hours
2	Speaker field burned out	25 min.	None
3	Generator completely disabled	22 min.	10 hours
4	Motor control transformer burned out	2 min.	6 hours
5	Tubes in voltage amplifier burned out by current surge	100 min.	6 hours
6	Film damage due to worn parts	(Hopeless)	

Our service facilities are not limited to this city alone, but are also available to projectionists in the many nearby small towns. However, managers in these towns who will not pay reasonable wages to their projectionists are politely informed that our assistance is limited to exhibitors who are willing to coöperate with their employees, and that a reasonable compensation to their projectionists is the surest indication of such a spirit of coöperation.

The author wishes to acknowledge the helpful criticism of F. H. Richardson in connection with the preparation of this paper.

DISCUSSION

MR. RICHARDSON: I should like to call your attention to the improvement that is gradually occurring in the class of men now engaged in projection. A few years ago there were few who could be induced to study the principles of projection. Some time ago I had the privilege of addressing the Lima Local Union on projection matters, to which meeting were invited members of unions of other cities and towns. Many of these unions were represented, although in some instances the round trip was more than 100 miles, which indicates a very encouraging improvement.

MR. EDWARDS: In speaking of managers who are generous enough to buy a spare tube and lock it in the safe, Mr. Hover assumes that that is small town practice. We have theaters in New York in which six to eight carbons are taken out of the safe in the morning and handed to the projectionist, who has to make them do for the whole day or he is out of luck.

One of the points where we need coöperation most is between the managerial staffs and the projection rooms. The coöperation is generally all from the one side, especially as regards material. On several occasions I have tried to induce the Society, through the Projection Practice Committee, to try to do something about educating the managers, but to date we have not gone very far with it.

In the majority of theaters the manager has no technical interest in projection. He takes projection as a matter of course, just as we do when you press a button to light a room in the home. It does not occur that in pressing the button we utilize hundreds of different agencies to produce that light. All we think about is that we press a button and the room lights up. Managers very largely do the same thing; their chief interest is on the lobby and the house.

MR. HOVER: To work a plan such as ours, in a small town, we must have the coöperation of the exhibitor, if only to the extent of placing a few passes appropriately. Our system has not solved the service problem. All it has done is to increase the speed with which we can get the picture back on the screen in case of stoppage. Success has been largely due to the fact that, with one exception, and that an independent house, we have had wonderful coöperation from the managers.

It is only fair to say, however, that the sound and servicing system in most of our theaters is very good. It is a fact, of course, that a breakdown usually occurs when the service engineer is elsewhere—that seldom fails; but during a period of five years, the engineer has never been called into a theater to find the picture off the screen. The show was always running long before he arrived.

A DISCUSSION OF SCREEN-IMAGE DIMENSIONS*

F. H. RICHARDSON**

Summary.—*An argument is presented for recommended standard screen-image proportions based upon the dimensions and brightness that will provide most comfortable viewing conditions at the center of the theater seating space. It proposes that such compromise would tend toward best average viewing conditions and, therefore, least eye-strain and most enjoyment for the audience as a whole.*

During past years various bodies have discussed screen-image dimensions from various points of view. Some have put forward recommendations as to what conditions might be regarded as correct for various seating arrangements. There does not appear to have been any point-by-point comparison of large and small screen images, with relation to the observer, upon which reasonable opinions as to the desirable shape and size may be formed by the exhibitor, the theater manager, or the projectionist.

For the theater audience the size of the image has a bearing on the ease of viewing the picture, freedom from visual weariness or eye-strain, and degree of enjoyment of the picture. The problem is quite complex, for the reason that from no two seats in any theater is the view of the screen the same; although it may reasonably be held that over a considerable area of the auditorium the conditions may not vary to any great extent. However, in other sections of the seating area there are very appreciable differences, often of such extent as to abuse considerably the eyes of a portion of the audience, especially if the dimensions of the screen image are not happily chosen. In average theaters the best we may hope for is greatest possible visual comfort for a portion of the audience, with as little abuse as possible for the remainder.

First of all, as is obvious, the size of image that would provide greatest eye comfort in a long auditorium for patrons seated at the front would be quite inadequate for comfortable viewing by those in the rear rows of seats. Were screen illumination kept at such value

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received August 16, 1937.

** Quigley Publishing Co., Inc., New York, N. Y.

as to afford greatest comfort for those occupying the front seats, it would not be sufficient to enable patrons at the rear to distinguish details of the picture without straining their eyes.

On the other hand, if, by virtue of either high illumination or great magnification, patrons seated, say, 125 feet from the screen were able to view the picture with ease, a poor condition would exist for those at the front. Either the illumination would be too great, thus inducing eye-strain; or the eyes would be forced to cover a wide area in following moving objects over the screen. Moreover, the image would be greatly distorted for those seated in the side front seats.

Moving the eyes to follow action over a large screen at short viewing distance may not be very important, if done intermittently or for only short periods of time. But performances nowadays last from two to three hours, with practically no relief; whence it should be evident that screen-image dimensions that are unnecessarily large should be avoided.

Another point to be considered is that as the size of the image increases, the distance at which the image appears clear and sharply defined increases also, and it seems to be important that the Society should not only establish the relation between maximum permissible magnification and front-row viewing distance, but should also impress upon exhibitors and theater managers the importance of not exceeding the limits so established. There are theaters even today in which the magnification is so great that the image is not acceptably sharp as far back as the tenth row of seats.

What is the criterion for correct screen-image size? The question can not at the present time be answered definitely, and before an answer should be even attempted, certain other factors must be examined carefully.

Ability to see is a complex of brightness and size of the object, and the distance from which it is viewed. If an object not brightly illuminated be viewed from a given distance, its finer details may not be clearly discernible. If the illumination be increased, more and more of the details will appear. But if the object be sufficiently illuminated as to appear at its best to an observer at the given distance, it will be too bright for comfortable viewing, over a space of time, for one situated appreciably nearer. If, however, the illumination remain as originally, but the object be magnified, the finer details will be more easily visible at the greater distance, but not so acceptable at the shorter one.

The matter is consequently one of compromise—between the excellence of the view and the ease of viewing at the long and short viewing distances. Unfortunately, there are theaters in which the rear seats are 150 feet from the screen and the front ones forty feet or less. Some screens with images 23 to 25 feet wide are located as close as 15 feet to the front row of seats, and not more than 75 feet from the rear seats. Such extremes can not be served simultaneously. With regard to screen illumination, perhaps the best we can do is to compromise on the value that will best serve the center of the auditorium.

Obviously, absurd conditions such as have been described must have their effect upon the box-office. Those who are in the front rows, within 25 feet of a 28-ft. screen-image, can see hardly more than an unbeautiful smudge, which does not become acceptably sharp until the viewing distance is increased to about forty feet. Patrons who unwittingly, or perhaps because no other seats are available, view the screen under such conditions, must leave the theater with strained or fatigued eyes, and the question may definitely be raised as to whether those patrons are likely to patronize the theater again unless they can be assured of seats more advantageously located.

There are other objections to large screen-images. A larger image demands more light through the projector aperture to maintain the same brightness or illumination per unit of area. Doubling the linear dimensions of a screen quadruples the area, and likewise the requisite amount of light. The electric power demand becomes greater; the difficulty of handling the arc and maintaining uniformity of illumination is increased; and the temperature at the film-gate, where the film passes the aperture, is increased. The latter fact increases the fire hazard and dries out the film, increases the likelihood of buckling, and renders the film more brittle and susceptible to damage.

Some persons favor the large image with respect to improving the visibility of details from the rear seats, especially in deep houses. Others seem to prefer a smaller image, brightly illuminated. A small screen-image may not be appropriate in a large auditorium, but the size should, on the other hand, not become excessive. Small images of the actors may seem out of proportion to the surroundings, and the actors may look like pygmies; conversely, excessively large images may appear gigantesque. We are accustomed to judge the sizes of objects by comparison with surrounding objects. If the screen-image of a man appears three feet tall, and if the surrounding objects are in the same proportion, the eye will see nothing wrong. Furthermore, the patrons become absorbed in the story and the picture, and become more or less unconscious of objects beyond the screen while projection is in progress.

In conclusion, it should be emphasized once again that it is important that the Society study this problem further, and establish a relation between screen sizes and viewing distances and angles.

DISCUSSION

MR. GOLDSMITH: The considerations advanced by Mr. Richardson merit study and certain practical conclusions. It is not possible to project upon the screen more detail than exists on the film, which fact is sometimes forgotten in projecting unduly large pictures on screens too close to a major portion of the audience. Present-day positive prints have a finely granular structure. Beyond a certain enlargement, the projected picture, if viewed fairly closely, shows crudity of outline and "crawling" (or grain-motion effect). If the picture is not sharply focused in part (as frequently happens because of the limited depth of focus of the camera objective), the effect of closely viewing a greatly enlarged picture is even less pleasant.

Probably an appropriate viewing distance for most of the audience in preferred positions lies between four and seven times the screen width; the effect of picture enlargement outside this range or of viewing the picture at a lesser distance being disadvantageous. Discretion in selecting picture size for a given theater is therefore necessary, for bigger pictures are not necessarily better pictures and may be distinctly the contrary.

MR. BRYANT: I do not think that a standard adopted by this Society would at all times work out satisfactorily throughout the world. In several theaters we have built in foreign countries, we have tried to maintain projection size in proportion to the viewing distance, but it has been impossible to do so because the patrons are not satisfied.

In South American theaters having 100- to 120-ft. viewing distances from the rear seats, we have attempted to use screens 18 to 20 ft. wide, thinking they were large enough—if anything, too large. Within three months after the opening of the theaters, we had to reconstruct our screen frames and install new screens to give the public the 24-ft. picture they demanded, by letter and memorandum to the management of the theaters. We had more than 150 requests in one theater to increase the picture size to 24 ft., despite the fact that the front row of seats was within 20 ft. of the screen, due to the fact that it was a small picture house.

MR. FARNHAM: Mr. Richardson pointed his remarks almost entirely at the theater owner. The architect should come in for his share of the criticism, because often the screen is built to fit into the proscenium arch.

A number of years ago we made some tests that indicated that the minimum desirable size of screen was very roughly one-seventh of the maximum viewing distance. There are, of course, many factors that may disturb that ratio—grain size and so forth; but the 7 to 1 ratio seemed to work out fairly well. This limit was based upon the fact that when the maximum viewing distance exceeds seven times the picture width, details in the picture became so small as to be seen only with difficulty.

MR. KELLOGG: This problem ties in very closely with the analysis Mr. Schlanger has been making with regard to proper utilization of the auditorium seating area. I do not see why theaters can not be designed so as to have larger seating capacity within reasonably satisfactory angles, and a smaller ratio of maximum to minimum viewing distance, merely by eliminating a great many of the front seats, using more or deeper balconies than at present, with greater total height at the back, and placing the screen so that the patrons in the bottom level seats will look up toward the screen at the maximum angle of comfort.

MR. SCHLANGER: The Projection Practice Committee has been doing a great deal of work toward solving this problem, and hundreds of our survey charts have been received from theaters all over the country, analyzing this very situation. As Mr. Farnham says, the architects are at fault. They build theaters to suit themselves, in any shapes that happen to please their minds, or according to the real estate they happen to buy. No consideration at all is given as to what shape of theater will provide the greatest number of satisfactory seats within the limitations of the projection system and the film. It is only now that we are beginning to realize that the building must be considered before we think of the equipment.

Mr. Farnham mentioned a ratio of seven times the width of the screen for the maximum viewing distance. The survey charts show an average ratio of 5.3, with a good proportion of the theaters far below 7. There are at least two factors to be considered in relation to screen size: One is the technical factor (film size, graininess, optical systems, *etc.*). The other, as has been mentioned, is the human element, dramatic value. Those, unfortunately, usually conflict. The only way in which we can tell how the two factors are related is by such a survey. The survey charts show the actual tendencies, taking into consideration the human factor.

PERFORATED SCREENS AND THEIR FAULTS*

F. H. RICHARDSON**

Summary.—*Certain faults of perforated screens are discussed, particularly with relation to the perforations. The question is raised as to what extent the faulty perforations, as illustrated, may be detrimental to sound and picture quality in theaters.*

Since the inception of talking pictures, the loud speakers have been placed almost universally behind the screens, into which thousands of small holes have been punched in order to permit passage of the sound-waves through the screen. The writer has a number of times taken issue with this practice, believing that as good acoustic characteristics, if not better, could be attained with the loud speakers located at the bottom, top, or sides of the screen, where structural conditions permit; and, by using solid, instead of perforated screens, the brightness of the image would be enhanced to the extent of approximately 10 per cent of the light lost in the perforations.

The loss of light has its effect not only upon the brightness of the image, but upon the cost of power; and the presence of the perforations adds to the maintenance cost because of the more rapid accumulation of dirt due to the perforations. Perforated screens become soiled much more rapidly than do solid screens. The continuous currents of air through the perforations draw with them dust and grime that deposits not only upon the inside walls of the perforations but also upon areas of the screen surface surrounding the perforations. Chemical action may be set up by these deposits that will gradually cause discoloration of the screen and render cleaning futile. The deposit, furthermore, tends to reduce the effective areas of the perforations, with a consequent effect upon the acoustic characteristic of the screen.

If we must continue to use screens that are perforated, and continue to suffer the loss of light and the detriment to quality, we should be sure that the perforations are always clean, free, and open. Ex-

*Presented at the Fall, 1937, Meeting at New York, N. Y.; received September 13, 1937.

**Quigley Publications, New York, N. Y.

amination of a number of commercial screens under a magnifying glass fails to show that even one of the screens studied has uniformly clean-cut, open perforations, although in most of the screens there is a certain proportion not subject to severe criticism. In some of the screens that are now being marketed at high prices the condition of the perforations is quite bad. Fig. 1 shows photographic enlargements of perforations of screens now being marketed.

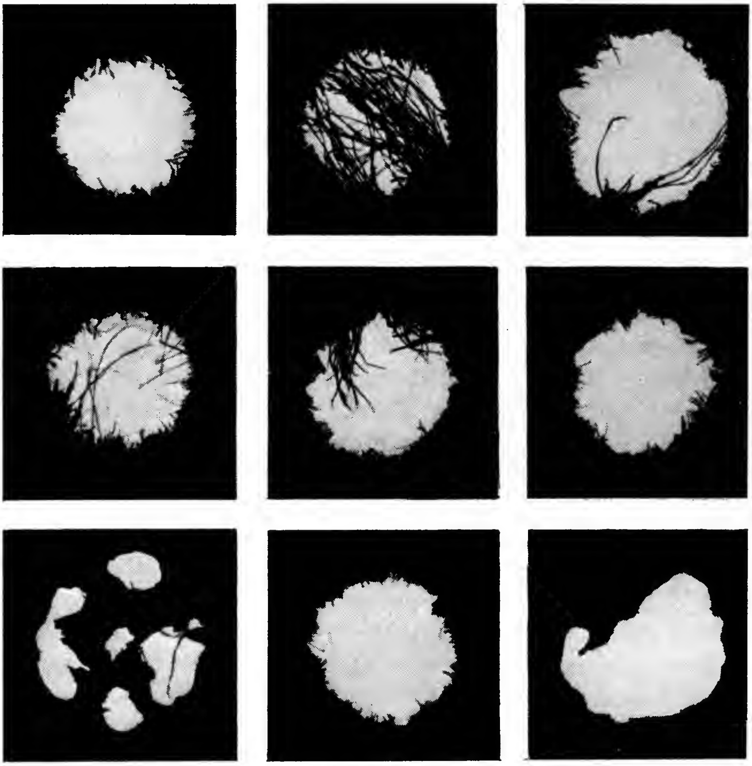


FIG. 1. Photographic enlargements of perforations.

The purpose of this paper is to bring this matter of faulty perforations to the attention of the Society, to show what variability may be expected from screen to screen, both as regards acoustic properties and image brightness, and to point out the obstructions in the perforation passages that lead to the rapid accumulation of dirt and the deterioration of the screen.

DISCUSSION

MR. MALMUTH: Briefly, the problem can not be solved by any known means, because the perforating dies are subject to the ordinary phenomenon of wearing. To make perfectly clean perforations at all times, we should have to sharpen our dies almost daily. It also happens, in all cases of screen manufacture, to my knowledge, that the perforating is not done by the screen manufacturer. There are two organizations in this country that do practically all the perforating for all the screen manufacturers. There is no possible means by which we can adequately control perforations so far as to be sure they are clean-cut.

The sound in most instances restricts the screen manufacturer to a thickness not greater than 0.015 inch, and a weight of not more than $1^3/_8$ ounces per square-foot, so that we must use what we call a 9 per cent perforation, or a hole that is 0.049 inch in diameter. In time the dies wear, until the holes become 0.051 inch in diameter and larger, and then they are discarded. When a very small pin strikes into fabric that is only 0.015 inch thick or thereabouts, the fabric gives and we do not get a true perforating action; we get a tearing action. Of course, most screens are made of cloth or fabric and coated. It is almost impossible in a fabric screen to avoid fraying or tearing at the edges when using a perforating die of the type used today.

MR. RICHARDSON: Is it not a fact that the thicker and softer the material, the greater is the tearing at the edges of the hole?

MR. MALMUTH: Most likely, but as the material is restricted to a 0.015-inch thickness, the effect will be about the same no matter what the surface is.

MR. RICHARDSON: There are some screens put out that are twice as thick as others.

MR. MALMUTH: Not perforated screens. There are woven screens that are much heavier than the requirements call for, but they are beaded. The beading fills the holes. Unless some other means of perforating is found or some other material is used for the manufacture of screens, we shall always have this condition.

COMMERCIAL 16-MM. PROJECTION FAULTS*

C. L. GREENE**

Summary.—*Because commercial motion pictures on 16-mm. film are an outgrowth of "home movies," the standards of projection are low. Less care is given to proper presentation than in theatrical showings of 35-mm. film; whereas, because of greater overall magnification, greater care should be taken. Some of the more glaring faults are treated in detail, a general treatment is set forth, and the importance of proper presentation is clarified by comparison of show-windows of the street and of the screen.*

In the rapid expansion of 16-mm. film into the commercial and advertising fields there has been a most lamentable lack of attention to the problem of achieving optimal results in projection. When the 16-mm. field was "growing up" the usual alibi, after demonstrations of highly questionable success, demonstrations "ballyhooed" as proving 16-mm. pictures the equal of 35-mm., was, "It's not so bad for 16-mm."

Now that 16-mm. pictures have been greatly improved, and apparently have retired to the field they had honorably won for themselves, one can appraise the 16-mm. technic in its own conceded field—and find plenty lacking.

This is the natural result of the 16-mm. film's being an outgrowth of the "home movies" and being sold primarily on the basis of simplicity. Never has an opportunity been missed to stress the claim that 16-mm. operation is childishly simple, and that is why the results have been, for the most part, simply childish.

To take up but a few typical items, consider first that of foreign matter in the aperture. The 16-mm. picture usually subtends an angle at the viewer's eye at least equal to that subtended by the 35-mm. picture in the theater, and since the 35-mm. aperture is four and one-half times as large as the 16-mm. aperture, the effective magnification of foreign matter in the 16-mm. aperture is $4^1/_2$ times as great as it is in the 35-mm. aperture. No more need be said as to the need for

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received September 1, 1937.

** Orpheum Theater, Minneapolis, Minn.

cleanliness, yet in the field of 16-mm. projection but scant attention is paid to it. The 16-mm. "operator," in childish simplicity, will go blithely on reel after reel with a piece of dirt in his 16-mm. aperture, to remove which from a 35-mm. aperture the professional projectionist in the theater would work like a beaver. Here is one phase of 16-mm. projection requiring the utmost vigilance over every source from which the film can pick up dirt, such as film containers, reels, work tables, *etc.* So simple a thing as picking up a reel that has lain upon a desk for a day or so and winding film upon it without first wiping it with a lintless rag or a chamois will almost certainly result in a dirty aperture. A further and permanent effect of this sort of neglect of detail will be scratches and "rain" marks on the film, and here again the greater magnification will show as glaring faults on the 16-mm. screen marks almost microscopic, which might pass unnoticed in a 35-mm. picture.

An excellent example of the tenacity with which dirt, once introduced into a system, will remain is afforded by the dirty aperture edges showing in many present-day release prints. This started with the studio strike of a number of years ago. Something happened to Hollywood at that time from which, with all its technical excellence and skill, it has not yet recovered.

There may, however, be a silver lining to this cloud. Remember how hundreds of physicians and dentists took up photography as a hobby with miniature cameras, processed their first films in the same sloppy manner as they did their *x*-ray films, and were horrified to see the results in 10 or 12× enlargements; how they reëntered the photographic kindergarten, learned how to process film properly, and then carried their new knowledge and skill back into their *x*-ray work, to its great, lasting, and much needed improvement. So, perhaps, will the distribution and exhibition branches of the 35-mm. section of the industry learn at last how 35-mm. film should be handled and cared for, by seeing upon 16-mm. screens the results of the faults in their present technic. If this happens 16-mm. experience will have conferred a genuine benefit upon the entire industry.

The aperture plates of all 16-mm. projectors should be easily removable for cleaning on both sides and behind the plate. Such safeguards are a part of the best theater projection practice. They need to be applied $4^1/_2$-fold to 16-mm. practice, not forgotten entirely. Would it be so impracticable to make the 16-mm. aperture an optical image like the scanning slit in modern sound-heads?

In spite of precautions the aperture-edge image will seldom, if ever, be clean and sharp, which renders screen masking all the more desirable; yet, not one 16-mm. picture in a hundred is masked. Again the technic is already well developed in the theater and needs only to be applied in this field.

In the same manner may be treated the matter of control of extraneous light. None that is perceptible should reach either the screen or the eye. The details have long since been worked out, and are so well known that it would be pointless to repeat them here.

To those who know the elaborate precautions professional projectionists take to keep their projector optical systems free from oil and dust, the questionable care given 16-mm. optical systems is rather shocking, and is further aggravated by the fact that most 16-mm. projectors are first-rate oil throwers. Certainly their optical systems *can* be kept in fit condition to achieve the magnification and resolution demanded of them, but more knowledge, care, skill, and *work* are required than often goes into the commercial showing of 16-mm. pictures. The old alibi "it's only 16-mm." is still in use, and still covers a multitude of sins—sins not always of the equipment. It would help considerably, however, if all manufacturers would so build their projectors that all elements in the optical train were either readily and completely accessible for cleaning or else readily removable, and those that are removable should be replaceable in adjustment; and, in the case of lenses in focus, something akin to the lens-mounts in theater projectors.

Into the commercial field, where commercial motion pictures with their own set of high and rigorous standards ought to be, "home movies" have come, bringing with them their own lamentable lack of standards. The change from 35-mm. to 16-mm. film does not automatically put all projection troubles into the discard. Rather it ushers in a whole family of new ones, faults that in a theater would send a patron post-haste to the box-office to demand a refund, but which we instead needlessly tolerate because "it is only 16-mm." The optimal presentation of 16-mm. film does not call for less knowledge, skill, care, and work than does 35-mm.; rather it calls for more. A 35-mm. projector and film neglected to the same extent as the average 16-mm. projector will show a superior screen-image.

In the word *work* is wrapped up much of the present difference between commercial 16-mm. projection and theatrical 35-mm. projection. In the former the fixed quantity is the amount of work the projectionist is willing to do; the dependent variable is the quality of projection that that much work will produce. In theatrical showings the screen-image quality is the fixed quantity, and the dependent variable is the amount of work necessary to produce that quality. Not long ago the writer overheard a conversation between a professional projectionist and a would-be one that well illustrates the point. The projector was a cheap one, and due to improper fit of the film in the upper edge-guiding assembly there was a quiver in the picture that the professional was suppressing with finger pressure. In a tone of surprise the other exclaimed, "But you're not going to hold your finger there all night." The reply was, "I'm not going to have *my* picture quivering all night." Two diametrically opposite points of view, two different conceptions of the dependent variable, they illustrate much of what commercial 16-mm. projection deserves, yet lacks.

The only advantages of 16-mm. pictures are reduction of bulk, weight, and cost. These are indisputable and powerful arguments for its adoption, but it should not be adopted under the delusion that it is childishly simple. Whenever it is so adopted the results are simply childish.

No good merchandiser ever gives a moment's consideration to any but the highest possible standards in dressing his show-windows, and with all his care it is only rarely that he creates a window that he would deem worthy of preservation as a still photograph. *Every motion picture made and used for advertising purposes is a show window that was deemed worth photographing.* It is one of those "once in a blue moon" achievements, and the projection of the film is the re-creation of the show-window with this additional condition imposed: that while those whom the merchandiser wishes to reach with his message may, and probably do, pass and repass his show-window on the street, and linger to look again, thus enabling him to correct mistakes in the original dressing and create a favorable second impression, *in advertising with a motion picture there is no second impression.* Those to whom he addresses his show-window of the screen look but once, and *they never pass that way again.* The producer will win or lose on that one effort, and that is not a childish matter.

DISCUSSION

MR. RICHARDSON: Unquestionably what Mr. Greene says contains much truth. I have seen a man buy a 16-mm. projector without knowing anything at all about projecting motion pictures; but he got out his instruction book and learned how to thread the machine almost correctly and proceeded to give a show.

MR. OFFENHAUSER: The same situation obtains in the 16-mm. field as in the 35-mm. field, as far as projection is concerned. We all know that faults exist and we all know that when they are made evident those who commit them are the ones most likely to correct them. Otherwise, such people do not continue to project pictures very long.

MR. FARNHAM: One point that could well be brought up is that of using lamps of the proper voltage. When it is realized that the output of a lamp changes 20 per cent with a change of only 5 volts, we can readily see how the projection may suffer. The professional projectionist uses meters and sees that the current is normal; but here again, as Mr. Greene says, it is "only 16-mm.," and "Let the voltage go where it will" seems to be the attitude.

MR. HOVER: The manufacturer and his salesmen furnish the users of equipment with bulletins describing the advantages of 16-mm. projection, but gives them no information whatever concerning the limitations of 16-mm. projection. Within my jurisdiction is an auditorium of 1800 seats in which 16-mm. projection equipment is installed. The screen is 14 feet wide, the projection distance 120 feet, and the lamp a 750-watt size. It is easy to imagine the kind of picture and the nature of the sound. They are using a 3-watt amplifier.

MR. TANNEY: The laboratory should not be overlooked. We have had several 35-mm. negatives reduced to 16-mm., and the results have been very uncertain. In some prints the sound is extremely fuzzy; in other prints the pictures jump considerably. How that can be remedied, I do not know, but if the laboratories would do something about it that would help the situation.

MR. TOWNSLEY: It is possible to make very good 16-mm. reductions from 35-mm. negatives, but a tremendous amount of care, skill, and work is required. There are laboratories in this country that are doing very fine jobs.

CARELESS WORK IN PRINTING*

I. GORDON**

Summary.—*Standards have established the exact location of the sound-track of motion picture film in relation to the perforations and the picture area. Numerous cases are described of prints wherein the sound-track location departs considerably from the standard. This is a source of annoyance to the projectionist and often results in faults on the screen or in reproduction.*

Examining the standards set up by the Society of Motion Picture Engineers,[1] one is impressed by the very exact placement of the sound-track with respect to the sprocket-holes and the picture area. Projectionists who must project the combined images of visual and sound effects contained in positive prints are well aware of the importance of these dimensional standards and of their strict observance in the production of prints for use in theaters.

The dimensions are expressed in thousandths of an inch, and any misplacement of the sound-track with relation to sprocket-holes is objectionable from the projectionist's point of view. The projectionist adjusts the sound-head elements that guide the film past the sound-head aperture in accordance with these dimensions; and unless they be adhered to with accuracy by the studio men, the close adjustment required will be in error exactly in the amount by which the studio misplacement is in error. If the error be sufficient, either the sound or the visual effect or both must and will suffer. Many projectionists take pride in the effects they present to their audiences, and they obviously can not produce perfect effects unless provided with films that are of themselves perfect.

Observations made during the past eight months have shown that for some reason there is serious deviation in many prints from the standard measurements. What the deviations are and how great they are are shown in the accompanying illustrations, which represent only a few of the many photographs taken in the projection room.

* Presented at the Fall, 1937, Meeting at New York N. Y.; received September 24, 1937.

** Forum Theatre, Akron, Ohio.

The photos are from prints of one large producer. The deviations from standard are sufficient to be quite noticeable in the reproduced sound in some instances; in others, very serious harm is done to the visual effect upon the screen.

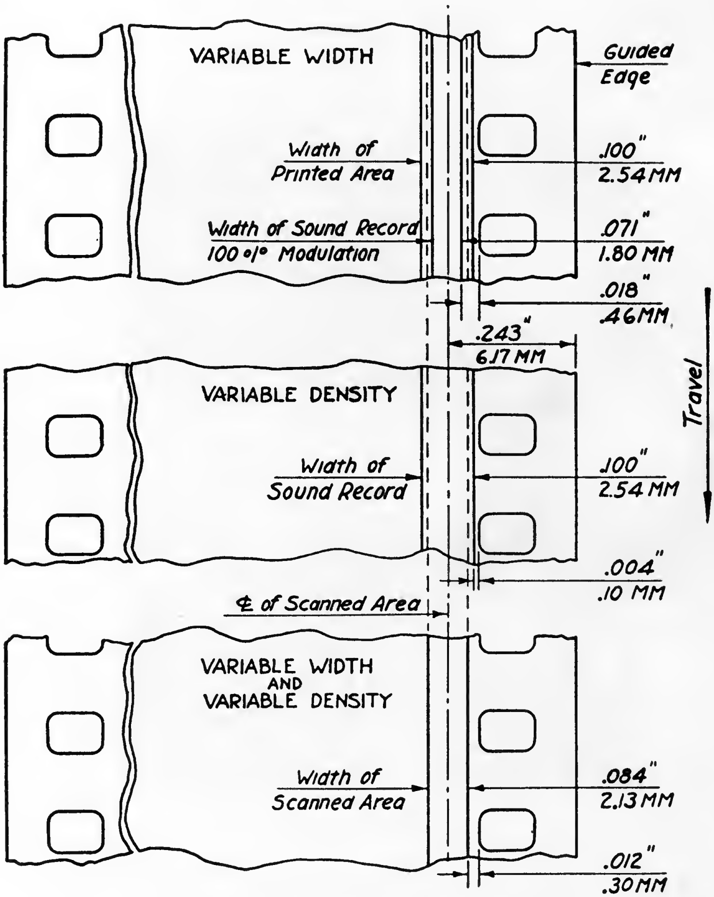


FIG. 1. Standard track position.

Fig. 1 illustrates the track position, which is the same for either variable-density or variable-width sound recording.

Fig. 2 is an enlargement of a section of sound-track of a theater release print. Whereas the standard demands that the black line at the left impinge upon the edges of the sprocket-holes, in this print the line as a whole, and a part of the sound record as well, overlaps the sprocket-holes. It is, of course, evident that this has the effect of shifting the entire track toward the sprocket-holes, leaving a broad, white line between it and the black line dividing it from the picture area.

The result of this is the pick-up of some surface noise, which is especially objectionable when the sound level is low or when a high fader setting is required. If bad enough it may induce motorboating.

FIG. 2. Enlargement showing sound-track encroaching upon sprocket-holes.

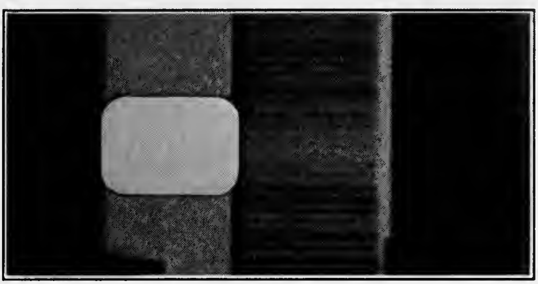


FIG. 3. Condition of Fig. 2 aggravated.

In Fig. 3 the condition shown in Fig. 2 is aggravated, and shows the frame lines jutting into the white space left between the sound-track and picture area. This causes a very unpleasant background "buzz" or hum; in fact, it was necessary with this film to displace the sound-head guide-rollers in order to cause the lines to miss the reproducing beam. Instead of an 8-mil opaque boundary line between the sound-track and the picture area, Fig. 4 shows a transparent space. Many times when shifting from one scene to another during projection this line also shifts far enough to show upon the edge of the screen as a broad strip of white light, appearing and disappearing as the scenes change. In one case this occurred three times during one reel. It was extremely annoying and highly detrimental to the visual effect. Had the line been black, the slight shift of the scene as a whole would have passed with but little notice.

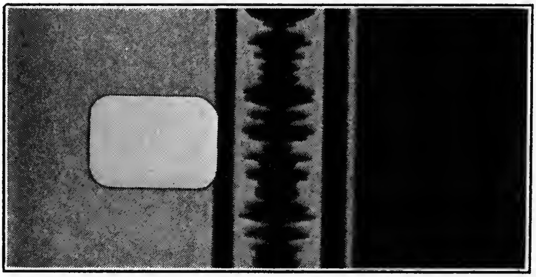


FIG. 4. Enlargement showing transparent space between sound-track and picture area.

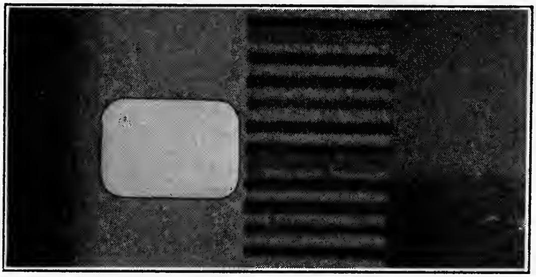


FIG. 5. Enlargement showing no separation between sound-track and picture area.

Fig. 5 illustrates the opposite extreme, where the edge of the sound-track appears upon the screen, due to the absence of any dividing space whatsoever.

Projectionists are asked to place before the public a sound motion picture—which is all this great industry has for sale, and to do so in the best possible manner. Unlike studio men projectionists are not all working in a single plant, and so can not voice their protests in a single body. They work either alone or at most in groups of two or three. They wish to present the picture and the sound in the best possible manner, and real motion picture-sound projectionists take great pride in the excellence of the effects, both visual and acoustical, that they can place before their audiences. However, excellence can not be attained unless the things requisite to attaining it are provided. Such inexcusable faults as have been shown tend to lower the standards of projection, discourage projectionists from striving for high excellence in displaying the salable wares of this great industry.

It is recommended, therefore, that the Society of Motion Picture Engineers take such steps as it may to stop producers from permitting the release of films containing such faults as have been shown here.

REFERENCE

[1] "Dimensional Standards for Motion Picture Apparatus, and Recommended Practice," *J. Soc. Mot. Pict. Eng.*, **XXIII** (Nov., 1934), p. 247. (See *Revision of Standards*, this issue, p. 267.)

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 copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in those magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C.

Communications

17 (Dec., 1937), No. 12

Instantaneous Recording Needles (p. 16). — R. H. Ranger

The Harmonic Producer (p. 19). — C. H. Bidwell

Filmtechnik

13 (Dec. 11, 1937), No. 16/17

Ernophon II mit Schnellanlauf (Ernophon II, with Rapid Starter) (p. 193).

International Photographer

9 (Dec., 1937), No. 11

New Track Standards (p. 24).

International Photographer

19 (Jan., 1938), No. 1

Agfa Introduces Two Super-Fast Motion Picture Negative Films (p. 10). — W. Stull

Make-Up Specialist Can Do Much To Assist the Cinematographer (p. 13). — P. Westmore

Engineer Discusses Requirements of True Stereoscopy in Motion Pictures (p. 14). — G. W. Wheelright

Art Reeves Shows New Ultraviolet Recorder (p. 16).

Bell & Howell Has Novel 8-Mm. Film Viewer (p. 29).

Bell & Howell Producing Four Film-on-Sound Projectors (p. 31).

International Projectionist

12 (Dec., 1937), No. 12

New Servicing Tools Needed for Visual Projection Equipment (p. 7). — A. C. Schroeder

Television Problems—A Description for Laymen (p. 11). — A. Van Dyck

Analyses of Modern Theater Sound Reproducing Units (p. 16). — A. Nadell

Some General Principles of Projection Optics (p. 20). — R. H. Cricks

Decision Rendered on Battle of Split Seconds Anent Frame Aperture Rest (p. 22).

The Elements of Vision—The Basis of Projection (p. 23). W. C. KALB

Kinotechnik

19 (Nov., 1937), No. 12

Aufgaben der Bildforschung für Film und Fernsehen (Problems in the Investigation of Subjects for Films and for Television) (p. 287). R. THUN

Stand der Tonfilmtechnik (Present Position of Sound Film Technic) (p. 290). H. WARNCKE

Motion Picture Herald (Better Theaters Section)

129 (Dec. 11, 1937), No. 11

Advantages of the New Methods of Servicing Sound Equipment (p. 29). A. NADELL

Violations of Standard Spacing in Release Prints (p. 36). F. H. RICHARDSON

Photographische Industrie

35 (Dec. 8, 1937), No. 49

Hochsdrucklampe als photographische Lichtquelle (High Pressure Lamps as a Photographic Light Source) (p. 1329). P. HATSCHEK

35 (Dec. 15, 1937), No. 50

Der neue Raumfilm, System Zeiss Ikon (New Stereoscopic Film, Zeiss Ikon System) (p. 1353).

Television

10 (Dec., 1937), No. 118

An Electronic Light Relay for Large Pictures (p. 716). W. H. STEVENS

British Television through American Eyes (p. 721).

SPRING, 1938, CONVENTION

WARDMAN PARK HOTEL
WASHINGTON, D. C.
APRIL 25th–28th, INCLUSIVE

Officers and Committees in Charge

W. C. KUNZMANN, *Convention Vice-President*
J. I. CRABTREE, *Editorial Vice-President*
G. E. MATTHEWS, *Chairman, Papers Committee*
W. WHITMORE, *Chairman, Publicity Committee*
E. R. GEIB, *Chairman, Membership Committee*
N. D. GOLDEN, *Chairman, Local Arrangements Committee*

Local Arrangements and Reception Committee

N. D. GOLDEN, *Chairman*

D. BENNETT
J. G. BRADLEY
H. T. COWLING
A. A. DETITTA
R. EVANS
N. GLASSER
C. L. GREGORY
N. C. HAEFELE
A. MUTO
R. F. NICHOLSON
W. K. PETTUS
J. A. PRATT
R. T. SCHLOSBERG
C. S. STODTER

Registration and Information

W. C. KUNZMANN, *Chairman*

E. R. GEIB
S. HARRIS
F. HOHMEISTER

Ladies' Reception Committee

MRS. R. EVANS, *Hostess*
assisted by

MRS. J. G. BRADLEY
MRS. H. T. COWLING
MRS. A. A. DETITTA
MRS. N. GLASSER
MRS. N. D. GOLDEN
MRS. S. B. RIDDICK
MRS. N. C. HAEFELE
MRS. A. MUTO
MRS. J. A. PRATT

Banquet Committee

R. EVANS, *Chairman*

J. G. BRADLEY
H. T. COWLING
A. A. DETITTA
N. GLASSER
N. D. GOLDEN
N. C. HAEFELE
W. C. KUNZMANN
A. MUTO

Publicity Committee

W. WHITMORE, *Chairman*

J. R. CAMERON
A. A. DETITTA
J. J. FINN
S. HARRIS
F. HEARON
G. E. MATTHEWS
P. A. MCGUIRE
A. MUTO
F. H. RICHARDSON

Convention Projection Committee

H. GRIFFIN, *Chairman*

N. C. HAEFELE
W. HOLZ
W. K. PETTUS
J. FRANK, JR.
J. A. PRATT
F. J. STORTY

Officers and Members of Washington Projectionist Local 224

Apparatus Exhibit

S. HARRIS, *Chairman*

J. FRANK, JR.
O. F. NEU
J. H. KURLANDER

Membership Committee

E. R. GEIB, *Chairman*

J. G. BRADLEY
R. EVANS
S. HARRIS
J. A. PRATT

Hotel and Transportation Committee

J. G. BRADLEY, *Chairman*

D. BENNETT
F. HEARON
C. A. LINDSTROM
R. F. NICHOLSON
R. T. SCHLOSBERG
C. S. STODTER

Headquarters

The headquarters of the Convention will be the Wardman Park Hotel, where excellent accommodations are assured. A reception suite will be provided for the ladies, for whom also is to be arranged an interesting program of entertainment.

By special arrangement with the Hotel Management, special breakfast, luncheon, and dinner service will be provided on the Continental Room Terrace, for SMPE delegates only.

The following daily hotel rates, European plan, are guaranteed to SMPE delegates attending the Convention:

One person, room and bath	$ 3.50
Two persons, standard bed	5.00
Two persons, twin beds	6.00
Parlor suite, one person	9.00
Parlor suite, two persons	11.00

Room reservation cards will be mailed to the membership of the Society in the near future, and those who plan to attend the Spring Convention should return their cards promptly to the Wardman Park Hotel to be assured satisfactory accommodations. Local railroad ticket agents should be consulted with regard to trains and rates.

For those who will motor to the Convention ample free parking space is available on the Hotel grounds. For those who prefer parking in the Hotel garage, a special rate of 75 cents a day has been arranged.

Technical Sessions

An attractive and interesting program of technical papers is being assembled by the Papers Committee. All technical sessions, apparatus symposiums, and film programs will be held in the *Little Theatre* of the Hotel.

Apparatus Exhibit

An exhibit of newly developed motion picture apparatus will be held, to which all manufacturers of equipment are invited to contribute. No charge will be made for space. Information concerning the exhibit and reservations for space should be made by writing to the General Office of the Society.

Apparatus displayed should be newly designed or developed, or should have features of technical interest for the engineers attending the Convention.

Registration and Information

The Convention registration headquarters will be located at the entrance of the *Little Theatre*, where all the technical sessions will be held. The members of the Society and guests attending the Convention are expected to register and receive their badges and identification cards for admittance to special evening sessions. These cards will also be honored at several *de luxe* motion picture theaters in Washington during the four days of the Convention.

Informal Luncheon and Semi-Annual Banquet

The usual informal Luncheon will be held at noon of the opening day of the Convention, April 25th, in the Continental Room of the Hotel. On the evening of Wednesday, April 27th, will be held the Semi-Annual Banquet of the Society, also in the Continental Room, at 8:00 P.M. Addresses will be delivered by prominent members of the industry, followed by dancing and other entertainment.

Motion Pictures

Delegates registering at the Convention will be supplied with complimentary passes to the following motion picture theaters in Washington during the dates of the Convention:

By courtesy of Mr. J. J. Payette: Warners' *Uptown* and *Earle* Theaters.
By courtesy of Mr. H. Meiken: *RKO Keith's* Theater.
By courtesy of Mr. C. Barron: Loew's *Capitol, Palace,* and *Columbia* Theaters.

Ladies' Committee

A number of interesting events are being planned by Mrs. R. Evans, *Hostess,* and the Ladies' Committee. On Monday, April 25th, at 5 P.M. Mrs. Franklin D. Roosevelt has kindly consented to receive the ladies of the Convention at the White House. All those who intend to be present at the reception should transmit their names as early as possible to Mr. W. C. Kunzmann, *Convention Vice-President,* at the General Office of the Society, Hotel Pennsylvania, New York, N. Y.

Recreation

The Wardman Park Hotel management is arranging for golfing privileges for SMPE delegates at several courses in the neighborhood. Regulation tennis courts are located upon the Hotel property, and riding stables are within a short distance of the Hotel. Trips may be arranged to the many points of interest in and about Washington.

Points of Interest

To list all the points of interest in and about Washington would require too much space, but among them may be mentioned the various governmental buildings, such as the Capitol, the White House, Library of Congress, Department of Commerce, U. S. Treasury, U. S. Bureau of Standards, Department of Justice, Archives Building; and other institutions such as the National Academy of Sciences, the Smithsonian Institution, George Washington University, Washington Cathedral, Georgetown University, *etc.* In addition may be included the Lincoln Memorial, the Washington Monument, Rock Creek Park, The Francis Scott Key Memorial Bridge, Arlington Memorial Bridge, the Potomac River, and Tidal Basin. Mt. Vernon, birthplace of Washington, is but a short distance away and many other side trips may be made conveniently *via* the many highways radiating from Washington.

SOCIETY ANNOUNCEMENTS

MID-WEST SECTION

At a meeting of the Section held on February 9th at the meeting rooms of the Western Society of Engineers, Chicago, Ill., Mr. H. A. DeVry of the DeVry Corporation, Chicago, presented a paper on "A New Mechanical Movement Developed for a Framing Device for the 35-Mm. Projectors." The meeting was well attended and an interesting discussion followed the presentation.

The next meeting of the Section is scheduled for March 15, 1938.

ATLANTIC COAST SECTION

The regular monthly meeting of the Section, held on February 23rd, took the form of a visit and tour through the laboratories of Consolidated Film Industries, Inc., at Fort Lee, N. J. The members were conducted through the plant in groups under the guidance of a member of the laboratories, who explained the various features of the equipment and processes. The meeting was very well attended and considerable interest was indicated by the number of questions put to the guides by the members.

PROJECTION PRACTICE COMMITTEE

At a meeting held at the Paramount Building, New York, N. Y., on January 20th, much consideration was given to the condition of release prints received at theaters, and a sub-committee was appointed for the purpose of looking into the questions of lack of transparency of numbers on Standard Release Print Leaders, which makes it difficult to thread film in frame without a framing light; the occurrence of change-over marks at beginnings of fade-outs instead of at the middle, or of numbering the footage on the leaders from the point where the picture appears after fade-in rather than from the start of the fade-in; out-of-focus prints; and feature films running less than sixteen minutes each.

Other discussion revolved about difficulties with edge-waxing; condition of 2000-ft. metal reels; the use of a noise-level meter for monitoring sound in theaters; and of correct film tension during projection.

Interim reports were presented by the Sub-Committees on Theater Structures, and Projector Output and Screen Illumination, and the following definitions were approved by the Projection Practice Committee:

"A *projectionist* is a qualified person professionally in operating charge of motion picture projection equipment."

"A *projection room* is a suitably arranged and protected enclosure wherein is placed motion picture projection equipment for professional use."

The next meeting of the Committee is scheduled for February 17, 1938.

ADMISSIONS COMMITTEE

At a recent meeting of the Admissions Committee, at the General Office of the Society, the following applicants for membership were admitted to the Associate grade:

BLANCH, R. C.
Cinesound Productions Pty., Ltd.,
Bondi Junction, N. S. W.

BLEAKLEY, L. M.
2027 Bleury St.,
Montreal, Canada.

COONEY, J. R.
The Knoll,
Waldoboro, Maine.

DUSTIN, E. J.
105 Maryland Ave.,
Palmyra, N. J.

FELDMAN, H. A.
2412 Cortelyou Rd.,
Brooklyn, N. Y.

HAGEN, P. A.
4518 N. Clarendon Ave.,
Chicago, Ill.

HAMILTON, P. M.
Dufaycolor, Inc.,
30 Rockefeller Plaza,
New York, N. Y.

HARDENBERG, J. J. C.
Philips Glowlamps Works,
Eindhoven, Holland.

HARRALL, R. F.
8120 Merrill Ave.,
Chicago, Ill.

HOLT, L. J.
5029 Tennessee Ave.,
St. Louis, Mo.

JANECZKA, H.
Burggasse, 67,
Vienna VII, Austria.

JONES, W. W.
RCA Manufacturing Co.,
Camden, N. J.

KATZ, L. J.
905 Clark Building,
Pittsburgh, Penna.

KATZ, W.
311 W. 44th St.,
New York, N. Y.

LEBOW, S. S.
862 E. 169th St.,
The Bronx, N. Y.

LONG, J. R.
1514 McCormick Ave.,
Washington, Indiana.

MOLE, J. E.
3847 Randolph Ave.,
Oakland, Calif.

MUGLER, C. M.
Acoustical Eng. Co.,
8461 Melrose Ave.,
Los Angeles, Calif.

ORSINGER, W. P.
2060 Fargo Ave.,
Chicago, Ill.

SERRANO, F. J.
Av. Neuvo Leon 68,
D. F., Mexico.

SEUBERT, C. A.
4913 N. 13th St.,
Philadelphia, Penna.

SHEPHERD, W. H.
67 Barrington Ave.,
Hurstville, N. S. W.

SINKEOWITCH, M. G.
4846 Rosewood Ave.,
Hollywood, Calif.

SMITH, R. C.
National Carbon Proprietary, Ltd.,
P. O. Box 24, Mascot, Sydney,
Australia.

SOHOR, P. H.
1393 Lexington Ave.,
New York, N. Y.

STANTON, J. M.
424 Patterson Building,
Denver, Colo.

THAYER, E. M.
6719 Templeton St.,
Huntington Park, Calif.

VAN WEYENBERGH, G.
55 Rue Vifquin,
Brussels, Belgium.

WARE, H. R.
844 6th Street,
Portsmouth, Ohio.

WENTKER, F. W.
37 Evergreen Lane,
Haddonfield, N. J.

In addition, the following applicants have been admitted by vote of the Board of Governors to the Fellow and Active grades:

ALBRECHT, R. M. (*M*)
2922 Davenport Ave.,
Davenport, Iowa.

BEAL, R. R. (*F*)
Radio Corporation of America,
30 Rockefeller Plaza,
New York, N. Y.

CARTER, C. C. (*M*)
Filmcraft Laboratories,
35 Missenden Road,
Camperdown, N. S. W.,
Australia.

DEMMER, A. H. (*M*)
111 Chestnut St.,
Audubon, N. J.

FARNSWORTH, P. T. (*M*)
Farnsworth Television Inc. of Pa.,
127 E. Mermaid Lane,
Philadelphia, Penna.

HANSON, O. B. (*M*)
184 Compo Rd.,
Westport, Conn.

IVES, C. E. (*M*)
Eastman Kodak Company,
Rochester, N. Y.

MURRAY, A. F.
Haddonfield Manor,
Haddonfield, N. J.

RUSSELL, C. L. (*M*)
5512 Mullen Ave.,
Los Angeles, Calif.

SHARP, E. R. (*M*)
2302 Scott St.,
Davenport, Iowa.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXX **APRIL, 1938** **Number 4**

CONTENTS

JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

Subscription to non-members, $8.00 per annum; to members, $5.00 per annum, included in their annual membership dues; single copies, $1.00. A discount on subscriptions or single copies of 15 per cent is allowed to accredited agencies. Order from the Society of Motion Picture Engineers, Inc., 20th and Northampton Sts., Easton, Pa., or Hotel Pennsylvania, New York, N. Y.

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

Publication Office, 20th & Northampton Sts., Easton, Pa.

General and Editorial Office, Hotel Pennsylvania, New York, N. Y.

West-Coast Office, Suite 226, Equitable Bldg., Hollywood, Calif.

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

A MODERN MOTION PICTURE LABORATORY*

C. L. LOOTENS**

Summary.—*A description of the new laboratory of Consolidated Film Industries, Inc., at Hollywood, Calif., completed during the winter of 1936–37. Included are lay-outs and illustrations of equipment on several of the floors. The description of the laboratory and equipment follows the sequence of negative development, dailies, master and release printing, together with a description of the special printers, processing units, chemical system. silver-recovery system, and other mechanical items of interest.*

The lay-out of the various buildings constituting the new Consolidated Film Laboratory at Hollywood, Calif., is shown in Fig. 1. A photograph of the Seward Street elevation of the laboratory and service building is shown in Fig. 2. The laboratory proper is constructed of reinforced concrete, and all laboratory workrooms in which film is handled are provided with ceiling explosion vents, which in case of fire automatically open for the escape of gases. In the daylight workrooms, the vents are provided with frosted glass for skylight illumination. In the darkrooms, the glass is made opaque. In case of explosion the glass will break, allowing the gases to escape. In order to minimize the problems of air-conditioning and cleanliness, no windows are provided in the laboratory proper, all daylight being obtained through the glass in the explosion vents. Emergency exits are placed at strategic locations in all workrooms. All rooms in which film is handled are completely air-conditioned by means of an adequate refrigerating and air-conditioning system.

In laying out the developing machines it was felt that a machine that could be used for either negative or positive development would conserve floor space and render greater flexibility in the kinds of work each machine could produce. The developing machines were therefore provided with individual negative and positive developing sections. The same hypo and water sections and drying cabinets

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received October 8, 1937.

** Republic Productions, Inc., North Hollywood, Calif.

were used for both types of film. Since the completion of the laboratory these arrangements have worked out very satisfactorily, due to the fact that on peak loads of positive or negative all machines can be used for the kind of work required.

The workrooms necessary for preparing the film during printing and developing were arranged around the developing room, so that the film could travel from room to room in accordance with the normal sequence of operations. This reduced the floor space required by the laboratory. All mechanical equipment was placed in a full-sized basement, an arrangement which resulted in a minimum of piping and air-conditioning ducts.

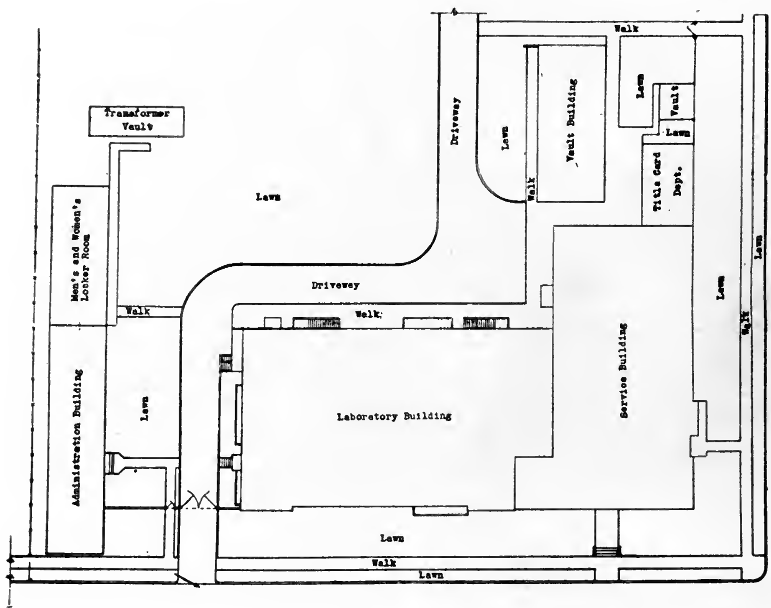


FIG. 1. Plot plan of laboratories of Consolidated Film Industries, Hollywood.

Projection rooms, tinting and toning machines, and miscellaneous offices are grouped on the first floor of the service building. Cutting rooms, title and optical department, and a third projection room are located on the second floor. Detailed lay-outs of all workrooms, together with the major equipment, are shown in the floor plans, Figs. 3, 4, and 5.

By referring to Fig. 3 it will be seen that the laboratory was laid out to minimize the handling of film between operations. Positive raw stock is received at the loading platform shown on the upper left-hand side of Fig. 3. The film is unboxed and passed into a positive storage vault, where it is stacked according to the types of film in standard vault racks. Adjacent to this vault is a negative mounting room, which contains steel tables with linoleum tops, on which are mounted specially designed flange rewinds.

The printing room is equipped with standard Bell & Howell printers which are adjustable for sound-track, standard picture, and full aperture printing; Cinex testing machines for making positive tests from negative scenes; and duplex color printing machines for printing bi-

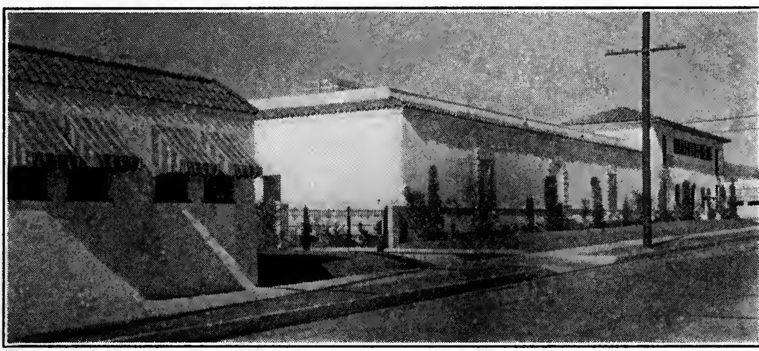


FIG. 2. Exterior view.

pack negative on double-emulsion positive film. A Duplex printer equipped with pilot pins is provided for registration and process prints. For conveniently handling the negative and positive film cans, individual racks are located at each printer.

Adjacent to the printing room is a sound-track mounting room equipped with steel linoleum-topped tables. In this room the negative sound-track is inspected for mechanical defects, and track tests are pulled and mounted for developing. An Eastman II*B* sensitometer is also located in this room for making all sensitometric exposures. The corridor adjacent to these rooms is provided with negative and positive safelights. The main corridor at this end of the building is dimly lighted so that there is no danger of fogging undeveloped film.

Six developing machines are installed in groups of three, each group being located in a separate room. Both developing rooms are equipped with negative and positive safelights. The outside developing room is primarily used for negative action development, while the inside room is used for negative sound-track development. Inasmuch as the continuous printers are located in the inside room, practically all dailies and master prints are processed in them. The machines in the outside room are also used for developing positives printed in the printing room. In case of peak loads it is possible to develop action

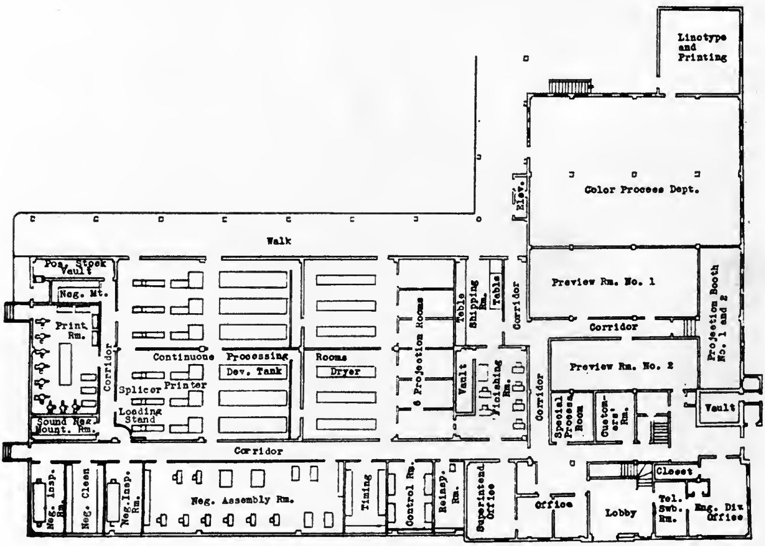


FIG. 3. First-floor plan.

negative or sound-track negative in all six machines. It is, of course, the normal procedure to use all six machines for positive development. A passageway between the developing room and the drying room serves as a light-lock, a feature making it possible to operate the drying cabinets in white light.

A negative cleaning room and two rooms each equipped with an inspection drum are located adjacent to the main corridor. The negative cleaning room is provided with steel linoleum-topped tables with rewinds mounted on the tables so that the film may be wound by hand and drawn through a cloth saturated with a high-test cleaning fluid. A vacuum pipe immediately back of the film draws away the fumes of the cleaning fluid and assists in the evaporation of the fluid from the film. The inspection rooms are equipped with large inspection drums $4^1/_2$ feet in diameter and 9 feet long. Each inspection drum is driven by an electric motor having an electromagnetic brake that will stop the drum within an angle of about 30 degrees. A foot treadle extending the entire length of the drum and within easy reach of the operator is provided so that the drum may be started or stopped at will. Adequate lights are placed above the drum so that it is possible for inspectors to detect the slightest abrasion of the film. All negative film is wound on these drums and inspected for mechanical

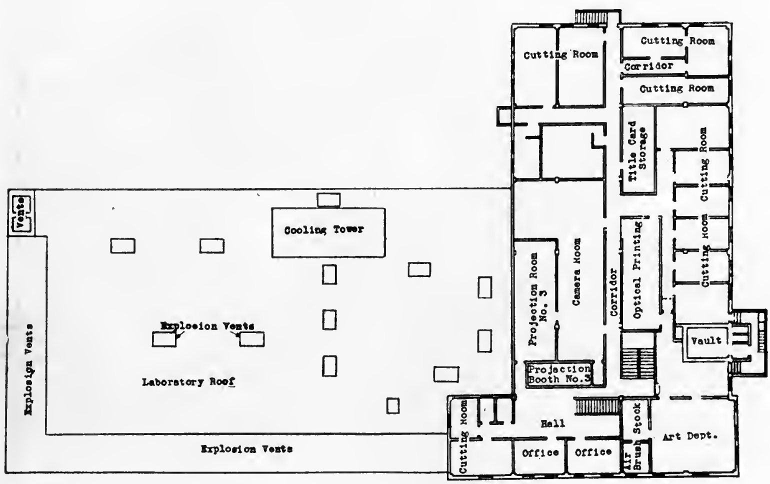


FIG. 4. Second-floor plan.

defects, a procedure that is followed for all negative entering and leaving the laboratory.

Adjacent to these rooms is a large negative assembly room (Fig. 6), at one end of which are located large steel linoleum-topped tables where newly developed sound-track and action negative is inspected. At the same time the "no print" or *B* negative is removed from the negative rolls, after which the "print" or *A* negative is passed to the splicing tables at the other end of the room, where the various negative scene rolls are assembled into 1000-ft. rolls in preparation for printing dailies or rushes.

The splicing tables are of desk design and are made of steel with linoleum tops. The splicers are of the standard Bell & Howell type, provided with specially designed lighting fixtures for proper inspection and assembly of the negative. Coding machines for foot-numbering assembled negatives are also provided. One coding machine is designed to number both edges of the negative in one passage through the machine.

A negative timing room is adjacent to the negative assembly room. This room is equipped with two light-boxes approximately sixteen feet long. Negative test-strips and Cinex positive test-strips can be laid on these light-boxes and inspected and timed.

Next to the timing room is located the control room, which is pro-

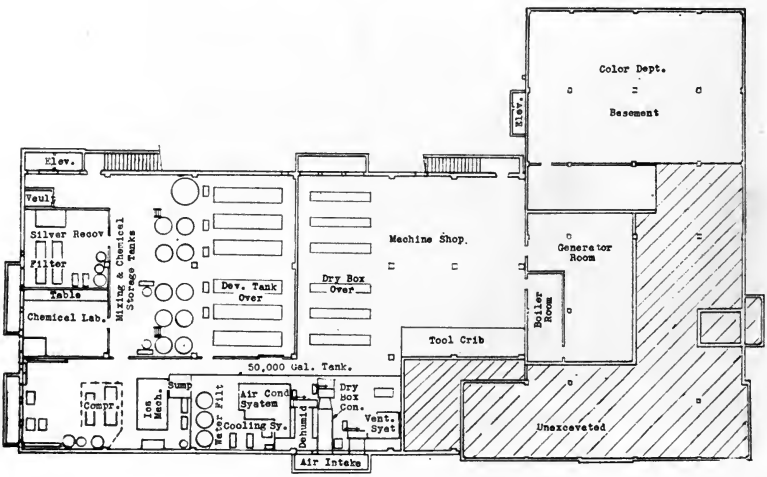


FIG. 5. Basement plan.

vided with densitometers, microscopes, and a wall panel of recording and indicating instruments. From the readings obtained in this room the functioning of machines and processes in the laboratory can be determined. Fig. 7 shows the large meter panel on which all recording and indicating instruments are mounted. In the top row are four Leeds & Northrup indicating temperature recorders for the developing solutions and a temperature recorder for hypo. The developing solution instruments indicate and record within 0.05 degree Fahrenheit. In the lower row from left to right are: a Leeds & Northrup 12-point recorder for wet- and dry-bulb temperatures of the six drying cabinets; a recorder for temperature of wash water; an indicating gauge for air-pressure; a recording voltmeter for the printing lamp generator; an indicating gauge for steam pressure; a recorder for temperature of ice-water used for air-conditioning and solution cooling; and a Leeds & Northrup 6-point recorder for the film speed of the developing machines.

By again referring to Fig. 3, it will be noted that six projection inspection rooms are located at the end of the drying cabinets. In these rooms are located continuous projectors provided for projecting the positive film as it leaves the drying cabinets. By means of conveyors the inspected film is passed into an automatic stacking machine located in the positive finishing room. This room is equipped

FIG. 6. Negative assembly room.

with table-type splicers similar to those in the negative assembly room. A storage vault is located next to the finishing room, for storing film between operations. A shipping room is adjacent to the finishing room.

Two preview rooms are located near the shipping room. One of these rooms is equipped with RCA projectors and sound equipment (Fig. 8), while the other room is equipped with Powers projectors and Western Electric sound equipment. The former room has a large screen for reviewing master prints; the latter has two smaller screens so that the two machines may be run simultaneously for the inspection of dailies.

Engineering and laboratory superintendent's offices and rooms for customers' men are located on the first floor (Fig. 3). Adjacent to preview room No. 2 is a film-treating room for removing celluloid scratches from negative or positive film. A machine specially designed and patented to accomplish this on action negative that has been scratched on the celluloid side, provides effective resurfacing so that the scratches will not show when either a contact or an optical print is made.

The susceptibility of green film to scratches and abrasions is common knowledge. A protective treatment for toughening and lubricating the emulsion, enabling it to resist scratching as well as or even better than thoroughly seasoned film, has been developed in the research

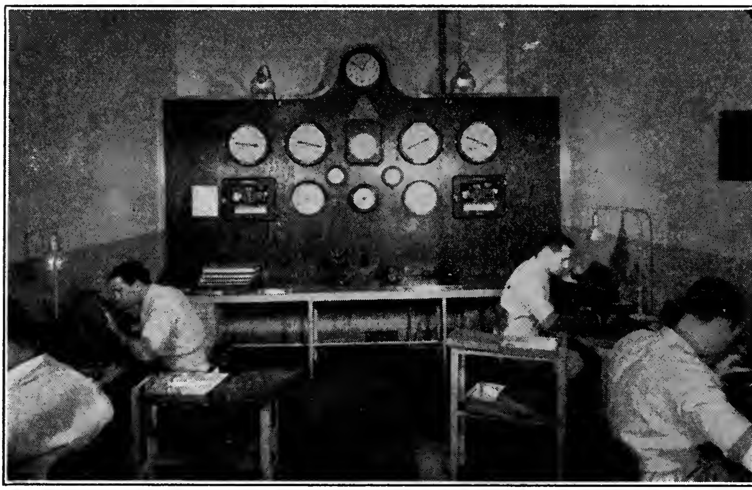


FIG. 7. Control room.

laboratories of the company at Fort Lee, N. J. In the case of positive prints, it has been found that film treated by this process survives its early bookings with appreciably less damage to the emulsion than untreated film. Negative film that has been subjected to the protective treatment may be handled, cleaned, and spliced with less chance of scratching or abrading the emulsion. The processing fluid is applied to the film either in the drying cabinets of the developing machines or in a special machine as an after-treatment. Application is by means of a cloth-covered roller rotating slowly in a direction opposite to the travel of the film.

A completely equipped plant for manufacturing color-prints (Magnacolor) is situated in the west wing of the first floor (Fig. 3). Positive film sensitized on both surfaces is used in this process, the color record of each component of a bipack negative being exposed on either side.

After ordinary black-and-white development, the double-coated print is converted into a color picture by dye-toning the side printed from the front element of the bipack with an orange dye and converting chemically the other image into a transparent blue image. The machines used for the production of color-prints are readily converted into toning machines for producing the recently revived tinted and toned effects such as sepia and blue tones.

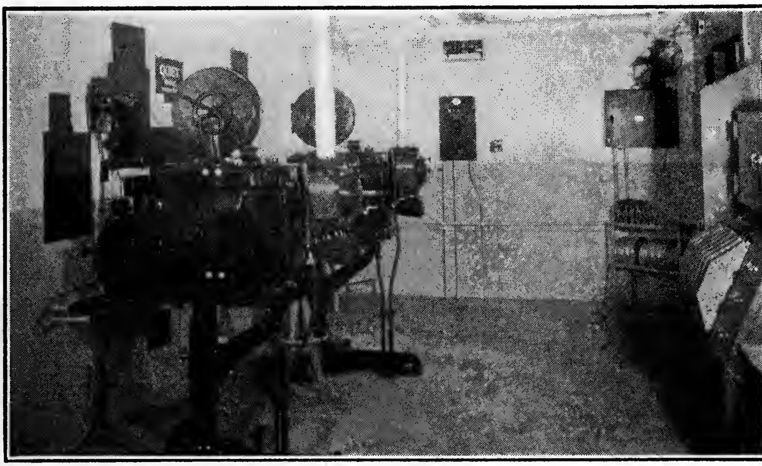


FIG. 8. Projection room No. 1.

Work is usually routed through the laboratory in the following sequence: Undeveloped negative is received and checked in the shipping room. The film is then transported to the negative mounting room, where it is inspected by hand for mechanical defects and tests are detached from the negative rolls. The tests are then mounted on reels and passed to the developing room. There they are developed at standard negative developing time, after which they are taken to the timing room where they are inspected by the customers' men, who make any changes in negative development time necessary. The negative rolls in the mounting room are then assembled according to the corresponding development times and the negatives developed. The rolls are taken from the drying cabinets of the machines and are moved to the negative breakdown tables, where "print" and "no print" scenes are separated. The "no print" scenes are placed in cans and delivered to the respective studios. The "print" scenes are assembled in numerical sequence in the negative assembly room, whence they are sent to the printing room where Cinex test prints are made from a section of each scene. The Cinex test prints are then developed and taken to the timing room, where they are separated and placed on the timing table. The timer then reviews the test prints and assigns the proper printing light for each scene. While the Cinex test prints are being developed, the negative roll is sent to the inspection room where it is placed upon an inspection drum and inspected for mechanical imperfections. After inspection, the negative is thoroughly cleaned and placed into cans awaiting the timing control strips for the printers. When the timing control strips are available, the negative rolls are sent to the continuous processing machines, where they are printed and the positive developed. The positive print is inspected on the continuous projector and the film is then sent by conveyor to the finishing room.

After the positive has been assembled properly, it is then available for projection in the review room by customers' representatives. After the review inspection the film is sent back to the shipping room.

All dailies, master, and release prints, with the exception of small re-orders and replacements, are handled by the continuous processing machines, into which raw stock is fed at one end and from which, forty minutes later and without a stop, a perfectly inspected print is available at the other end. This process continues at the rate of more than 6000 feet per hour per machine. The continuous processing machines combine into one operation printing, developing, fixing, washing, drying, and projecting finished prints. The machine consists of specially designed unloading cabinet, splicer, and loading elevator which enable an operator to splice on successive rolls of raw stock, permitting the raw stock to pass to a printing machine as a continuous strip. By means of a specially designed printing machine, the picture and sound-track are printed continuously on the positive raw stock. The printer is designed to operate at a higher speed than the developing machine, so that at the end of each negative reel the printing machine can be stopped to change negatives. Because the printing machine runs faster than the developing machine, a continuously running film-storage elevator is provided between the printing machine and the developing machine. While the printing machine is running, the elevator accumulates the excess film between the printer and and developing machine. While the printer is stopped for rethreading negative reels, the developing machine draws film from the continuously running storage elevator. By this means, the developing machine is provided with a continuously running strip of film, and time has been allowed for the printing operator to stop the machine for changing negatives. The developing, fixing, washing, and drying are accomplished in an improved type of Spoor-Thompson developing machine.

At the discharge end of the dryer, a continuously running film-storage elevator is provided so that film may be passed through it to a projector where an operator projects and inspects the finished positive. The projector operates at a higher speed than the developing machine, so that when the projector is running, the excess film is provided by the storage elevator, a condition allowing time for the operator to stop the projector and examine the film by hand for mechanical defects. It also provides sufficient time for him to stop at the end of each reel of film and break the film at the start of successive reels. The reel of film is then placed into a can and sent by conveyor to the finishing room.

The loading stand consists of two 2000-ft. magazines for loading raw stock. Each magazine is equipped with a signal bell to indicate when the roll of film has reached 200 feet. At the end of each roll of raw stock the next roll is spliced on a standard Bell & Howell splicing machine. In order to feed the raw stock continuously to the printer, a loading elevator is released, allowing excess film to be taken up on the elevator. The capacity of the elevator allows one minute for splicing, during which time film is supplied to the printers by the elevator. A synchronizing mechanism between the elevator and the splicer guarantees that splices are made on frame lines.

The Consolidated continuous automatic printer (Fig. 9) is of the unit design type, each unit complete in itself and each printer requiring a picture head, non-slip track head, two control-strip units, two light-changer units, two light-changer electrical control units, six positive and negative cleaners, and four take-up units. All units are mounted on a main welded steel plate body frame containing the driving mechanism for the various units.

The printing machine is reversible for forward or backward printing, so that it becomes unnecessary to rethread the negative reels when printing successive prints of the same negative. The picture

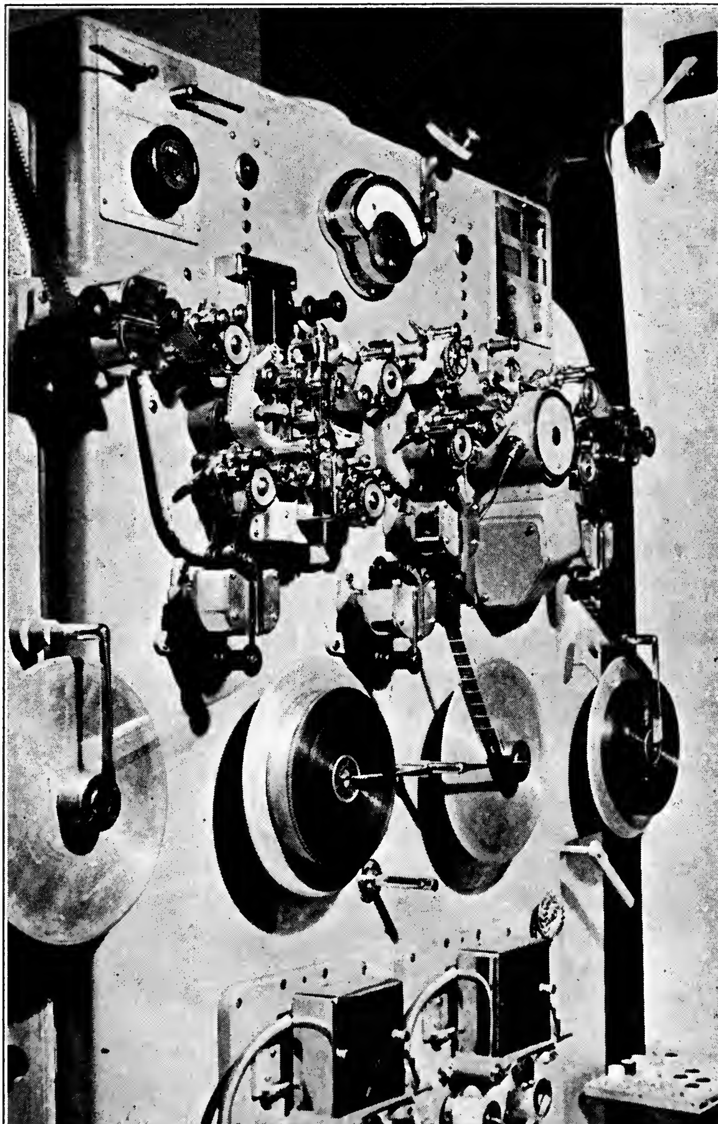


FIG. 9. Automatic printer.

head is a Consolidated high-speed continuous printing head, with sprockets cut with the utmost precision. A special printing gate assures perfect contact and no reflection, while a narrow printing aperture produces increased definition. A high-intensity mercury-vapor lamp is used as the printing light-source, with a special filter in the picture-head optical system that produces the same contrast on highlights and lowlights.

The track head is designed on the non-slip principle. The light-source used for the picture head is also used for the track head. A choice of filters in the track head optical system permits ultraviolet

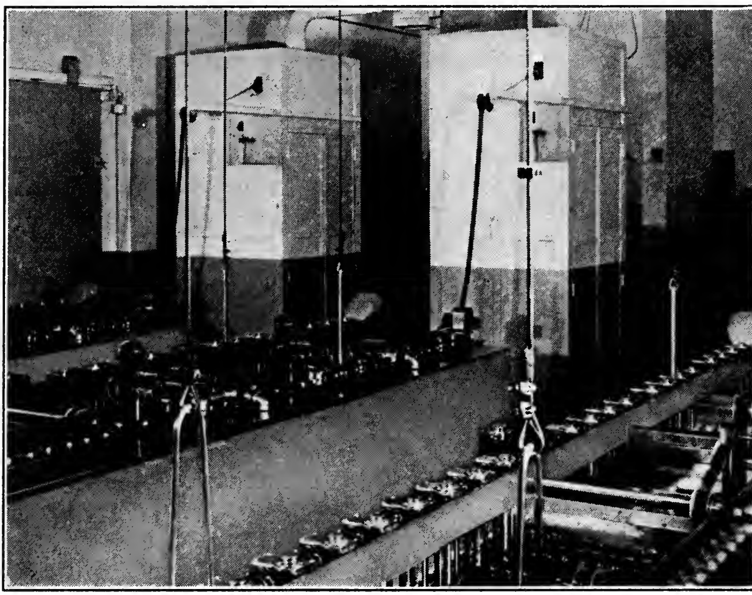


FIG. 10. Developing machine.

as well as white-light printing. Faithful reproduction of negative recording is accomplished through non-slip, high-pressure contact printing. A separate positive and negative guiding system at the track-printing aperture allows regulation of track placement. Elimination of printer flicker and sprocket flutter is accomplished by a carefully designed mechanically filtered drive and properly sized loops of film, between the negative feed and hold-back sprockets and printing apertures. All track negative splices are automatically blooped with a bloop of controllable length and taper.

The automatic light-change operates from a control film-strip. By punching the proper combination of holes in the control film-strip, the proper aperture can be inserted automatically into the optical system, thus controlling the printing-light intensity. Dual negative contactors provide a positive check on the operation of the light-changer, and automatically stop the printer in case of trouble. A complete signal-light system informs the operator of any irregular operations of the machine.

The operation of the machine is entirely automatic. The negative, raw stock, and control-strips are threaded by the operator. All film is threaded tightly over loop-setting rollers, and when the machine is started the loop rollers are automatically set in the operating position by a solenoid-and-link system. After the operator threads the machine he pushes the starting button and does not again touch the machine until it automatically stops at the end of the reel. A one-way drive clutch makes it possible for the take-ups to act alternately as take-ups and take-offs. Their driving tension is adjustable and the flanges used are "floating" so that the energy of their rotation has no effect upon the film. This insures a very "soft-acting" take-up. Pressure and vacuum cleaners keep the negative and raw stock speck-proof. The cleaners are located so that all negative and raw stock is vacuum cleaned before passing over the printing apertures in either direction.

To eliminate all extraneous mechanical oscillations a separate motor is used to drive the two printing heads. The take-ups and control-strip units are driven by the main motor and transmission. The power supplied to the printer is 120-volt d-c. for relay control of the automatic light-changer; 500-volt d-c. for the mercury-vapor printer lamp; and 220-volt, 3-phase a-c. for the motor drive and control.

To allow the operator time to rethread the printer after each print and maintain continuous development, a printing elevator is located between the printer and the developing machine. The printer operates at a speed of 180 feet a minute, whereas the speed of the developing machine is between 110 and 130 feet a minute. While the printer is running the elevator takes up the excess film and discharges it to the developer when the printer is stopped. During this time the elevator stores up approximately 350 feet of film while the printer is running, allowing $2^1/_2$ to 3 minutes for changing negatives.

The developing machine (Fig. 10) is an improved Spoor-Thompson type. It is constructed of stainless steel throughout, including the solution tanks. The machines consist of two tanks for negative development, one tank for positive development, a stop-bath tank, a hypo tank, and a wash-water tank with partitions for counterflow washing. The wash tank is also equipped with water jets for spray washing. Either of two negative developing solutions or two positive developing solutions may be used, and the circulation piping is such that a solution may be drained out of one tank and replaced by a different solution in eight minutes. Rubber squeegees remove excess solution from the film as it travels from one tank to the next. The machine is driven by a Link-Belt *P. I. V.* drive with a control for changing speeds at the developing end of the machine. A Weston generator and tachometer indicates the speed at which the film is travelling and records it on a Leeds & Northrup 6-point Micromax recorder on the control room board. The film passes over and rotates a rubber roller that is exactly one foot in circumference and is connected to the Weston generator. A signal system also connected to the generator flashes a light and rings a bell, calling the attention of the operator to a break in the machine so that it can be fixed without loss of film in the developer. A Shepard-Niles electric hoist is attached by cable to the machine to lift the entire mechanism out of the tanks for inspection. At the end of the wash tanks the film passes through a partition out of the darkroom into the drybox room.

The film entering the drybox passes through a vacuum type squeegee which removes excess water from the film. The drying cabinet drive is part of the developer transmission system. A film-waxing and emulsion-processing unit is located in the projector elevator which is the fourth compartment of the drying cabinet. Here the film may be waxed or processed as required, with enough drying time in the projector elevator to evaporate the processing fluid. The film is projected at 165 feet a minute, and the projector storage elevator allows the inspector to stop the projector for examining the film by hand and placing the reels into cans. The projector elevator (Fig. 11) is also equipped with an improved type of "comealong" and film take-up in case it becomes necessary to take up the film without projecting. The film, on leaving the drying cabinet, passes through two fire-traps on its way to the projector. One trap is located at the end of the drying cabinet and one in the projection room wall. In case of fire in the projector an electrical contact energizes a solenoid in the fire-trap and releases a sharp blade, which cuts the film at the projection room wall and at the drying cabinet, thus preventing fire from travelling from the projector to the cabinet. The continuous projector (Fig. 12) consists of a Simplex double-pin intermittent mechanism mounted upon a specially designed table and equipped with an individual motor drive. A 400-watt projection lamp is used with a reflector and Bausch & Lomb condenser assembly *41-26-13*. The lamp house is cooled by a 2-inch 3400-rpm. fan. A $2^1/_2$ *E.F.*

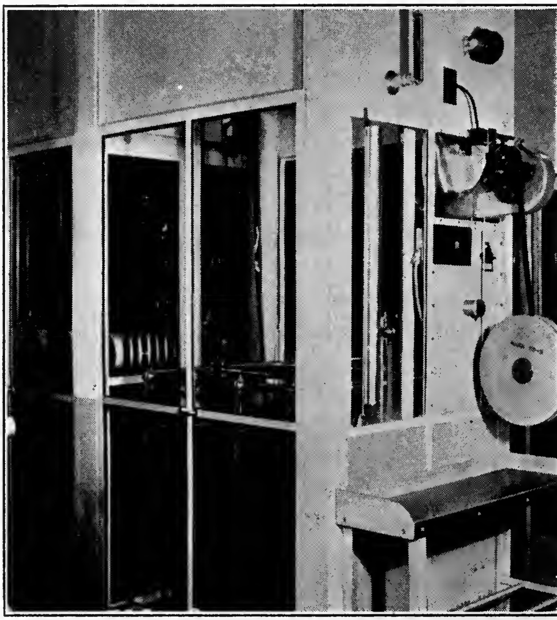


Fig. 11. Drying cabinet.

lens is used having a throw of 12 feet. A roller conveyor system transfers the inspected reels to the finishing room where a vertical can-stacker automatically stacks the cans.

The basement floor plan, Fig. 5, provides space for the chemical laboratory, chemical mixing and circulating systems, silver recovery system, refrigeration, air-conditioning and ventilating systems, film-drying system, temperature and pressure controls, compressors, printer generators, water filters and softener, machine shop, boiler room, and generator room.

There are four developing baths: action negative, variable-density sound negative, variable-width sound negative, and positive print. Each of the four developing baths circulates from a 1000-gallon tank through a stainless steel heat interchanger to the developing tanks on the first floor.

By means of an automatic air-operated motor valve, circulation rates of 25 gallons a minute for positive and 50 gallons a minute for

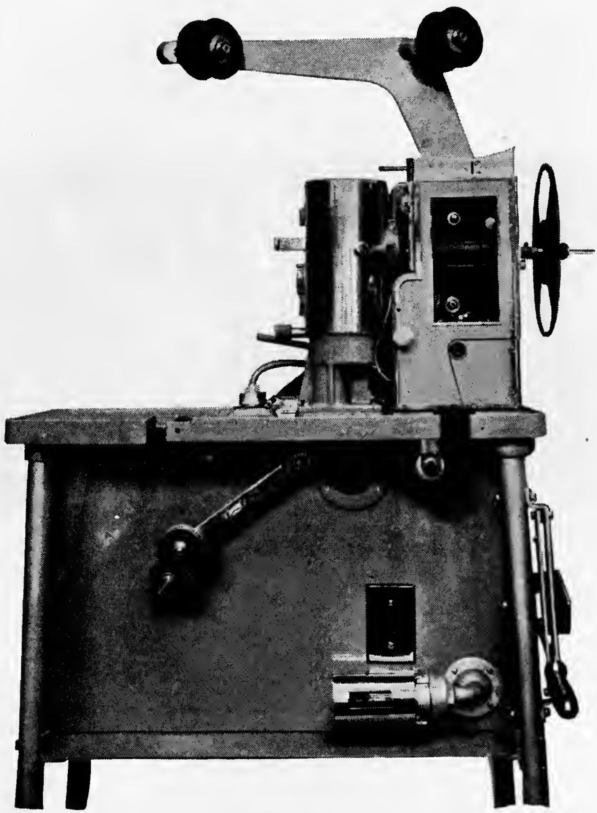


FIG. 12. Continuous projector.

negative, per machine, are maintained regardless of the number of machines open for circulation. This unusually high rate of circulation makes possible a nicety of temperature control seldom encountered in industrial processes. The Taylor Instrument Co. control mechanism limits temperature variation to a value or range not exceeding 0.1°F, as indicated and recorded by a Leeds & Northrup Micromax recorder in the control room.

All piping in the developer circulation system is of hard rubber, and all parts of a LaBour centrifugal circulating pump that come into contact with the solution are of lead or *G-60* steel alloy. A spare 1000-gal. tank is also connected with each system to provide storage for new developer which may be mixed in advance. The chemicals are dissolved in a 120-gal. Pfaudler glass-lined mixing tank with built-in stirring propeller. Two mixing tanks have been provided, one for the two low-alkaline developers and the other for the two high-alkaline developers. Two high-capacity stainless steel heat inter-

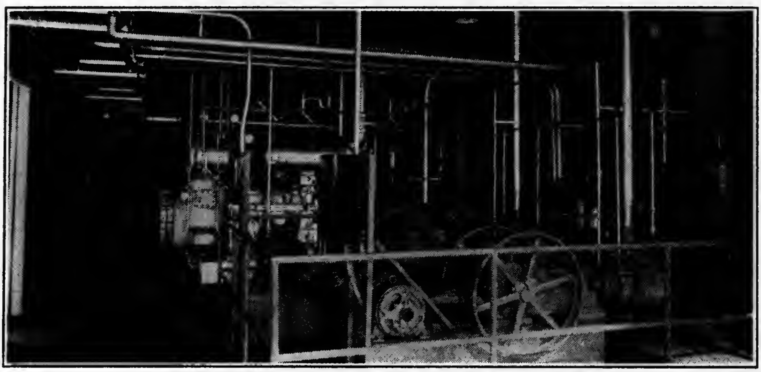


Fig. 13. Machinery room, basement.

changers connected with both the mixing tanks rapidly cool newly prepared solutions. The developing baths are kept free from colloidal developer sludge and other suspended matter by continuous filtration through Bowser monel metal leaf-type filters using Johns-Manville Filter-cel as the filtering medium. The efficiency with which this system removes colloidal silver sludge from the action negative developer makes it possible to use a developing formula of very low alkalinity (*p*H 8.1) producing extremely fine-grain characteristics. This type can not be used commercially without filtration because of its tendency to sludge rapidly and deposit scum on the film.

Standard negative action development time is $11^1/_2$ minutes at 67°F. The negative developing solution is a modification of the Eastman *D-76* formula, containing such concentrations of borax and boric acid as to produce a buffered solution at *p*H 8.1. As discussed above the unusually low alkalinity of the developer and the relatively long time of development are conducive to fine-grain results. Both the test and the time-temperature methods of negative development are employed depending upon the instructions of the customer. Development at the laboratory's standard time produces a gamma of about 0.68 as measured by an Eastman sensitometer exposure on Eastman Super-X film.

A special developer capable of producing a gamma of about 2.70 with a minimum of fog is used for variable-width track negative. Tests are usually removed from the end of each roll, developed, and density measurements made to determine the developing time for the complete roll.

All the variable-density track recordings are developed in one machine to an average gamma of 0.38. The developer used is a dilute modification of the *D-76* formula, with the sulfite concentration restored to 60 grams per liter.

Standard positive development time is $4^1/_2$ minutes at 68°F in a developing bath that is a modification of the Eastman *D-16* formula. Under these conditions an average gamma of 2.10 is maintained.

The condition of all developing baths is checked by running sensitometric strips at the standard developing times. The strips are exposed 12 hours in advance, to reduce to a minimum errors caused by loss or growth of the image immediately following exposure. The strips are developed every thirty minutes and are read and plotted without delay. By this means any tendency of the developing bath to deviate from its normal characteristics is detected and changes are made in the rate of addition of replenisher before the characteristics of the bath have changed appreciably. Development of action negative, variable-density sound negative, and positive prints is governed by the time-gamma curves obtained from the sensitometric strips. All emulsions received by the laboratory are tested sensitometrically and graded according to relative speed and contrast. Exposure level and scale of all printing and Cinex testing machines are checked daily, using the sensitometer as a constant-exposure standard. Exposure levels are adjusted by means of a rheostat and voltmeter on each machine. The control of developing and printing is therefore effected entirely by sensitometric methods.

The fixing bath is compounded in accordance with Formula *F-5* of the Eastman Kodak Company, and contains potassium alum as the hardening agent. Its fixing power is continuously maintained at the proper level by an automatic hypo and silver-recovery plant, and its acidity is likewise continuously maintained by a slow manually controlled acetic acid feed at the main circulation tank. The time of immersion in the fixing bath is $11^1/_2$ minutes. The hypo and silver-recovery system installed in the new plant is a modern, completely automatic version of the original sulfide precipitation process used in the early days of the industry.

A fully equipped chemical laboratory adjoins the mixing room (Fig. 5). Samples of each lot of chemicals received are tested chemically and photographically before acceptance. Such tests and ex-

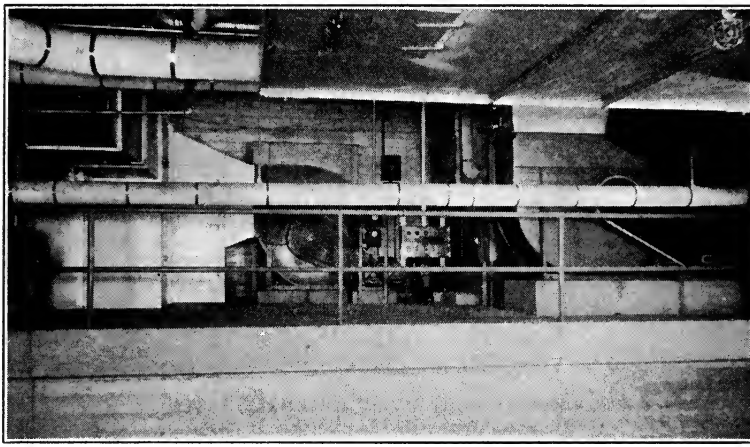


FIG. 14. Ventilating system and dehumidifier.

perimental work as are necessary for control of the developing and fixing baths are performed by graduate chemists.

The refrigeration (Fig. 13) for the laboratory is provided by a 100-ton Carrier centrifugal refrigeration machine, which cools water in a tank located nearby. The tank is part of the building structure and has a capacity of approximately 50,000 gallons. The machine is equipped with an automatic control for the liquor pump that will stop all refrigeration when the desired temperature is attained in the tank. There are five pumps on top of the tank: one for cooling and maintaining the temperatures of the solutions in the various chemical systems; a second for cooling the wash water; a third for air-conditioning the laboratory; a fourth for conditioning the dryboxes; and the fifth for controlling solution temperatures in the color department.

The air-conditioning system (Fig. 14) for the laboratory proper maintains an average temperature of 72°F dry-bulb and 70 per cent relative humidity. The distribution system is divided so that the two developing rooms will be under one control, the printing and negative mounting rooms under a second control, and the negative cleaning, negative inspection, negative assembly and control rooms under a third control. There is one dew-point control at the air washer for regulating the dew-point temperature of the air leaving the fan. A thermostat located in the central room of each of the three groups listed above controls the volume damper and heater for regulating the temperature in each group of rooms. There is a complete filtering system using airmat pocket-type filters located on the discharge side of the fan.

The color department air-conditioning equipment is located in the color room. It is complete with an air washer, fan, filters, heater, and controls. A similar condition is maintained here as in the laboratory proper. The ventilating system, which supplies the work rooms on the first floor that are not conditioned, and the basement, consists of a fan, filters, four sets of heaters, and a duct distributing system. One heater controls the temperature of the air going into the machine shop; a second controls the temperature of the air going into the chemical tank and machine room; a third, the temperature of air going into the first-floor work rooms; and a fourth, the projection rooms. Each heater has a thermostat centrally located in the rooms that it heats. The filters of the system are installed in the discharge side of the fan unit. A similar system is installed on the second floor to heat and ventilate the cutting rooms, title department, and offices.

Individual exhaust systems serve the negative cleaning room, projection booth, six inspection rooms, waxing room, machine shop, chemical laboratory, optical printing room, art department, and spray room.

The film-drying system consists of an individual recirculating system for each drybox. Each unit consists of a fan with a heater on the intake side, mixing casing, and airmat filters. The filters are located so that the air is discharged into the drying cabinets immediately after passing through the filters. The air enters the cabinet at the film-discharge end and, after passing through four compartments in the drybox, returns at the film-entering end through the heater to the intake of the fan. Each drying cabinet has an automatic temperature control. A thermostat located at the end of the cabinet where the air enters, operates a diaphragm valve on the steam line connected to the heater. An automatic humidity control which opens a damper to a duct of dry air is located at the air-discharge end of the drying cabinet. As the air becomes wet due to the moisture removed from the film, the hygrostat automatically opens the damper, allowing enough dry air to enter the sytem thereby regulating the humidity to the preset percentage. The dry air is supplied by a dehumidifier and heater. The air is washed and the dew-point becomes approximately the same as the temperature of the water in the refrigeration tank, which is 42°F. By heating this low-dew-point air to about 70°F, a supply of dry air (35 per cent humidity) is available. A thermostat controls the heater on the intake side of the fan for this common supply for all six dryboxes. The film is dried in each drybox at 75°–80°F and 45–50 per cent relative humidity. A wet- and dry-bulb, connected to the recorder in the control room, is located after the filters in each drybox for recording the condition of the entering air.

Two Chicago pneumatic compressors (Fig. 13), complete with coolers, oil and water separators, filters, and storage tanks, supply the air for all controls and blowout nozzles. An auxiliary compressor supplies the air for the controls when the large compressors are not running.

The direct current for the tester and printer lamps is supplied by three printer generators. A 6-kw. 120-volt d-c. generator supplies the printing room and the d-c. power line to the Consolidated automatic printers. A 2-kw. 120-volt d-c. generator, connected in parallel at the switchboard through a disconnect switch, is available for emergency use. A 500-volt 3-kw. generator supplies power for the high-intensity mercury-vapor lamps used in the automatic printers.

All water entering the plant for use in washing film or mixing developer and hypo is filtered. Three sand-and-gravel filters are located on top of the 50,000-gallon refrigeration tank, which filters approximately 150 gallons of water a minute when all developing and color machines are operating. A 10,000-gallon Permutit Zeolite water softener supplies filtered soft water for mixing developer.

A modern machine shop is located at the north end of the basement. A large tool crib for storing mechanical and electrical maintenance supplies and replacement parts is located along the east wall of the shop.

Adjacent to the machine shop is the boiler room. Two 25-hp. Peerless gas-fired boilers supply steam for laboratory heating and temperature control. Six pounds of steam is maintained in the boilers by automatic control of the gas-supply line. The boilers are equipped with automatic feed-water supply devices.

The generator room consists of a bank of six d-c. generators which supply current to the projector arc lamps in the three projection booths, and to the optical printers and camera department. A McCormick-Deering model *Pa-50* power unit directly coupled to a 22.5 kw. Palmer 3-phase, 60-cycle, 220-volt, electric generator is used as an emergency stand-by generator. The power unit is operated on natural gas, and is equipped with an electric starter and automatic choke. The generator is connected in parallel with the city power lines through an automatic electrically operated disconnect switch to the continuous process developing machine motors and drying cabinet air-circulating fans. In case of power failure on the city line, the power unit will automatically start and reach full speed in less than 10 seconds and supply power to the developing machines. This prevents serious losses that would result with negative in the developer should the machines stop when the city power fails.

The second-floor plan (Fig. 4) shows the location of offices, projection room No. 3, cutting rooms, and title department. The cutting rooms are for the use of customers, and are fully equipped with modern cutting tables, light-wells, bins, racks, rewinds, and moviolas. Vault space is provided for the negative and for positive work prints. The title department may be subdivided into the art, camera, and optical departments. It is in the art department that the ideas for main titles originate. The artists blend their creative ability with trained hands and furnish the producer with a number of ideas from which he chooses his main title. When the producer selects the idea for the main title, the artists make the cards and letter the titles and screen credits and pass their finished product to the camera department for photographing. This department is equipped for many novel effects, and also, in many instances, photographs the production inserts and lettering for superimposed titling. An animating stand and a dolly for zoom work are included in the equipment. In the optical department with its battery of optical printers and their operators, are produced the lap dissolves, wipes, superimposed titles, montages, transitions, and many other valuable tricks of dramatic presentation.

With the facilities as described, the laboratory can give its customers complete service starting with main title, developing and printing, release printing, inserts, and optical work, and ending with end titles.

The author acknowledges and appreciates the assistance of Messrs. S. P. Solow and E. H. Reichard for their assistance in preparing this paper.

DISCUSSION

MR. CRABTREE: With regard to silver recovery, how do you filter out the precipitated silver sulfide? Is it so colloidal that it does not filter easily, or do you so arrange conditions that you get a flocculent precipitate?

MR. MILLER: We have a 100-gallon tank which is used to allow the particles in the solution to coalesce before it goes into the filter press. The filter press is fed with one of the Johns-Manville filter aids, to cause a porous cake to form and the filtration to continue. We use an ordinary hard-rubber press for the filtration.

MR. CRABTREE: To what extent are the negatives timed with the so-called "timing machines," and to what extent do you still employ the visual method of timing?

MR. MILLER: There seems to be quite a difference of opinion between the East and West Coasts as to the better method of timing. On the West Coast, for several reasons, we use the Cinex testing machine to make test-strips before the negative is printed. That is required by most of our customers, and the cameramen want to see the test-strips. However, here in the East we rely upon visual timing inspection of the negatives. That places dependence upon the timer's judgment, but it is done with surprising accuracy.

MR. CRABTREE: This system in which the film goes into the machine at one end and comes out ready for the theater at the other end involves a rather long train of operations. Suppose there is a breakdown of one machine; then expensive machinery is tied up until repairs are made. How serious is that factor?

MR. MILLER: We have not found it serious at all. We have been operating continuously at Fort Lee (N. J.) for four years now without any really serious breakdown. Of course, breakdown of the developing machine proper is the only thing that really ties up the machine completely. We can use the developing machine for work from other types of printers that are not connected, in case the printing machine fails. We can wind film on a take-up, as you saw, in case of projection failure, so we are really limited only by the developing machine.

MR. NICHOLSON: What is the construction of the rollers in the fixing solution? How are the ball bearings mounted, and what is the nature of the roller itself?

MR. MILLER: The rollers in the bottom of the solution are made of molded material, by our own company at Scranton. The bottom roller is a single unit; that is, the entire shaft with rollers is a single unit. There are no ball bearings. We use a Celeron bushing for the shaft. The top rollers are merely bushed on a stainless steel shaft. They are not fastened to the shaft, or interconnected. The bottom rollers, of course, in this kind of machine are molded rollers.

MR. ROBERTS: Do I understand that the printer runs in either direction? Does that mean that half the reels will come off reversed in the projector?

MR. MILLER: In release printing that is true. First prints from freshly developed negatives are always fed through head first.

MR. M. RICKER: What mechanical patchers are used in patching the film?

MR. MILLER: We use various types depending upon the situation. We use some of the Mercer type of patch, which links in the perforations.

MR. RICKER: Narrow or wide?

MR. MILLER: The narrow type, engaging two perforations on each side. For emergency breaks in the drying cabinet we also use ordinary paper fasteners. The two ends can be linked together very quickly.

MR. RUTHERFORD: I understand that after precipitation with the sulfide, the bath is used again. In my experience, I have found that that is not a practical thing to do in small laboratories.

MR. CRABTREE: As long as no more sulfide is added than is necessary to precipitate the silver sulfide, then effectively there is no sodium sulfide in solution. The silver sulfide is very insoluble and, therefore, the concentration of sulfide ion is extremely low and does not sulfide the silver halide emulsion. If you have an excess, then it will fog the film.

MR. SCHAEFFER: What is the speed of your printing machines?

MR. MILLER: 180 feet per minute.

MR. SCHAEFFER: Do you project at 180 feet?

MR. MILLER: Yes.

MR. SCHAEFFER: Is the projection silent?

MR. MILLER: Silent. Any projection with sound is on separate projectors in one of the larger screening rooms.

MR. RICKER: Do you use the acid fixing bath, or do you harden separately from the hypo?

MR. MILLER: We use a standard formula, Eastman *F-5*, I believe it is; a potassium alum, acetic acid type of fixer.

MR. BRADFORD: I should like to inquire about the tanks and the other stainless-steel equipment. Are they welded?

MR. MILLER: The tanks are welded. I am not familiar with the exact process.

MR. CRABTREE: What materials are you using for the toning bath tanks? Are you using continuous machines for toning, or the rack and tank?

MR. MILLER: The continuous machine. We use the same machines designed for the Magnacolor process, in which one side of the film is floated and the second toning is carried out by immersion of the double-coated stock.

MR. CRABTREE: We made some resistivity tests of stainless steel in relation to the uranium and the iron baths, and we found that ordinary 18–8 stainless steel is surprisingly resistant to both those baths. However, if the iron toning bath contains much ferric chloride, the steel goes to pieces very quickly.

LIGHT CONTROL IN PHOTOGRAPHY*

GJON MILI**

Summary—*The principles underlying light control by means of various types of reflectors and lenses for the attainment of proper light-modeling in photography are formulated. The basic units that may be employed are discussed with particular reference to their performance, advantages, and limitations.*

The main problem of photographic technic is to reproduce a subject with the maximum possible range of contrast without loss of detail. Because of the great variety of subjects and the still greater number of possible effects, this is best achieved by means of artificial lighting, which is constant and can readily be controlled in intensity, direction, and spread. While the brightness pattern changes with each set, and may appear to be entirely different in practically every type of photograph, the lighting of any subject may be divided into three main components as illustrated by the three photographs in Fig. 1.

(*a*) Front lighting, which represents the minimum intensity required for retaining detail in the shadows.

(*b*) Side lighting, which provides blunt modeling for a relatively large portion of the subject.

(*c*) Highlighting, which brings into sharp prominence such small features as possess greater significance than their mere size would indicate.

It is entirely feasible to achieve these three constituents of photographic lighting by placing bare lamps at various angles and distances. Such an arrangement would, however, be extremely unsatisfactory because of rank inefficiency. A bare light-source is primarily a converter of electrical energy into light radiated in all directions, and, in most cases, only one-tenth or less of its total light output is delivered within the angle included in a picture, which seldom exceeds 40 to 60 degrees. By employing a reflector or a lens, or a combination of both, in conjunction with the light-source,

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received December 9, 1937.

** Westinghouse Lamp Division, Westinghouse Electric & Mfg. Co., Bloomfield, N. J.

FIG. 1. Components of photographic lighting.

it is not only possible to project a much larger portion of the total light output within the effective photographic angle, but also to provide the wide range of beam intensities and angular spreads so necessary for interesting modeling. The purpose of this paper is to

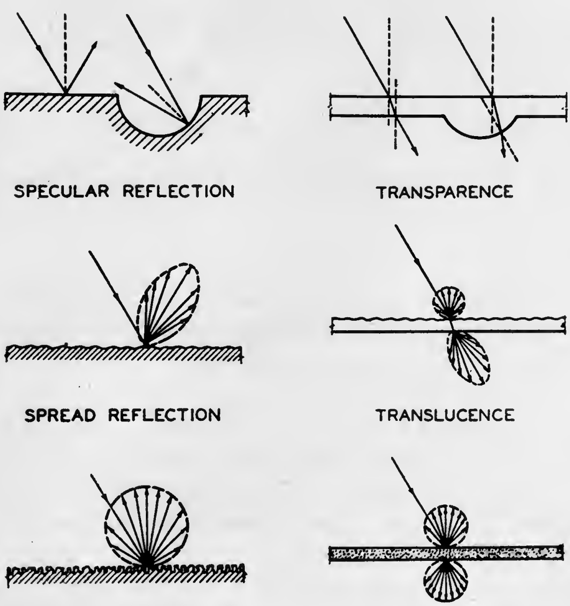
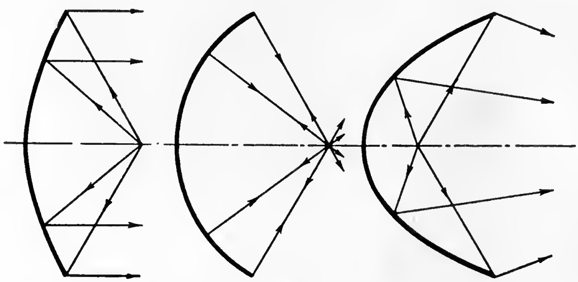


FIG. 2. Types of reflection and transmission, depending upon surface finish and structure of the medium.

set forth the advantages afforded by, and some of the limitations in the use of, reflectors and lenses for light control in photography.

Reflection and Transmission.—The manner in which a narrow pencil of light striking an extended surface may be redirected by reflection is indicated diagrammatically in Fig. 2. If the various infinitesimal areas that compose an extended surface are all lined up in the same plane, the surface acquires a specular polish, and a pencil of light falling upon it is reflected in a given direction. If the structure of the surface is such that the infinitesimal areas composing it are set at extremely varied angles, the surface acquires a diffuse or matte finish, thereby destroying any directional control through reflection. There are also surfaces in which the infinitesimal areas are set partly



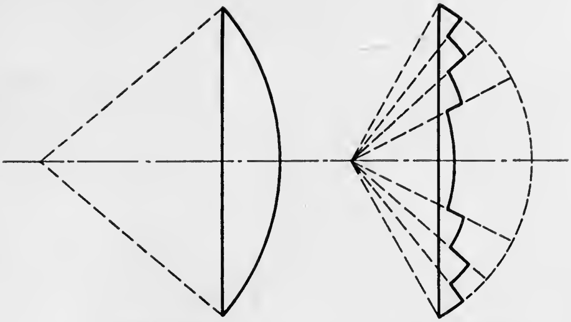
(*a*) *Parabolic* (*b*) *Spherical* (*c*) *Elliptical*

FIG. 3. Geometrical contours for concentrating the light radiated by a bare source.

at various angles and partly in one plane. By this means a certain amount of diffusion is achieved without complete loss of directional control. This is known as spread reflection, while the surfaces are usually designated as semi-matte.

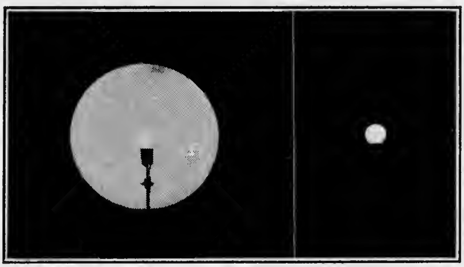
The manner in which a narrow pencil of light falling upon a glass surface may be transmitted is also shown in Fig. 2. It is well to note that when diffusion and translucence are achieved by structural or surface treatment light is only partly transmitted and partly reflected back, thereby reducing the efficiency.

As pointed out above, the problem in photographic lighting is to concentrate light radiated in all directions into a relatively narrow beam. This is achieved by employing reflectors having contours patterned after geometrical curves, such as the parabola, circle, and



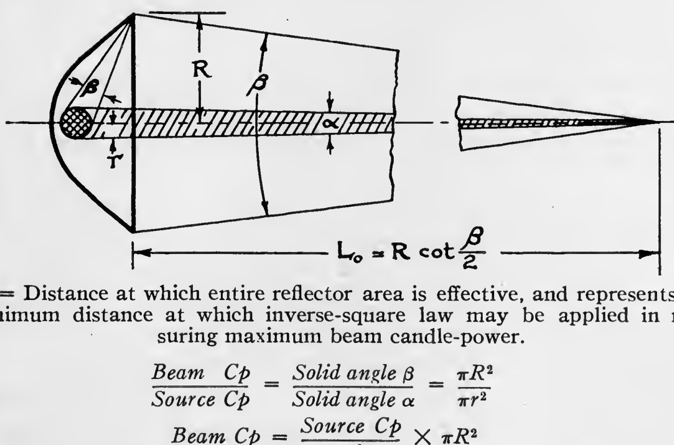
(*a*) *Plano-convex* (*b*) *Fresnel*

FIG. 4. The Fresnel construction makes practicable short-focus lenses with large pick-up angle without increased-thickness.



Lighted reflector *Bare light-source*

FIG. 5. A lighted reflector as seen from a point in the beam. Note that the increase in beam over bare light-source intensity is due to an increase in the apparent size of the light-source.



L_0 = Distance at which entire reflector area is effective, and represents the minimum distance at which inverse-square law may be applied in measuring maximum beam candle-power.

$$\frac{\textit{Beam Cp}}{\textit{Source Cp}} = \frac{\textit{Solid angle } \beta}{\textit{Solid angle } \alpha} = \frac{\pi R^2}{\pi r^2}$$

$$\textit{Beam Cp} = \frac{\textit{Source Cp}}{\pi r^2} \times \pi R^2$$

$$= \textit{Source brightness} \times \textit{mirror projected area}$$

FIG. 6. Maximum beam candle-power with parabolic reflector.

ellipse, as shown in Fig. 3. It is obvious that with matte surfaces the contour of the reflector has no important bearing upon its performance, although poor design may conceivably somewhat reduce the efficiency of the combined unit. To a degree this is also true of semi-matte reflectors, although here some contours are slightly more effective in beam control than others. With specular surfaces the reflector contour is the determining factor in beam formation.

Accurate beam control may also be achieved by means of a clear plano-convex lens, which duplicates in every respect the performance of a specular parabolic reflector. Such a lens is shown in Fig. 4(*a*). In order to increase the pick-up angle without increasing the lens thickness, a modified form known as the Fresnel type, shown in Fig. 4(*b*), is now more widely employed. With the Fresnel lens it is possible, because of the larger pick-up angle, to double and even to triple the efficiency usually attained with a plano-convex lens.

The Parabolic Projector.—A parabolic reflector has the well known property of reflecting a ray of light, originating at its focal point, parallel to its axis. Accordingly, with a point-source placed at the focus the beam would be parallel. With light-sources of measurable dimensions, however, the beam has a definite angular spread, its divergence being equal to the largest angle subtended by the source to any point on the reflector surface.

In Fig. 5 are shown two photographs, one of a bare source and one of the source placed at the focal point of a paraboloid. It must be realized that the increase in intensity gained by means of the reflector is caused entirely by an increase in the effective source size, which now equals the projected area of the reflector. This relationship is expressed mathematically in the equation embodied in Fig. 6. Assuming the reflection factor to be unity, the maximum beam candlepower is equal to the product of the light-source brightness and the projected area of the reflector. Actually the reflection factor is always less than unity, and should be included in the product when determining the candle-power attainable with any given reflector.

With the light-source at or near the focal point, the beam from a parabolic reflector is much too narrow to afford sufficient coverage except for lighting restricted to very small areas. It is possible, however, to increase the beam spread by moving the light-source away from the focal position. This movement is relatively slight, and does not materially affect the pick-up angle of the reflector or the volume of light projected into the beam. Consequently the

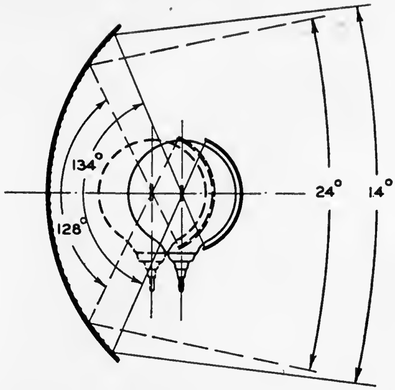


FIG. 7. Diagram of parabolic projector with slightly corrugated reflecting surface. The useful range in beam spread and the change in light-source position are indicated.

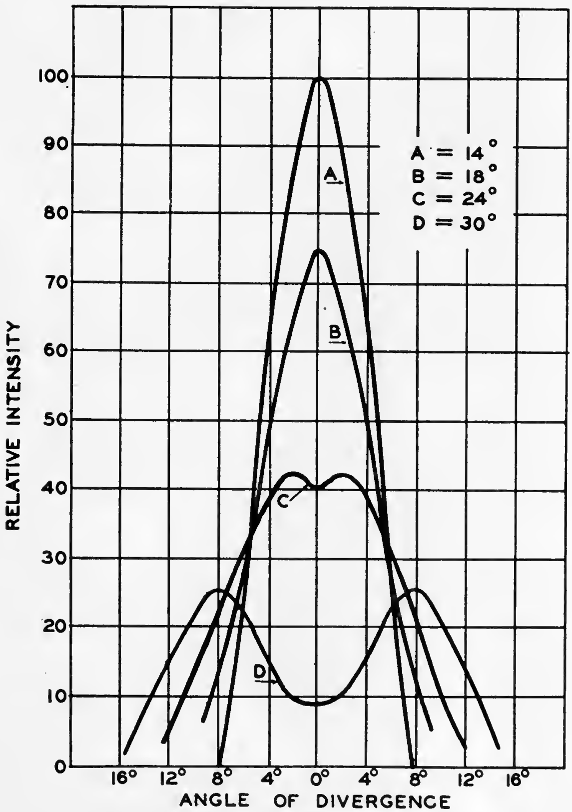


FIG. 8. Relative intensity curves for parabolic projector with slightly corrugated reflecting surface.

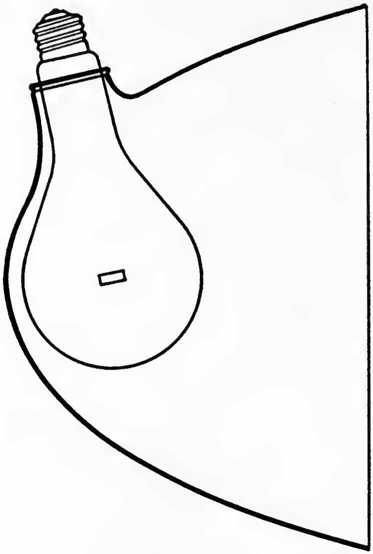


FIG. 9. Deep parabolic reflector with semi-matte surface finish, ideally suited for front lighting.

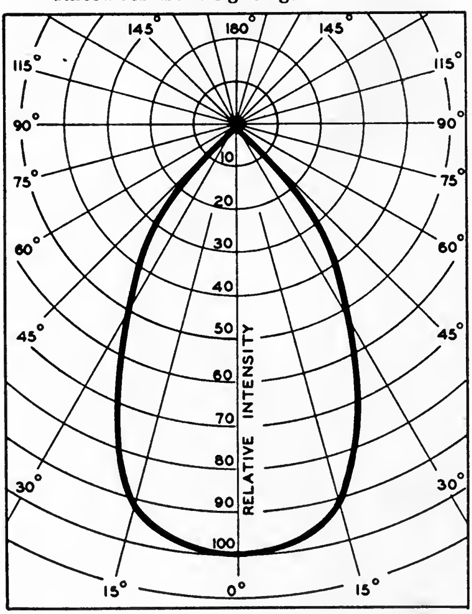


FIG. 10. Relative intensity distribution for deep parabolic reflector with semi-matte surface finish.

average beam intensity must necessarily drop in proportion to the beam spread. It can be established by visual inspection of the reflector from a point along or near the axis of the beam that, as the light-source is moved out of focus, the active reflector area—that is, the area redirecting light to that point—decreases, thereby causing the corresponding drop in intensity. Furthermore, the increase in beam spread is more pronounced at the center than along the edge of the reflector, resulting in greater reduction of intensity at the center

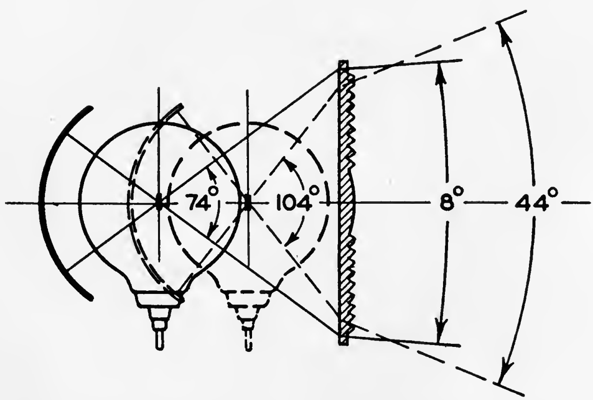


FIG. 11. Diagram of Fresnel lens spotlight, indicating useful range in beam spread and change in light-source position.

than at the edges of the beam. This is very objectionable, since it leads to the formation of a dark area in the center of the beam. The simplest method of overcoming this deficiency is to introduce slight corrugations on the reflector surface. Such a reflector is shown in Fig. 7, while in Fig. 8 are plotted various candle-power distribution curves for beam spreads ranging from 14 to 30 degrees. It is obvious from the curves that even with corrugations the useful range of this paraboloid, which is representative of present practice, is limited to beam spreads between 14 and 24 degrees, if even distribution is required.

For wider spreads with absolute uniformity, deep paraboloids with a semi-matte finish are employed. Such units have a fixed lamp position, and the spread may be changed only very slightly by the use of different light-sources. A unit of this type is shown diagrammatically in Fig. 9, while its performance is given by Fig. 10.

The Fresnel Lens Spotlight.—Greater range of beam spread than is usually possible with a corrugated parabolic reflector may be attained with the Fresnel type of lens spotlight, a diagram of which is drawn

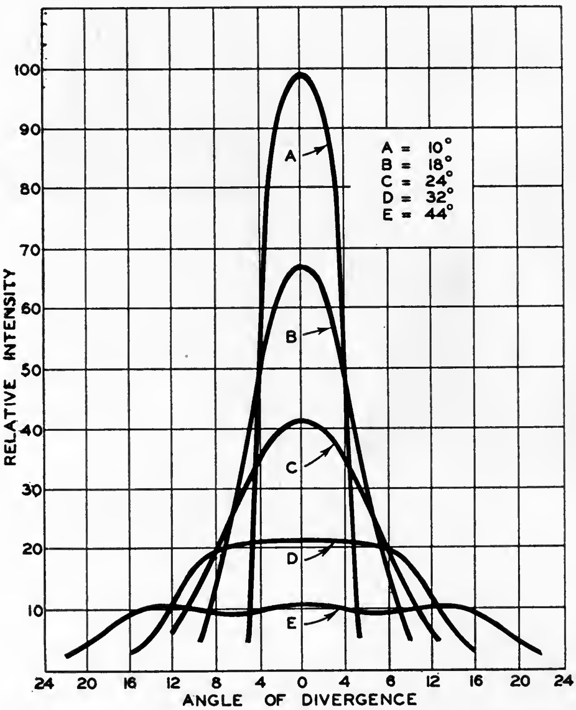


FIG. 12. Relative intensity curves with Fresnel lens spotlight.

in Fig. 11. The relative performance of a representative unit of this type is given in Fig. 12, which shows a practically uniform beam distribution between 10 and 44 degrees. In order to achieve this, it is necessary to make the Fresnel lens with a narrow circular or rectilinear divergence by ribbing the plain back surface, a feature that is embodied in the unit shown.

The Spherical Reflector.—A spherical reflector is included in the diagrams of the two units described. As is well known, the spherical reflector has the property of redirecting a ray of light originating at the center of curvature back to the same point. For this reason the spherical reflector is used mostly as an auxiliary to redirect stray light, which would otherwise be lost, back into the main beam. The increase in beam efficiency provided by a spherical reflector will range from 35 to 75 per cent, depending upon the reflection factor and the type of light-source. The proper focusing of a spherical mirror when used in conjunction with a monoplane filament lamp is illustrated in Fig. 13.

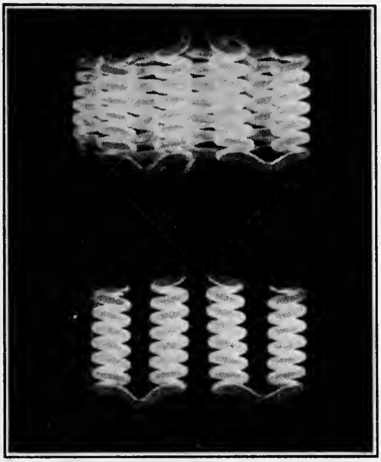


FIG. 13. Proper use of spherical mirror with monoplane filament. (*Top*) filament and reflector image; (*bottom*) filament alone.

The Aperture Spotlight.—Occasionally it is necessary to illuminate an area well defined in outline without any spill of light. This may be achieved by means of a spotlight designed on the principle of a motion picture projector. The elements of one of the most efficient units of this type—elliptical reflector, aperture, and plano-convex lens—are indicated in Fig. 14. Fig. 15 is a photograph of a spotlight of this type, lighted by a similar unit, showing the precise pattern of the lighted area in the background. In some cases the elliptical reflector is replaced by a shallow paraboloid. A unit equipped with this type of reflector gives a lighted area with somewhat sharper outlines, but its efficiency is much lower. For versatility, the aperture is made of vanes which can be set at various angles and moved in and out to change both the shape and the size of the lighted area.

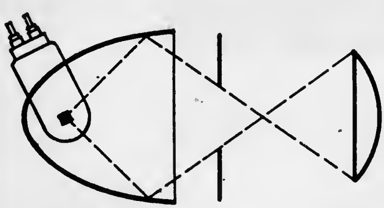


FIG. 14. Optical elements of aperture spotlight.

Lighting Considerations.—While it is possible by the use of reflectors and lenses to increase the amount of light within the effective photographic angle and to increase intensities to a level permitting short exposures, one further factor must be considered. Since the lens or the reflector, which becomes the effective light-source, is much larger than the bare light-source, the shadows cast by such units are of necessity diffuse. Sharp shadows may be attained only by the use of bare light-sources, or by placing the source sufficiently far from the focal position of the lens or reflector so that only a small portion of the reflector or lens is active at any point in the beam. For this

FIG. 15. Aperture spotlight lighted by means of a similar unit. Note the definite outline of the projected beam on the background.

reason, lens spotlights with the source in the "flood" position give the sharpest shadows, next to the bare light-sources themselves.

Theoretically it would be entirely feasible to obtain most of the lighting effects required under any given set of conditions by employing several units of one kind and merely adjusting their distance from the subject. However, working conditions in the studio require two or more types of unit, depending upon the size of the set, the distance at which the units may be placed, and the effect to be achieved. Because of their narrow beam spread and extreme intensity, parabolic projectors are used to the greatest advantage for long throws and strong highlighting. The lens type of spotlight comes into its own in highlighting at close range and in floodlighting large areas from medium distances, although with the present trend toward large heat-resisting lenses it may supersede the parabolic reflector for most applications. The semi-matte deep parabolic reflector unit may be used to best advantage for general illumination in medium-sized or small sets, for which it is ideally suited because of its beam uniformity, wide angular spread, and high efficiency. The aperture spotlight is only rarely used, its field being limited, as has already been pointed out, to very special pattern lighting effects.

Only the basic lighting units have been described, although many others are available which differ only slightly from those herein discussed. It need not be said that they too will be found satisfactory, once their precise performance, modeling possibilities, and practical limitations have been investigated carefully. It is hoped that some of the principles here established will assist in the performance of this task.

SPECTRAL DISTRIBUTIONS AND COLOR-TEMPERATURES OF THE RADIANT ENERGY FROM CARBON ARCS USED IN THE MOTION PICTURE INDUSTRY *

F. T. BOWDITCH AND A. C. DOWNES**

Summary.—*Color-temperatures of various carbon arcs have been calculated from spectral energy data. The dominant wavelength and per cent purity of each arc are given with reference to both "Average Daylight" and "Noon June Sunlight."*

It is pointed out that the color-temperatures of these carbon arc light-sources are of value in comparing them on a visual basis only. The effect of the radiant energy from the arcs upon any photosensitive medium other than the human eye, for example, photographic film, is very different from the visual impression.

Spectral energy distribution curves of several carbon arc sources are published for the first time.

In the last few months there have been a number of requests for the color-temperatures of various carbon arcs used in the motion picture industry. It is the purpose of this paper to provide such information, but at the same time to call attention to the limited usefulness of this method of expression as applied to the uses of the motion picture industry.

In comparing light-sources on this basis, one must bear in mind that the effect of a light-source in terms of color-temperature is referred to the sensitivity of the average human eye. From a visual standpoint, therefore, the color-temperatures of the carbon arcs may be very useful.

It is very important to realize that color-temperatures will give very little and only approximate information as to the effect of light-sources upon photosensitive materials other than the human eye. The best criterion to use in evaluating the effect of a light-source upon photosensitive materials is the spectral distribution of the radiant energy of the source in question. It has been shown that one can calculate the effect of the radiant energy from any light-source upon any photo-

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received September 17, 1937.

** Research Laboratories, National Carbon Co., Inc., Cleveland, Ohio.

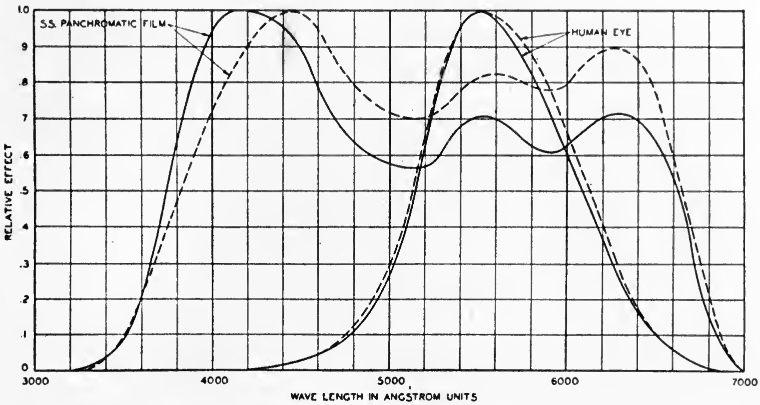


FIG. 1. Comparative effect of light-sources upon photographic film and upon the eye: *broken curves*, sunshine; *solid curves*, 8-mm. motion picture studio arc, 37.5 volts, 40 amps.

sensitive material if the spectral energy distribution of the light-source and the spectral sensitivity of the sensitive material are known.[1] We have shown in a previous paper the effect of the radiant energy from several carbon arcs upon a photographic film.[2]

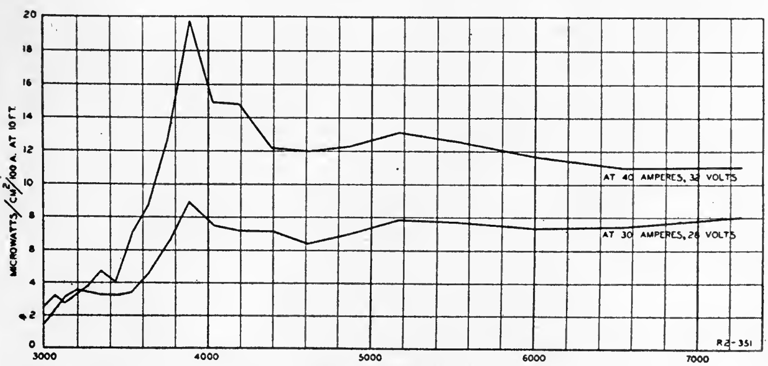


FIG. 2. Spectral energy distribution of d-c. Suprex arc—Positive crater radiation only (16-mm. Suprex positive, 5-mm. Suprex negative). One square represents 4 microvolts per sq. cm. at 10 feet.

Fig. 1 gives the results of such calculations, showing the effect of sunlight and the light from 8-mm. National Motion Picture Studio carbons at 40 amperes and 37.5 volts upon photographic film and upon the average human eye. Comparison of the eye and film re-

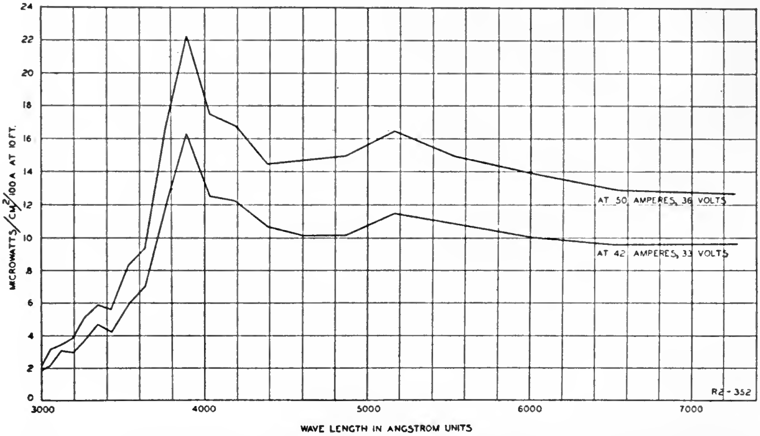


FIG. 3. Spectral energy distribution of d-c. Suprex arc—Positive crater radiation only (7-mm. Suprex positive, 6-mm. Suprex negative). One square represents 4 microwatts per sq. cm. at 10 feet.

sponse curves illustrates very well the very different results or effects of the radiant energy from a light-source upon two photosensitive media whose spectral sensitivities differ considerably from one an-

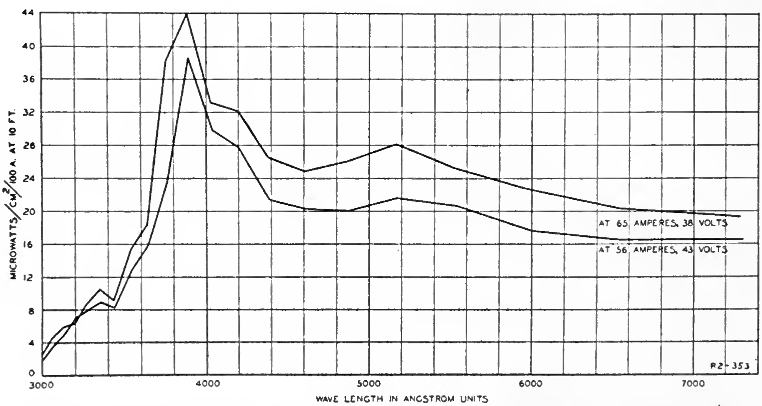


FIG. 4. Spectral energy distribution of a-c. Suprex arc—Positive crater radiation only (8-mm. Suprex positive, 7-mm. Suprex negative). One square represents 8 microwatts per sq. cm. at 10 feet.

other. The futility of using color-temperature, which is a measure of the effect produced upon the eye, for the purpose of evaluating the effect of a light-source upon any other photosensitive material is thus apparent.

The curves show also that the effects of the radiant energy from the sun and the 8-mm. National M. P. Studio carbons at 40 amperes and 37.5 volts are quite similar upon either the eye or supersensitive panchromatic film.

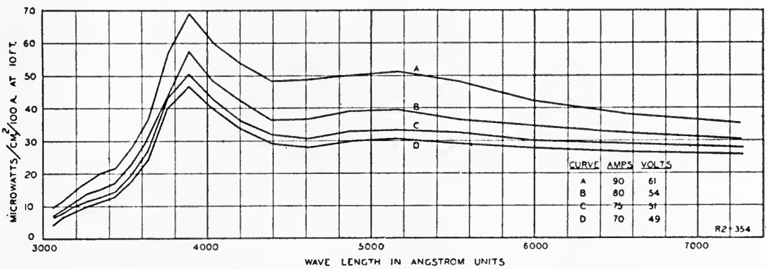


FIG. 5. Spectral energy distribution of 9-mm. d-c. high-low reflecting projector arc—Positive crater radiation only (9-mm. high-low positive, $^5/_{16}$-inch orotip c.c. negative). One square represents 20 microwatts per sq. cm. at 10 feet.

The spectral energy distributions of 6-, 7-, and 8-mm. Suprex carbons, 9- and 11-mm. High-Intensity carbons, and 13.6-mm. Super High-Intensity carbons are given in Figs. 2 to 7, inclusive.

The spectral energy distributions of low-intensity projector car-

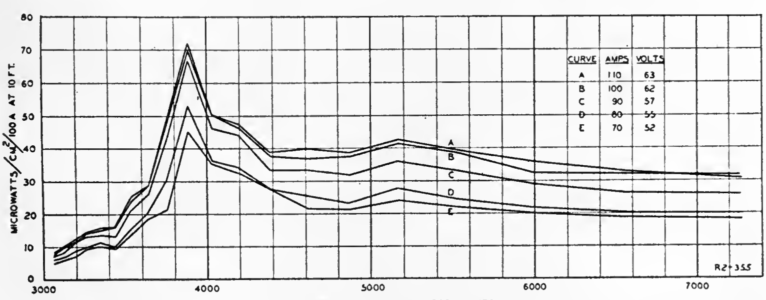


FIG. 6. Spectral energy distribution of d-c. high-intensity motion picture projector—Positive crater radiation only (11-mm. h-i. projector positive, $^3/_8$-inch c.c. orotip negative). One square represents 20 microwatts per sq. cm. at 10 feet.

bons,[3] National M. P. Studio carbons,[2,4,5,6] Rotary Spot carbons,[2,6] 16-mm. Sun Arc carbons,[2,6] and 13.6-mm. High-Intensity carbons[3] also used in the motion picture industry have been published previously. Spectral energy distributions of sunlight and various other types of arcs will also be found in the literature.[7–12]

If one is interested only in the visual comparison of light-sources, color-temperatures are valuable and do serve to differentiate them from one another. The color-temperature of a source of light is defined as the absolute temperature at which a perfect black body must be operated in order to produce a color matching that of the source in question. Obviously this nomenclature can not be applied to any light-source whose color is widely different from that of a black body at any temperature. The various carbon arcs used in the motion picture industry do match black bodies closely enough so that color-temperatures give significant values.

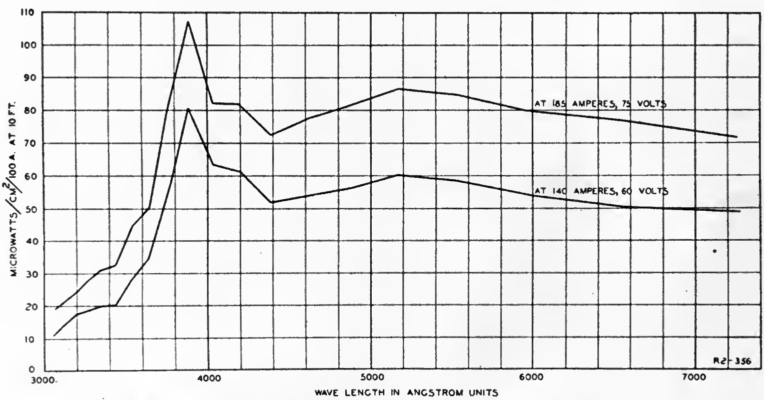


Fig. 7. Spectral energy distribution of d-c. high-intensity motion picture projector—Positive crater radiation only (13.6-mm. super high-intensity positive, $^7/_{16}$-inch extra-heavy copper-coated negative). One square represents 20 microwatts per sq. cm. at 10 feet.

In the determination of the color-temperatures given in this paper, the writers have followed the method outlined by D. B. Judd of the Bureau of Standards.[13] This method involves the calculation of the trichromatic coefficients of the color in question from its spectral energy distribution curve, according to standardized methods.[14] A comparison is then made between the location of the resulting point on a chromaticity diagram and the locus of black body colors.

Through the use of a similar chromaticity diagram any light-source may be defined visually in terms of a fixed standard of comparison, for example, average daylight, as standardized by the International Commission on Illumination in 1931 as Illuminant "*C*".[14] The dominant wavelength and the per cent purity of the source in

TABLE I

Color-Temperature of Carbon Arcs with Dominant Wavelength and Per Cent Purity Referred to Average Daylight

Light-Source	Current	Voltage	Color-Temperature °K	Dominant Wavelength, Angstrom Units	Per Cent Purity
Average Daylight[14]			6500		
11-mm. H.I. Carbons	90	56.5	6400	5640	4
8-mm. Suprex Carbons	65	38	6400	5650	5
8-mm. Suprex Carbons	56	43	6250	5700	5
16-mm. H.I. Carbons	150	81	6000	5740	7
7-mm. Suprex Carbons	50	36	5950	5710	9
$^1/_2 \times 12$ Rotary Spot Carbons	80	53	5600	5900	9
6-mm. Suprex Carbons	40	32	5850	5750	9
9-mm. H.I. Carbons	70	49	5800	5760	9
7-mm. Suprex Carbons	42	33	5800	5740	10
13.6-mm. Super H.I. Carbons	185	75	5480	5740	10
13.6-mm. H.I. Carbons	125	63	5650	5730	12
6-mm. Suprex Carbons	30	28	5250	5770	16
8-mm. Nat. M.P. Studio Carbons	40	37.5	4650	5780	25
12-mm. Low-Intensity Carbons	30	55	3550	5830	40

TABLE II

Color-Temperature of Carbon Arcs with Dominant Wavelength and Per Cent Purity Referred to Noon June Sunlight at Springfield Lake, Ohio

Light-Source	Current	Voltage	Color-Temperature °K	Dominant Wavelength, Angstrom Units	Per Cent Purity
Noon June Sunlight[8]			4200		
8-mm. Nat. M.P. Studio Carbons	40	37.5	4650	4750	6
12-mm. Low-Intensity Carbons	30	55	3550	6050	9
6-mm. Suprex Carbons	30	28	5250	4780	13
13.6-mm. Super H.I. Carbons	185	75	5480	4800	14
13.6-mm. H.I. Carbons	125	63	5650	4800	16
9-mm. H.I. Carbons	70	49	5800	4780	17
7-mm. Suprex Carbons	42	33	5800	4790	17
$^1/_2 \times 12$ Rotary Spot Carbons	80	53	5600	4750	17
6-mm. Suprex Carbons	40	32	5850	4790	18
16-mm. H.I. Carbons	150	81	6000	4780	18
7-mm. Suprex Carbons	50	36	5950	4800	19
8-mm. Suprex Carbons	56	43	6250	4790	20
8-mm. Suprex Carbons	65	38	6400	4800	21
11-mm. H.I. Carbons	90	56.5	6400	4800	22

question can then be determined with reference to this standard. The dominant wavelength is the wavelength of the spectral color that must be added to the standard to match the color of the source. The per cent purity of the light-source is its purity referred to this dominant wavelength. The higher the purity, the greater is the energy of the dominant wavelength that must be added to the standard to match the color of the source in question.

Table I gives the color-temperatures, dominant wavelengths, and per cent purities of various carbon arcs referred to average "daylight," and Table II gives the same values referred to noon June sunlight at Springfield Lake, Ohio.[8]

The dominant wavelengths and per cent purity values for any arc are not the same in the two tables because they are referred to different standards, "average daylight" in one case and a certain noon June sunlight in the other. If any other standard is chosen as a reference the dominant wavelengths and per cent purity values will be still different.

REFERENCES

[1] Jones, L. A.: "Use of Artificial Illuminants in Motion Picture Studios," *Trans. Soc. Mot. Pic. Eng.* **V** (1921), No. 13, p. 74.

[2] Bowditch, F. T., and Downes, A. C.: "Photographic Effectiveness of Carbon Arc Studio Light-Sources," *J. Soc. Mot. Pict. Eng.*, **XXV** (Nov., 1935), p. 375.

[3] Kalb, W. C.: "Present Trends in the Application of the Carbon Arc to the Motion Picture Industry," *J. Soc. Mot. Pict. Eng.*, **XXVII** (Sept., 1936), p. 253.

[4] Joy, D. B., Bowditch, F. T., and Downes, A. C.: "A New White-Flame Carbon for Photographic Light," *J. Soc. Mot. Pict. Eng.*, **XXII** (Jan., 1934), p. 58.

[5] Handley, C. W.: "Lighting for Technicolor Pictures," *J Soc. Mot. Pict. Eng.*, **XXV** (Nov., 1935), p. 426.

[6] Bowditch, F. T., and Downes, A. C.: "Radiant Energy Delivered on Motion Picture Sets from Carbon Arc Studio Light Sources," *J. Soc. Mot. Pict. Eng.*, **XXV** (Nov., 1935), p. 383.

[7] Greider, C. E., and Downes, A. C.: "Sunlight—Natural and Synthetic," *Trans. Ill. Eng. Soc.*, **XXV** (1930), pp. 378–396.

[8] Greider, C. E., and Downes, A. C.: "Physical Characteristics of Sunshine and Its Substitutes," *Trans. Ill. Eng. Soc.*, **XXVI** (1931), pp. 561–571.

[9] Greider, C. E., and Downes, A. C.: "The Carbon Arc as a Source of Artificial Sunshine, Ultraviolet, and Other Radiation," *Trans. Ill. Eng. Soc.*, **XXVII** (Sept., 1932), pp. 637–653.

[10] Dorcas, M. J.: "Ultraviolet Radiation in Industry," *J. Ind. and Eng. Chem.*, **XXII** (Nov., 1930), pp. 1244–1246.

[11] Greider, C. E.: "Energy-Emission Data of Light-Sources for Photo-

chemical Reactions," *J. Ind. and Eng. Chem.*, **XXIII** (May, 1931), pp. 508–511.

[12] KALB, W. C.: "Characteristics and Uses of the Carbon Arc," *Elect. Eng.*, **53** (Aug., 1934), p. 1173.

[13] JUDD, D. B.: "Estimation of Chromaticity Differences and Nearest Color-Temperature on the Standard 1931 I. C. I. Colorimetric Coördinate System," *J. Opt. Soc. Amer.*, **XXVI** (Nov., 1936), pp. 421–426.

[14] "Handbook of Colorimetry," The Color Measurement Laboratory, *Mass. Inst. of Technology*, A. C. Hardy, Editor.

DISCUSSION

MR. POPOVICI: How were the spectrograms made?

MR. DOWNES: The spectral energy distribution curves were determined with a quartz monochrometer by standardized methods originally outlined in the Bureau of Standards Scientific Paper No. 539, by Coblentz, Dorcas and Hughes.

MR. RICHARDSON: In theaters we are interested most in the effect of the light upon the eye and the relation of the heat to the condition of the film. Have you made any such studies? All these arcs have light of various characteristics.

MR. DOWNES: It is very doubtful whether anyone can visually distinguish differences in the lights from the various high-intensity arcs.

MR. RICHARDSON: You think then that they would all be equally easy upon the eyes?

MR. DOWNES: Yes.

MR. RICHARDSON: How about the heat developed at the aperture, and the effect upon the film?

MR. DOWNES: There is no light-source used for projection that does not develop a great deal of heat. The percentage of heat energy, if heat is defined as being the radiant energy of wavelengths longer than those visible to the human eye, is about 65 per cent of the total radiant energy.

MR. SCHUMAKER: What is the maximum amperage in the super high-intensity arc?

MR. DOWNES: We have used as high as 195 amperes with 13.6-mm. carbons, and with the 16-mm. carbons 205 to 210 amperes.

MR. RACKETT: I noted in two of the illustrations, differentiation between daylight and sunlight. What are the differences, and where and how are the measurements made?

MR. DOWNES: Average daylight as used in this paper is the International Commission on Illumination's Illuminant *C*, which is a tungsten lamp operated at a certain absolute temperature with very carefully described chemical filters giving a color-temperature of 6500°K. That is a close approach to ordinary daylight, which is a mixture of sunlight and light from the sky. The sunshine value was from direct measurements of sunshine at Springfield Lake, Ohio, which is about fifteen miles south of Akron.

MR. RACKETT: In the table, the column of deficiencies, in one case, revolved largely about the value of 5700 Å. Was that the daylight comparison?

MR. DOWNES: Yes.

MR. RACKETT: The dominant wavelength is shown as 5700 Å, and if my memory is correct, 5500 Å is about the center of the green band and about the peak sensitivity of the eye.

MR. JONES: 5550 Å is the maximum.

MR. RACKETT: That means, then, that the light is deficient in green?

MR. DOWNES: The dominant wavelength is that of the radiant energy that must be added to the standard to produce the color match with the unknown light-source. It is not added to the unknown.

MR. RACKETT: That is, the arcs are generally deficient in the green. In the table referring to sunlight the deficiency was lower in the spectrum, about 4700 and 4800 Å, from which we might draw the conclusion that June sunlight is richer in blue than the daylight that you used.

MR. DOWNES: That is not correct; if it were, the color-temperatures of sunlight would be higher. The color-temperature of daylight is higher than that of sunlight, which means that there is more blue. For example, the color-temperature of clear blue sky is estimated at 20,000°K; and as the temperature of any black-body source is increased, the dominant wavelength, or the wavelength of maximum energy, shifts toward the short end of the spectrum, so in skylight we have much more blue than in daylight, and in daylight there is more blue than in sunlight.

MR. RACKETT: A point of interest in the curves is the sharp step in the blue region at about 3850 Å. Am I correct in saying that that is largely due to the cyanogen band in the arc?

MR. DOWNES: No cyanogen is liberated by the arc, although the so-called "cyanogen band" is present in the radiant energy from all carbon arcs. If cyanogen is present in the arc stream, it is entirely burned and disappears.

MR. KELLOGG: I believe I have read somewhere that for years astronomers wondered why there should be such strong cyanogen bands in sunlight, and found later that they could be accounted for on the assumption that some gas was doubly ionized. I thought that the idea that the bands were produced by cyanogen was abandoned.

Is it not a little misleading, on the basis of color-temperature, to say that a light is deficient in the green? I thought that the color-temperature given meant that you began to lose in the green but lost still more in the blue. Is that right?

MR. DOWNES: It should be remembered that the dominant wavelength is the wavelength that must be added to the standard light-source to produce a match with the source under consideration. That does not mean that the divergence of the source in question from the standard is necessarily confined to the portion of the spectrum about the dominant wavelength. It is well known that any color can be matched with three primary colors, but sometimes in making a match on a colorimeter one of the three primaries must be added to the source being measured, which may be considered as a subtraction from the three primary colors in order to secure the match.

MR. KELLOGG: Then the dominant wavelength may not bear much relation to color-temperature?

MR. DOWNES: No, it might not.

MR. FRENCH: Can these carbons be burned under any conditions in the theater at the prescribed voltage and amperage and maintain the same color-temperature, or are special burning conditions required?

MR. DOWNES: The spectral energy distribution curves of the Suprex arc at, say, 30 amperes and 40 amperes are not exactly alike, and the color-temperatures corresponding to those two amperages are somewhat different; but within the range of 30 to 40 amperes you would have a hard time visually to tell the difference so far as the appearance of the light is concerned.

MR. FRENCH: Does the color-temperature vary among carbons individually or in batches?

MR. DOWNES: Our measurements on any given type of carbon have been remarkably uniform from one carbon to another as long as the arc voltage and current have been kept constant.

MR. SHULTZ: In the motion picture theater, the eyes are generally dilated; they are in a darkened room looking at a screen having a brightness of 7 to 14 footlamberts. In sunlight the irises close, to compensate for the great quantity of light. Would not eye-strain become more apparent more rapidly in a theater wherein the eye must dilate more rapidly to compensate for changes?

MR. WORSTELL: I believe the discomfort that the eye experiences in a theater is due to contrast rather than to the levels of illumination on the screen. The difference of brightness between the surroundings and the screen is in the dominant factor from the standpoint of visual comfort. Normal brightnesses outdoors, where the illumination may be as high as 8000 to 10,000 foot-candles, are not uncomfortable to the eyes because there is an absence of contrast.

MR. RACKETT: The house illumination in many motion picture theaters is such that you see the surroundings of the theater with the low-intensity receptors, which I believe are the cones; whereas the screen illumination is considerably above the top levels of the cones, and you see the picture with the rods of the eye. The eye is therefore experiencing stimuli from sources having contrasting characteristics, not only in objects being seen, but in the receptive mechanism of the eye itself. The question is a little more complex than merely involving differences in color-temperature of the illuminants; probably the color-temperature of the illuminant is a far less important factor in theaters than the conditions of the theaters themselves.

MR. RICHARDSON: What effect does moisture have upon the characteristics of the arc?

MR. DOWNES: After the first few seconds, none at all. If the carbons contain moisture it will cause "popping" at the arc until the moisture has been driven off, which may prolong slightly the time required for the arc to arrive at a steady condition. If care is taken to see that carbons are dry before trimming, no trouble of this kind will occur.

NEWER TYPES OF STAINLESS STEEL AND THEIR APPLICATION TO PHOTOGRAPHIC PROCESSING EQUIPMENT*

H. A. SMITH**

Summary.—*Within the past three years, two new types of stainless steel have been developed: (1) type 315 which contains approximately 18% chromium, 8% nickel, 1.5% copper, and 1.5% molybdenum: and (2) a modification of type 316 (the usual 18–8 S Mo) where the molybdenum content has been raised to from 3 to 4% molybdenum. Considerable test data are now available for type 329, containing approximately 27% chromium, 4.5% nickel, and 1.5% molybdenum. The latter steel shows promise in that pit-corrosion tendency is considerably reduced. Satisfactory welds may also be made with this type. From the corrosion-resisting standpoint, three other compositions are discussed: type 309, 24% chromium, 13% nickel; type 310, 25% chromium, 20% nickel; and type 446, 27% chromium.*

It is pointed out that a polished (No. 6) and a finely ground (No. 4) finish are more corrosion-resistant than a pickled finish, not only from the potential standpoint but due to the decreased possibility of their collecting foreign matter that will accelerate corrosive attack.

In a previous paper[1] a short history was given of the development of stainless steels and of the application of certain types for structural equipment where corrosive conditions are mild. A more detailed résumé was given of the application of the commoner types to processing equipment. The present discussion will therefore be limited to the presentation of experience obtained since 1934 with the commoner types of stainless steels and to experience obtained with special types.

TYPES OF STAINLESS STEELS

(*a*) *Composition.*—Table I lists the alloy types and range of analysis obtained for each type. Types *304*, *316*, *329*, and *446* were used before 1934; however, modifications have been made in *304*, *316*, and *446* since 1934 to render them suitable for various applications. Type *329* was known before this and was used principally in

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received October 8, 1937.

** Republic Steel Corp., Massillon, Ohio.

TABLE I

Composition Ranges of Various Types of Stainless Steel

Enduro	Type	C	Si	Cr	Ni	Mo	Se	Cb	Cu
18–8	302	Over 0.08/0.20	0.75 Max.	17.50/19.00	8.00/ 9.00				
18–8 *B*	302*B*	Over 0.08/0.20	2.0/3.0	17.50/19.00	8.00/ 9.00				
18–8 *FM*	303	0.20 Max.	0.75 Max.	17.50/19.00	8.00/ 9.00		0.07 Min.		
18–8 *S*	304	0.08 Max.	0.75 Max.	17.50/19.00	8.00/ 9.00				
HCN	309	0.20 Max.	2.0 Max.	22.00/26.00	12.00/14.00				
NC3	310	0.25 Max.	2.0 Max.	24.00/26.00	19.00/21.00				
315	315	0.15 Max.	0.75 Max.	17.00/19.00	7.00/ 9.50	1.0/1.50			1.0/1.5
18–8 *S Mo*	316	0.10 Max.	0.75 Max.	16.00/19.00	14.00 Max.	2.0/4.0			
329	329	0.10 Max.	0.75 Max.	25.00/30.00	3.00/ 5.00	1.0/1.50			
18–8 *S Cb*	347	0.10 Max.	0.75 Max.	17.00/20.00	8.00/12.00			*Cb* 10 × *C*	
AA	430	0.12 Max.	0.50 Max.	14.00/18.00					
HC	446	0.35 Max.	0.50 Max.	23.00/30.00					

Note: Within the standard range of analysis given for any type suitable compositions may be selected for specific applications. Type *303* is usually obtainable only in bar form.

castings; but only recently has it been obtainable in strip, sheet, and plate form. Type *315* has been developed for improved service in special applications. Steels *329* and *316* with a high molybdenum content (high Mo) have been developed for use in corrosive media of a strongly acid nature. Type *304* has been modified and developed for severe spinning operations. Type *446* is not suitable for welding but when modified is adaptable to arc, atomic hydrogen, and resistance welding. Type *347* is offered for welding because columbium does not burn out in the weld as readily as titanium, yet prevents precipitation of carbides and hence intergranular corrosion. Columbium has an additional advantage over titanium in that it does not lower the corrosion resistance of the sheet as much as titanium. For the elimination of carbide precipitation in austenitic steels at the weld a low-carbon analysis (Type *304*) is preferred; however, an *18–8* (Type *302*) may be used where corrosive conditions are mild or where a proper anneal follows the welding operation. Of the steels listed only Types *430* and *303* may not be satisfactorily welded.

(*b*) *Physical Properties.*—The range of physical properties of these stainless steels are given in Table II.

TABLE II

Range of Physical Test Data for Various Types of Stainless Steel

Enduro	Type	Hardness Rockwell	Elastic Limit, Lbs./Sq. In.	Tensile Strength, Lbs./Sq. In.	Elongation, (%) 2 Inches.
18–8	302	75*B*/35*C*	35,000/150,000	80,000/180,000	60/10
18–8 *B*	302*B*	80/90*B*	40,000/ 50,000	80,000/100,000	60/50
18–8 *FM*	303	72/80*B*	35,000/ 45,000	80,000/ 90,000	60/50
18–8 *S*	304	75*B*/35*C*	35,000/150,000	75,000/180,000	60/10
HCN	309	78/90*B*	40,000/ 60,000	90,000/110,000	65/50
NC3	310	80/95*B*	40,000/ 60,000	90,000/110,000	55/45
315	315	75/85*B*	45,000/ 60,000	80,000/100,000	60/45
18–8 *S Mo*	316	70*B*/30*C*	35,000/125,000	80,000/150,000	70/15
329	329	90/100*B*	75,000/ 85,000	90,000/120,000	20/10
18–8 *S Cb*	347	70/90*B*	35,000/ 45,000	80,000/ 90,000	60/55
AA	430	80/105*B*	40,000/130,000	70,000/130,000	30/2
HC	446	78/90*B*	45,000/ 60,000	75,000/ 95,000	30/20

Values shown in Table II compare the annealed as well as the extreme cold-rolled ranges of physical properties for most of the types listed. Types *329* and *446* (modified) may be given only shallow draws; the austenitic type of chromium nickel steels may be deep-drawn without much difficulty. Type *430* takes only medium draws, unless annealed between drawing operations, but its drawing properties do not compare with those of the austenitic types.

All these steels, in simple operations, are reasonably machinable when the proper technic of machining stainless is understood. Type *303* is offered for intricate and delicate machining operations together with maximum corrosion resistance for a free-machining type.

None of the alloys, with the possible exception of *329*, is subject to hardening by heat-treatment. They may be hardened by cold working, *i. e.*, by drawing or rolling.

(*c*) *Commercially Available Forms.*—Any of these analyses may be obtained in the form of hot-rolled, cold-drawn, turned, or centerless ground bar. They may be obtained in the form of cold-drawn or annealed wire and cold-heading rivets. Wood screws, machine screws, bolts and nuts, welded and seamless tubing, may be obtained in most of the analyses mentioned.

Any of these types may be obtained in the form of hot and cold-rolled strip, sheets, and plates. The usual finishes obtainable on cold-rolled strip are:

No. *1* (annealed and pickled)
No. *2* (annealed, pickled, and rerolled)

The usual finishes on sheets are:

No. *1* (hot-rolled, annealed, and pickled)
No. *2B* (bright cold-rolled)
No. *4* (commercially ground and polished)
No. *6* (commercially ground, polished, and Tampico brushed)
No. *7* (high-luster polish)
No. *8* (mirror finish)

The usual finishes on plates are:

No. *1* (hot-rolled, annealed, and pickled)
Annealed, pickled, and cold-rolled
No. *4* (commercially ground and polished)
No. *6* (commercially ground, polished, and Tampico brushed)
No. *7* (high-luster polish)
No. *8* (mirror finish)

THE CORROSION RESISTANCE OF STAINLESS STEELS

The corrosion resistance properties of stainless steels are due primarily to the relatively high chromium content of the alloys. The addition of nickel primarily influences the physical properties, although, in general, it also favorably affects the corrosion resistance. The addition of molybdenum further influences favorably, in most instances, the corrosion resistance of such steels. Other additions to these basic analyses are made for obtaining variations in chemical and physical properties.

It should continually be borne in mind that primarily the resistance of stainless steels to chemical attack is possible because of the passive film present on the surface of the alloys. Various additions to the steel and variations in surface treatment affect the stability of this film, and hence the corrosion resistance of the product. It has been fairly well established that this passive film is a very thin oxide-like film whose characteristics depend primarily upon the composition and physical structure of the underlying metal.

Passivation treatment, *i. e.*, chemical surface treatment, improves the corrosion resistance. The corrosion resistance is improved also by grinding and polishing, if properly done, *i. e.*, by mechanical surface treatment. The higher the finish the more corrosion-resistant is the product. The various surface finishes listed in the order of decreasing resistance to corrosive attack are:

No. *8* (mirror finish)
No. *6* (commercially ground, polished, and Tampico brushed)
No. *4* (commercially ground and polished)
No. *1* (hot-rolled, annealed, and pickled)

This clearly shows that in finishes created by grinding and polishing, the smoother the finish the more highly corrosion-resistant is the steel. In the fabrication of equipment from steels with finishes above No. *1* it should be noted that if welding is employed the welds should be ground down and finished off to the same finish as the sheet. Thus the entire surface presented to the action of the solution is as uniform in finish as possible. In making recommendations, the corrosion resistance, the alloy type, the finish, the relative costs of alloy and finish, fabricating methods, and service conditions must all be considered.

It may generally be stated, with perhaps minor exceptions, that corrosion resistance decreases with increase of temperature of the corrosive medium. It should be remembered, further, that while stainless steel is more resistant than most other metals or alloys to electrolytic attack resulting from concentration cells, it may be attacked where the stainless equipment is allowed to become excessively dirty in the presence of a corrosive medium. Processing equipment made of stainless steel should be cleaned periodically even though it is stainless, just as equipment made of other materials should also be cleaned.

CORROSION RESISTANCE IN PHOTOGRAPHIC PROCESSING

In general, the most severe corrosive conditions exist in various types of fixing baths. Here there is an acid condition with sulfites, thiosulfates, alums, and, occasionally, chlorides present as the active corrosive constituents in water solution.

Developers may contain sulfites, sulfates, bromides, iodides, and borates as the more corrosive constituents. Such developers contain organic compounds which, together with basicity of the solution, render such solutions less corrosive than fixing baths. Acidic reducers and toning baths may contain chlorides, bromides, sulfides, nitrates, sulfates, dichromates, and other constituents. Such reducers and toning solutions are used for special work, and each bath of this type must be considered as a special problem.

With the usual type of basic developer containing hydroquinone, elon, borax, and sodium sulfite, and with the ordinary fixing bath containing alum, acetic acid, sodium sulfite, and hypo, service experience and laboratory tests place the corrosion resistance of the various types of stainless in the order shown in Table III. In each listing in this table the type of steel at the top of the list is the most corrosion-resistant, and the one at the bottom is the least resistant to corrosive attack.

TABLE III

Corrosion Resistance of Various Types of Stainless Steel in Fixer and Developer

(*Listed in order of decreasing resistance to corrosive attack*)

Fixing Bath	Developer
316 (high Mo)	310
309	329
310	304
316	302
329	316
446	316 (high Mo)
304	446
302	309

Note: These listings are based upon results obtained on the steels when properly used, *i. e.*, solutions were not allowed to dry or become concentrated in the equipment when not in use.

In the fixing bath column, all the steels, from the top of the list down through Type *329*, have been found to give satisfactory service in fixing solutions. In the developer column, all the steels listed will give satisfactory service in the usual applications to the usual developing solutions. It may thus be seen that the difference in performance between the top and the bottom types listed under "developer" is markedly less than the difference in performance between the top and the bottom types listed under "fixing bath."

The superiority in fixing solutions of Type *316* (high Mo) is directly reflected in the high molybdenum content as the passive film on such steels is exceptionally stable to acid solutions. The relative superiority of the next two steels is reflected in their high chromium content. Type *316* has a lower chromium content, but this deficiency is made up by the addition of molybdenum. Type *329* is of special interest, as it is less subject to the localized pitting type of corrosive attack than any of the other steels, except Types *316* and *316* with high Mo content. When *329* is attacked, a general overall type of corrosion often occurs.

In developer solutions, the *316* types of stainless are rated somewhat lower than in fixing solutions, primarily because of the basicity of the former solutions. A passive film exceptionally stable in acid solutions is less so in definitely basic ones.

Numerous tests have shown that fogging of film in the developer will not be encountered as the result of using stainless steel equipment for holding the developer.

CARE OF STAINLESS STEEL EQUIPMENT

The importance of properly caring for stainless steel equipment when not in use should be stressed, as the majority of complaints received are from such causes. When equipment is to be idle for a period of time and it will be necessary to make up new solutions on processing again, all solutions should be drained and tanks and mechanical equipment flushed well with warm water before shutting down, to insure that solutions will not evaporate to dryness on the stainless steel.

SPECIFIC APPLICATIONS

Type *316* has been used most extensively for tanks, trays, piping, and mechanical equipment exposed to the action of fixing solutions. As mentioned above, other types (*329* and above) also give satisfactory service in such solutions. Rubber equipment has been replaced by stainless steel in a number of instances where the acid conditions cause the rubber to exfoliate after some service.

For developing solutions Types *302* and *304* have been most widely used and have proved to be quite serviceable. Any of the alloys in Table III may be applied, but Type *302* is most economical in first cost.

Individual storage of motion picture film presents a corrosion problem satisfactorily met by the use of Types *430* and *302*. In storage, film evolves small quantities of gases composed of a mixture of nitrogen oxides, which attack other types of metal storage cases employed. Such metal containers have been drawn satisfactorily from the 18-per cent chromium type of steel (Type *430*) and *18–8* and thus far have resisted any corrosive attack.

Ordinarily washing and drying equipment may safely be made of Type *302*.

Stainless steel has been used in the fabrication of photographic print dryers of which there are three main types:

(*A*) Endless-belt type
(*B*) Segmented-plate type
(*C*) Rotating-drum type

The essential requirement here is a high polish, and, in the plate and drum types, freedom from warping due to heat. In the first class of dryer, Type *304*, cold-rolled and polished, is quite serviceable. In the plate and drum types, freedom from warping may be obtained by the use of Type *446* with a high polish.

Wherever springs or clips are to be used, the application of Type *316* (high Mo) is to be preferred.

The use of stainless steel in the photographic industry has not been as general as it has been in other industries and as it should and undoubtedly will become in photographic processing. This means that the experience of the steel producers in the application of their product is not as great as they should like. However, specific corrosion data are available for the various types of steel mentioned in this paper and will be furnished upon request.

When possible, it is desirable that steel be subjected to tests under actual operating conditions, and to that end samples are furnished for testing, the results of which tests are of mutual benefit to the producer and consumer of stainless steels.

In recommending stainless steel for specific requirements it is especially desirable that the steel user should coöperate as fully as possible with the steel manufacturer in supplying fabricating and operating details so that the most suitable types of steel may be recommended. Only in this way can the greatest satisfaction from the use of stainless steel be expected.

REFERENCE

[1] MITCHELL, W. M.: "Application of Stainless Steel in the Motion Picture Industry," *J. Soc. Mot. Pict. Eng.*, **XXIV** (April, 1935), No. 4, p. 346.

DISCUSSION

MR. CRABTREE: Under Type *316* there are two varieties with 2 and 4 per cent molybdenum. How long have you been supplying two types?

MR. SMITH: The table designation does not mean 2 *and* 4; it means a range of molybdenum content that may be specified as 2 to 4 per cent. Up to about six months ago we had been supplying the steel with molybdenum between 2.25 and 2.75 per cent. Our practice now is to supply a steel containing 2.75 to 3.25 per cent molybdenum. The steel with the modified molybdenum analysis contains molybdenum above 4 per cent and is not included in the regular *316* type of steel.

MR. CRABTREE: Then we must specify the high content or the regular product?

MR. SMITH: We prefer, depending upon the application, to vary the molybdenum content. The reason for the range of analyses given for any of these steels is that by varying (within the range listed) the chromium or nickel or molybdenum, or any other specific addition, we may make a steel especially adaptable to the service conditions that must be met.

MR. CRABTREE: Is the stainless steel business a custom business? In other words, if I ordered Type *316* 2-per cent molybdenum with *7-A* finish in, say, cold-rolled tubing—do you carry it in stock, or do you have to make it to order?

MR. SMITH: We keep in stock a large variety of analyses, both standard and special. We stock standard finishes on the more common analyses. Finishes No. 1 and No. 2*B* are stocked for nearly all analyses. We can furnish, through our corporation, electrically resistance welded tubing of any of the analyses except the straight chrome types.

MR CRABTREE: Getting back to the *316*, you say that the range of content of molybdenum gives you a leeway. Can you control the content?

MR. SMITH: The molybdenum content can be closely controlled. We have found from experience that, in certain applications where the details of the service are not known, Type *316* steel with 2.0–2.5 per cent of molybdenum has not been as satisfactory as it should be. For general applications we prefer this type of steel with molybdenum more in the center of the range, 3.0 per cent. When a customer can give us definite information with regard to the service conditions, we can apply the steel that will be most useful and most satisfactory for that application.

MR. CRABTREE: In many cases we are looking for the most resistant metal we can find. In such cases what do we order? If we order 18–8 molybdenum, what do we get?

MR. SMITH: Type *316* Enduro *18–8 S Mo* containing 2.75–3.25 per cent of molybdenum.

MR. CRABTREE: If we require the high molybdenum content, do you have to make it?

MR. SMITH: We regularly stock 2.75 to 3.25 molybdenum steels. Values above that vary according to the application. On the modified Type *316* material there has been no Iron & Steel Institute standardization. We make it for special purposes up to 6 per cent molybdenum.

MR. BRADLEY: The members of the Committee on Preservation of Film will remember the extensive discussion we had before we selected the containers for the storage of film in The National Archives, and finally selected the 18–8. We did not know at the time whether there was any particular difference in the finish. Samples were submitted to us in the pickle finish, satin, and the mirror finish. We got the pickle finish because it seemed a little cheaper. Now I learn that the pickle finish is not as resistant to oxides of nitrogen as the mirror finish. It is fortunate that I heard your paper this morning because I am just getting ready to order an additional quantity. You say the additional cost of the mirror finish would be justified in our problem?

MR. SMITH: If you use the higher finish steels on welding the fabricated container, the weld must also be brought up to the same finish as the plate, otherwise the weld will be poor and the plate unsatisfactory. The cost is considerably higher, and I should think for your application that the pickle finish would be satisfactory. You have a condition where there are largely gases present, and not a water solution.

MR. BRADLEY: I noticed in handling the cans that they are very easily soiled and finger-marked. What would you suggest as the best way of cleaning the cans?

MR. SMITH: If finger prints are fresh, they may be washed off with water, followed by benzene or some solvent for greases. Finger prints more difficult to remove may be cleaned off usually by treatment in 20 per cent nitric acid solution at 130°F. If finger prints still persist, the container must be given a suitable light pickle.

MR. CRABTREE: If a highly resistant sheet is not welded satisfactorily, or if the welding rod is not of the proper composition, corrosion may take place at the weld and ruin the whole apparatus?

MR. SMITH: If the weld rod is not of the proper composition or if the welding is not properly done, corrosion may take place rapidly at the weld. In a highly resistant sheet that is satisfactorily welded with the proper rod there is little likelihood of severe corrosion.

In the case of individual film containers, which are merely compressed out of steel, you can use the higher finish quite satisfactorily, because the finish is not damaged if the drawing operations are carefully done.

MR. BRADLEY: There is no welding at all; it is a matter of drawing the metal.

MR. SMITH: Then I believe a higher finish might have an advantage.

MR. BRADLEY: Our cabinets are made of the polished steel—satin finish, I think. The containers are made of pickle finish.

Mr. Smith: The No. *8* finish comes at considerably higher cost than the No. *4* finish, which I believe should be quite satisfactory in case you want a higher finish than you are now using.

Mr. Cox: I should like to take slight exception to one statement of Mr. Smith's—that nickel adds principally to the physical properties, and not chemical resistance. Most of us who are familiar with metals and alloys, particularly stainless steels, realize the importance of nickel from the standpoint of chemical resistance to corrosion. None of the materials we manufacture requires passivating treatment, and I believe a little more information on the subject would be helpful.

Mr. Crabtree: If you machine the metal or file it or weld it, or do something that will more or less break the skin, the resistivity of the metal is reduced, according to our experience. If you treat the metal with, say, hydrochloric acid, the passivation is removed. I would much prefer to work with a metal that does not depend upon passivation for its resistivity. We do not know when the metal is going to become non-passive and hence corrode. I have no objection to passivation, but I certainly would not care to rely upon it.

Mr. Smith: Mr. Crabtree is right. We should not depend upon a passivation treatment for creating a surface on a steel so that it may be applied in a corrosive agent that would otherwise call for a higher grade of steel. That is one reason why we apply the molybdenum type of stainless steel in so many instances; because we find it has a more stable passive film and when damaged will reform itself more readily than on the other types of steel. Passivation should be done in 20-per cent nitric acid for 10–15 minutes at 150°F. Such treatment is principally useful in cleaning up a stainless surface that may have picked up mild steel contamination which is likely to cause pitting and rusting.

Mr. Cox: Were the tests to which you referred made with passivated stainless or with materials, say, taken right from stock?

Mr. Smith: They were made with materials taken from stock and freshly pickled, in the standard pickle of nitric hydrofluoric acid. They were not passivated.

In answer to the comment about nickel, my statement was that nickel added largely to the physical properties and that it also helped the chemical properties. However, we find in gases containing sulfur, and in some solutions containing sulfites, that nickel sometimes is not as advantageous as a steel containing higher chromium content. That is, an 18–8 would be less preferable than a steel containing 25 per cent chrome without the addition of the nickel.

Mr. Crabtree: With regard to acid fixing solutions containing silver, of the commercially available metals or alloys the 18–8 molybdenum is the most resistive material we have been able to find to date. That is why I am interested in knowing something more definite about the molybdenum content. I am anxious to get a steel with more molybdenum for more resistivity. That is why I wish Mr. Smith would specify the content more definitely rather than merely as "high" and "low."

Mr. Smith: You have been using Type *316* steels with molybdenum contents of about 2.5 and 2.80 per cent. The table in the paper is the kind specified by the Iron & Steel Institute and shows a range of composition. We preferred to show this sort of table rather than specific compositions because from our experience we are able to apply variations with the range of the analysis for special uses.

MR. HUBBARD: In the majority of cases where stainless steel is used for these purposes, we can not order in quantities big enough to have the content made up to suit our particular needs. What is the best thing to order that you have in stock?

MR. SMITH: The Enduro *18–8 S Mo*, Type *316*, 2.75–3.25 per cent molybdenum. There is, of course, some slight variation in analysis from heat to heat, but from the corrosion-resistance standpoint such small variations are not significant. When you want the most resistant type of steel, we ordinarily furnish this steel unless there is some specific requirement as to resistance, in which case we may apply the special molybdenum steel, which has not yet received an Iron & Steel Institute number.

AIR-CONDITIONING WITH LITHIUM CHLORIDE*

G. A. KELLEY**

Summary.—*A system of air-conditioning is described that employs lithium chloride for independently controlling both the relative humidity and the dry-bulb temperature of air. It is used both for comfort air-conditioning and for treating air for industrial processing work.*

Lithium chloride is one of the most hygroscopic of inorganic compounds, and the aqueous solution has the property of absorbing moisture from, or adding moisture to, the air, depending upon the vapor pressure difference between the air and the solution. From this it is seen that, by properly controlling the concentration and temperature, the lithium chloride solution is capable of either dehumidifying or humidifying the air, depending upon the requirements. The air is cooled or warmed when passed over an aqueous solution of lithium chloride, depending upon whether the solution is cooler or warmer than the air. Further cooling or warming of the air when desired is attained by using an after-cooling or after-heating coil.

The cycle of air-conditioning is explained and illustrations of an air-conditioning unit are shown. The application of the system to a typical problem of interest to motion picture engineers is discussed and illustrated by means of a schematic flow diagram. Operating data for full-load and for less than full-load conditions show low cost of operation and efficiencies equally as high when operating either at maximum load or at less than maximum load. Washing, deodorizing, and neutralizing bacteria from the air by contact with lithium chloride are important factors where pure clean air is desired.

Lithium chloride is used in air-conditioning for controlling both the relative humidity and the dry-bulb temperature of air independently. It is used for comfort air-conditioning and also for treating air for industrial processing work.

The importance of an air-conditioning system that provides independent control of relative humidity and dry-bulb temperature is shown in Fig. 1, which shows the variation for August, 1936, in Dayton, Ohio, in tons of refrigeration required for moisture removal and tons of refrigeration required for sensible cooling per 1000 cu. ft. per minute of outside air to comfort conditions. These curves show that during a considerable portion of the time very little temperature re-

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received October 5, 1937.

** Surface Combustion Corporation, Toledo, Ohio.

duction is required at the same time that a large amount of moisture should be removed. With this system, the moisture removal and the temperature reduction are two entirely independent operations, and the user can control either at will.

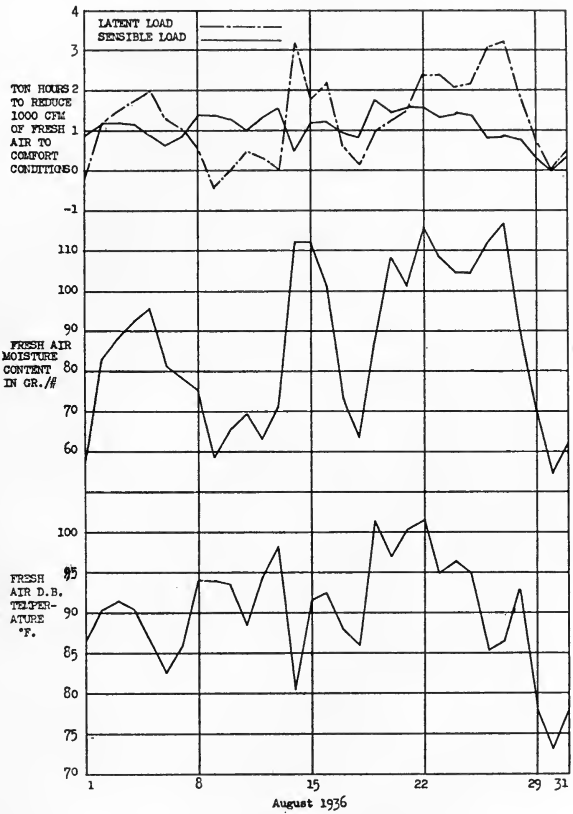


FIG. 1. Refrigeration required for moisture removal and sensible cooling, per 1000 cu. ft. per min. of outside air, to comfort conditions (Aug., 1936).

Lithium chloride is one of the most hygroscopic of inorganic compounds, and the aqueous solution has the property of absorbing moisture from, or adding moisture to, the air, depending upon the vapor-pressure difference between the air and the solution. The equilibrium vapor-pressure of the solution is dependent upon the temperature and the concentration of the solution, so that by controlling these items properly the solution is capable of either dehumidifying or humidifying the air, depending upon the requirements. By cooling the solution below the temperature of the air for the dehumidifying operation, the air can be cooled at the same time the moisture is removed.

The viscosity of lithium chloride solution is higher than that of water, but low enough to permit the use of ordinary pipe sizes for the circulation of the solution.

The cycle for the lithium chloride system of air-conditioning is quite simple. For summer operation the air to be conditioned is brought into contact with lithium chloride solution at a vapor-pressure less than that of the air, so that moisture is absorbed from the air by the solution due to the vapor-pressure difference. In absorbing moisture from the air a certain amount of heat is generated, which is the heat of condensation of the water-vapor in the lithium chloride solution. The temperature of the air in passing over the solution tends to rise, due to the loss of water-vapor; but the temperature rise of the air can be kept down by precooling the solution to a temperature below that of the air. In most comfort applications, the solution is precooled by cooling water in a solution-cooler, so that the air in passing through the air conditioner is cooled as well as dehumidified.

The solution passing to the air conditioner is continuously cooled in a solution-cooler with city, well, refrigerated, or cooling-tower water. The quantity of water required is a function of the water temperature and the total heat, either sensible or latent or both, removed from the air by the solution. Where water is scarce or expensive, an evaporative cooler can be used to cool the solution directly, without the use of a cooling-tower. In this case, the water requirement is only that required for make-up purposes, and amounts to a fraction of a gallon per minute per ton of equivalent refrigeration.

The lithium chloride solution is weakened by the absorption of water, and a small percentage of the solution is passed to the solution conditioner where it is concentrated by driving off the water absorbed by the main body of solution. The solution conditioner consists of a contact surface in which the weak solution is heated with ten-pound steam to a temperature at which the vapor pressure of the solution is considerably higher than that of outside air and contacted with outside air for the purpose of removing water from the solution. Three-pound steam can be used with slight increase in steam consumption. The steam can be produced with a small low-pressure, gas-fired boiler, automatically controlled for summer and winter operation, which requires no attention by the user. The moist air that is discharged to the outdoors also has a cooling effect upon the hot solution as it passes through the concentrator. The warm concentrated solution returns to the sump and mixes with the main body of the solution to maintain the solution at the desired concentration. Considerable operating economies are effected in this system because

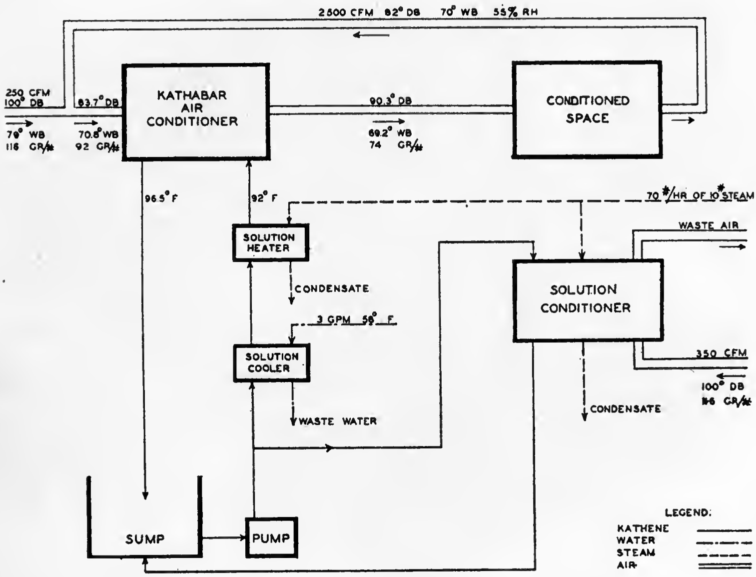


FIG. 2. Flow diagram showing application of lithium chloride air-conditioning system to a typical industrial drying problem.

the solution conditioner is under automatic control and operates only as required to remove the water absorbed from the air, with the result that the fuel consumption is in direct proportion to the water removed. With the equipment operating at 50 per cent of maximum moisture-removal load, the fuel consumption is approximately 50 per cent of that required for maximum load.

Lithium chloride solution absorbs, to a very large degree, most of the odorous materials in the air. The odors absorbed from the air by the solution are driven off in the concentrator and discharged to the outdoors so that the solution, after concentration, is odorless.

In this way there is a continuous cycle in which odors are absorbed from the air in the air conditioner and then removed from the solution in the solution conditioner. The greater portion of the dust and dirt in the air is removed and bacteria neutralized when the air is washed with lithium chloride.

For winter operation, the air to be conditioned is preheated and brought into contact with lithium chloride solution at a vapor-pressure higher than that of the air, so that moisture is added to the air by

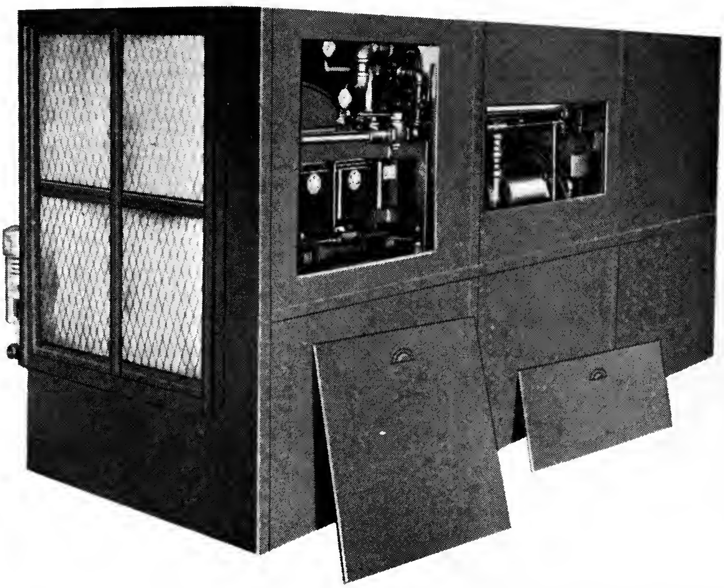


FIG. 3. Standard self-contained lithium chloride air-conditioning unit.

the solution due to the vapor-pressure difference. There is practically no change in the dry-bulb temperature of the air in passing through the air conditioner under winter operation. Heating or cooling coils can be added to the air conditioner when necessary to effect any heating or cooling of the air beyond that effected by passing the air over the solution.

This cycle permits independent removal of moisture from the air, since the moisture content of the air leaving the air conditioner is dependent upon the temperature and concentration of the solution, which is under automatic control, so that the concentrator operates as required to maintain the proper strength of solution.

Fig. 2 is a schematic flow diagram showing the application of the lithium chloride air-conditioning system to a typical industrial drying problem in which the drying takes place along the adiabatic line except for extraneous losses and gains. In this particular problem 250 cu. ft. per min. of fresh air was admitted to the air conditioner in order to keep the room under pressure, and the drying process was such that 2750 cu. ft. per min. of air was introduced from the air conditioner to the drying room. The operating data given in Fig. 2

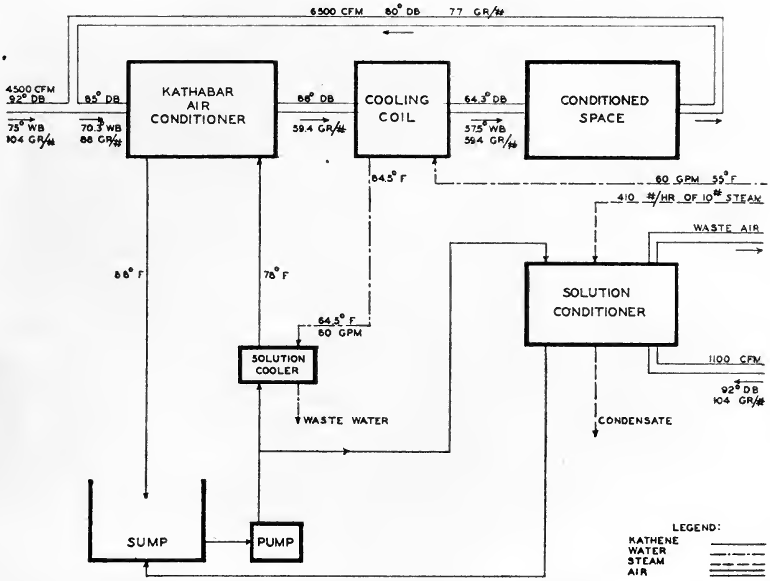


FIG. 4. Application of lithium chloride system of air-conditioning to a typical theater.

indicate that the drying cost of this system is extremely small compared with that of the more usual drying methods. However, in many cases, the savings in operating cost are not the major consideration governing the choice of a drying system. Accurate control of dry-bulb temperature and relative humidity of air is often of great importance in maintaining uniform quality and uniform drying rate of product. This is attained with the lithium chloride system because it is possible to achieve independently modulated control of dry-bulb temperature and relative humidity of the air within very close limits. The system should be of considerable interest to engineers because of the wide range of drying conditions possible at low operating costs. Equipment for maintaining process rooms at drying conditions such as 73° dry-bulb and 18 per cent relative humidity, and 100° dry-bulb and 10 per cent relative humidity is now in operation. Fig. 3 is a standard self-contained lithium chloride air-conditioning unit that will treat up to 2750 cu. ft. per min. of air. The circulating fan and all equipment are within the cabinet.

Fig. 4 shows the application of the lithium chloride system of air-conditioning to a typical theater. Design conditions for this theater are 750 occupants, with an internal sensible heat gain of 188,000 Btu per hour, an internal latent heat gain of 132,000 Btu per hour. Forty-five hundred cu. ft. per min. of fresh air and 6500 cu. ft. per min. of recirculated air pass through the lithium chloride air conditioner, where it is dehumidified, deodorized, the bacteria neutralized, and the air passed to an after-cooling coil where sensible heat is removed before discharging the conditioned air to the theater. The total computed sensible heat load is 19.8 tons and the total latent heat load 19.1 tons, which is a total load of 38.9 tons. Inside design conditions are 80° dry-bulb, 50 per cent relative humidity, with outside conditions of 92° dry-bulb, 104 grains of moisture per pound of dry air. In this application, sensible cooling of the air is obtained with 55° water. Mechanical refrigeration or re-evaporation is used for sensible cooling in cases where the water temperature is too high.

Summarizing the operating data shown in Fig. 4 for maximum summer design operation, it is seen that the operating cost is very small:

60 gal. per min. of 55° water at 12¢ per 1000 gal.	= $0.432/hr.
410 pounds per hour of 10-pound steam at 50¢ per 1000 pounds	= 0.205/hr.
2.2 B.H.P. for solution pump at $2^1/_2$¢ per kw.	= 0.055/hr.
	$0.692/hr.

or a total of 39.8 tons of refrigerating effect at $0.0175 per ton-hour.

Assuming the average load to be 70 per cent of full load, the operating data would be:

30 gal. per min. of 55° water at 12¢ per 1000 gal.	= $0.216/hr.
280 pounds per hour of 10-pound steam at 50¢ per 1000 pounds	= 0.140/hr.
2.2 B.H.P. for solution pump at $2^1/_2$¢ per kw.	= 0.055/hr.
	$0.411/hr.

or a total of 28 tons of refrigerating effect at $0.0147 per ton-hour.

The better-than-proportional decrease in operating cost while operating at part load with this system is obtained because energy is used for direct and independent removal of the latent load and the sensible cooling load.

In many public places, such as theaters, the purifying and deodorizing, and neutralizing bacteria are as important as the savings in operating cost. Lithium chloride, because of its antiseptic and purifying characteristics, offers a means of purifying the air as well as of reducing the dry-bulb temperature and moisture content.

For winter operation, the total computed heat loss for heating and humidifying is 385,000 Btu per hour, so that the same boiler is used for winter operation as for summer operation of the air-conditioning equipment. The same equipment is used for winter operation as for summer operation with the exception that heating coils are used instead of cooling coils.

To summarize, the lithium chloride system of air-conditioning is designed for year-round operation to perform the following functions:

(*1*) Dehumidifying in the summer-time.
(2) Cooling in the summer-time.
(*3*) Heating in the winter-time.
(*4*) Humidifying in the winter-time.
(*5*) Circulating.
(*6*) Cleaning.
(*7*) Washing.
(*8*) Deodorizing.
(*9*) Neutralizing bacteria in the air.

DISCUSSION

MR. CRABTREE: It always seemed to me to be a wasteful procedure to cool air and then to warm it again in order to dehumidify it. Your system would appear to be the ideal one for theaters that are likely to overdemonstrate to the public that they have cooling systems, and produce temperature differences between the inside and the outside air of 30 degrees.

I noticed that considerable mixing of air and solutions was indicated on the chart. Is the procedure fixed, or does the janitor have to juggle the controls?

MR. KELLEY: The mixing of the solution at the start is practically balanced. We have a solution-cooler on one side and a solution-heater on the other side, and the pressure drop through the two is set so that the mixing is done automatically. An orifice or valve is set at the factory and the rate is never changed.

The air is mixed once. The hand damper is set when the equipment is put into operation and is not changed unless the operator wishes to vary the air flow.

MR. CRABTREE: What are the engineering advantages of lithium chloride as compared with those of other desiccating agents such as calcium chloride and potassium carbonate solutions?

Mr. Kelley: I am not familiar with the potassium carbonate, but as for comparing it with calcium chloride, the vapor-pressure of lithium chloride is considerably lower, so it is possible to get a much lower dew-point of air leaving the lithium chloride solution.

Another advantage of lithium chloride over calcium chloride is the freezing point. At the concentrations we use, lithium chloride freezes at about 45°, which of course is lower than the temperatures at which we operate. The freezing point of calcium chloride is considerably higher.

Mr. Crabtree: It is interesting that the lithium chloride solution is so effective in absorbing the gases and the odors from the air. Is it more effective than, say, water? We all know that activated charcoal, and substances with very large surfaces, are very active in removing or adsorbing gases and odors. Why is the lithium chloride particularly effective?

Mr. Kelley: In most of our air washing we recirculate the water. With lithium chloride we have a continuous cycle. We absorb the moisture and the odors in the air conditioner, and then at the same time on the other cycle we have the solution conditioner where the moisture and odors are driven off the solution. We have some evidence that lithium chloride has a greater absorbing capacity for odors than has water.

The continuous cycle, such as we use, is probably very important in removing odors from the air. One demonstration of odor removal in one of our installations this summer was very startling. Some oily rags were set afire accidentally in the fresh-air duct, and the oily smoke passed through the lithium chloride air-conditioning equipment and then was discharged into the various conditioned rooms. Of course, everybody became alarmed immediately and ran into the rooms. There was no trace of odor at all in the air-conditioned rooms.

Mr. Roberts: How effective or applicable is this system for film drying? Would it be applicable in a fairly close system where we do not have to add much outside air, where we clean the air once and keep it fairly clean?

Mr. Kelley: It is very applicable to such a drying problem. The system is very applicable where very little fresh air is required, and has a very low operating cost. The operating conditions are easily within limits of the equipment.

Mr. Carver: Is this the only company that makes this system?

Mr. Kelley: Yes. There is one other company that made the equipment for shoe drying conveyors, as part of the conveyor equipment.

Mr. Crabtree: I presume the cost of the lithium chloride is insignificant compared with that of the mechanical equipment. I have to admire the man who had the courage to proceed with a commercial process such as this, using what chemists have always regarded as a rather rare chemical.

Mr. Kelley: Commercial lithium chloride, of course, is not as expensive as the chemically pure. However, its cost is somewhat of an item, although I believe that the reason is, as you say, that up to the present it has been quite a rare chemical and there has not been a great use for it. The price seems to be dropping now with increased use, though we wish it did not cost quite as much as it does.

Mr. Millner: Is there any danger of corrosion of the ducts or the apparatus by the solution?

Mr. Kelley: Of course, no solution gets in the ducts, and as long as we select the materials properly in the various parts of the equipment we are able to avoid corrosion. If we were to pick the metals without carefully choosing them, we should have trouble due to corrosion.

MR. PATTERSON: Do I understand correctly that the efficiency of this method is a function of vapor-pressure difference between the air treated and the lithium chloride?

MR. KELLEY: Yes.

MR. PATTERSON: It occurs to me then, particularly for motion picture theater conditioning and where it would seem desirable to introduce as much outside air as possible, that it would be economical to treat a comparatively larger quantity of outside air with lithium chloride solution. In that case you would be treating a high moisture content air with a low vapor-pressure solution and the wide vapor-pressure difference will give a high efficiency of moisture removal. You would be operating the machine at greater efficiency by treating all outside air rather than by using a mixture of outside air and recirculated air, and at the same time provide more fresh air per person.

MR. KELLEY: That is quite correct. It would be that much easier to remove the moisture and the system would be operating at a little higher efficiency. However, the lithium chloride, which is very good at deodorizing, also has an antiseptic value, and we feel that we do not need all the fresh air that would be needed otherwise. By recirculating the air, purifying it, and neutralizing the bacteria, so much fresh air is not required.

DIE-CASTINGS FOR PHOTOGRAPHIC APPLIANCES*

J. C. FOX**

Summary.—*Die-castings are defined as castings made by forcing molten metal into a metallic mold or die. The alloy most generally used is of the zinc base type, having a tensile strength of approximately 40,000 lbs. per sq. inch. For photographic appliances, the alloys of lower specific gravity are more desirable. Aluminum base alloys are used more extensively in photographic appliances for that reason. Physical properties of various aluminum die-casting alloys are given.*

Since low specific gravity is of prime importance in castings used for photographic appliances, the development of the process of die-casting the lightest of all commercial metals, magnesium, is of particular interest to motion picture engineers. Magnesium is one-third as heavy as aluminum, and magnesium die-castings are now being used wherever light weight is important. Physical properties of magnesium die-castings are given. Reference is also made to die-casting brass and German silver, a recent development.

It is doubtful whether there is a metal fabricating process that has contributed so greatly to the economic quantity production of metal parts as has the die-casting process, defined as the production of metal castings by forcing fluid metal into a metallic mold or die under external pressure.

Die-castings have assumed great importance in many branches of industry and have been instrumental in the development of worldwide markets for many domestic appliances. Some of the reasons for the extensive use of this method of production are:

(*1*) High-speed production of strong, accurately finished castings at relatively low cost.
(*2*) Production of castings of close dimensional limits.
(*3*) Production of sound castings with surfaces so smooth as to require very little preparation for plating, painting, and other finishes.
(*4*) Production of rigid castings of very thin wall section.
(*5*) Production of castings of a wide variety of shape and sizes, from a very small part weighed in grams to a large automotive grille casting weighing about 27 lbs.

---

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received October 12, 1937.

** Doehler Die Casting Co., Toledo, Ohio.

(6) Ease of machinability.
(7) Good corrosion resistance.
(8) A wide selection of alloys of varying physical and chemical properties.

APPLICATIONS

Die-castings have played a prominent role in the automotive, machinery, household utility, electrical, radio, hardware, business machine, and other industries. Without the economy and speed of production of die-casting, it is safe to state that many industries

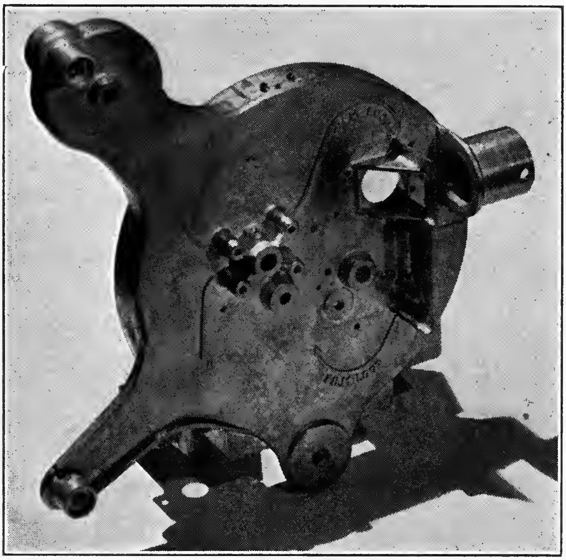


FIG. 1. One-piece zinc die-casting of motion picture projector.

would not be able to hold the wide markets created. What is true of developments in these industries is true of the photographic appliance industry. Zinc base, aluminum base, and brass die-castings are being extensively employed as parts for still and motion picture cameras and projectors. One sound projector, recently developed contains a total of thiry-five die-cast parts, of which 17 parts are of aluminum base alloys, 13 parts of zinc base alloy, and 5 of brass alloy die-castings.

Zinc Alloys.—Motion picture manufacturers have been quick to recognize and take advantage of the many economies inherent in zinc alloy die-castings. The intricate designs of most motion picture parts present obvious applications for this modern metal and process. The projector housing illustrated in Fig. 1 is a one-piece die-casting instead of an assembly of many parts, without the many machining and assembly operations that other methods of manufacture would entail. Several popular low-priced cameras and projectors have been constructed of zinc alloy die-castings. In no other metal and by no other process could these cases have been produced at comparative low cost and durability without sacrificing appearance. Other die-castings in several of these units are the shutter mechanism frame within the camera, and the shutter wheel housing main frame and film feeder housing on the projector.

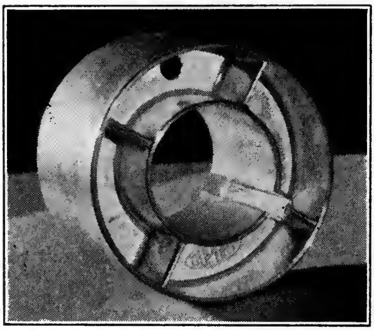


FIG. 2. Die-casting of motion picture film core.

The die-cast film reel for a 16-mm. commercial camera shown in Fig. 2 presents an interesting study in complexity. There is no other way that this part could be produced with the same qualities and economies of a die-casting.

Aluminum Alloys.—Because of their characteristic properties, especially that of low specific gravity, aluminum die-castings are extensively employed in photographic appliances, as in other portable equipment where weight is an important factor. Figs. 3 and 4 illustrate various assemblies and parts made of aluminum die-castings. Such castings have been used for camera cases for both still and motion picture cameras; frames for projectors and mechanisms; housings for shutter, clamp, fan, lamp, and lens mechanisms; brackets for take-up and rewind mechanisms; lens mounts; range finders; tripod tables and parts; shutter parts; and slide blocks and various other mechanical parts.

Fig. 3 illustrates an assembly of six aluminum die-castings for a projector. The use of light aluminum alloys with extremely thin-walled sections makes an ideal combination for small light-weight pocket cameras. Fig. 4 illustrates a large collection of miscellaneous aluminum die-castings used in photographic equipment.

Brass Die-Cast Parts.—Brass die-cast parts in photographic equipment have been used especially where their high strength and resistance to wearing have been required.

Magnesium Base Alloys.—Of great interest to the photographic appliance manufacturer is the development during the past few years of die-casting magnesium base alloys. Although magnesium alloy castings are not especially new, the die of magnesium is comparatively new. The development of a suitable casting machine and process for casting this type of metal and alloy has greatly expanded its use commercially.

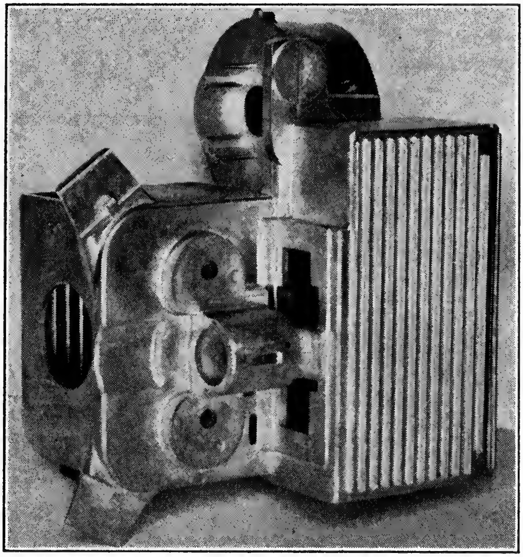


FIG. 3. Assembly of aluminum die-castings in projector.

As designers and engineers become more familiar with the properties of magnesium and its alloys, numerous uses will be found for them. The greatest use of these alloys will perhaps be in the extension of applications, because of its ultra-lightness. A study of the mass-strength ratios of magnesium to other metals will clearly indicate that this material can be employed advantageously for many structural parts. Magnesium has not yet received the attention it deserves, as there are undoubtedly many uses to which strong, light alloys can be put, resulting in higher working speeds and lower running costs.

The most outstanding characteristic of magnesium is its extreme lightness. The average specific gravity of magnesium alloys is 1.80 or a weight per cu. in. of 0.065 lb. A saving of one-third of the weight when magnesium replaces aluminum, and three-fourths of the weight where steel is replaced, can be affected by using magnesium alloy die-castings.

Another important quality of magnesium and its alloys is in machinability. Magnesium is machined faster and better than any

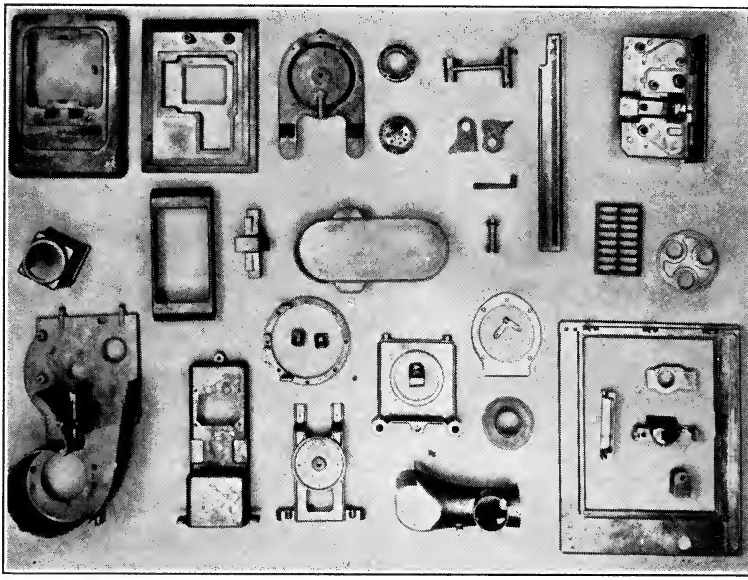


FIG. 4. Miscellaneous aluminum die-castings used in photographic appliances.

other metal. Magnesium possesses good physical properties and has demonstrated its stability and resistance to atmospheric exposure in a large number of applications extending over a number of years.

FINISHING

Zinc die-castings are finished in a variety of ways, both for decoration and protection against tarnishing. There are, however, many applications in which zinc die-castings are used in the natural or "as cast" state without surface treatment. Such parts may be used for long periods of time without any effect upon their utility. Surface oxidation of zinc castings may be greatly inhibited by the application of a short dip in certain solutions of alkali metal chromates or dichromates.

The majority of zinc die-castings used in photographic equipment are enameled, japanned, lacquered, or finished in a combinaton of electroplate and enamel. They may be enameled and high-lighted sections may be simply polished and the exposed zinc protected against tarnishing by the application of a coat of clear varnish.

Realistic wood-grain designs may be readily applied to die-castings, as well as other novel finishes of a great variety of color, design, and texture. Crackle, crystal, opalescent, wrinkle, cobweb, suede, metal luster, and other effects are possible. Many novel and attractive patterns may be obtained by combining some of these finishes. For instance, a combination of wrinkle or crackle finish topped with a flat top-coat of solid color gives a leather-like appearance. Aluminum, gold, or bronze enamels can be used in connection with a wrinkle finish to produce an attractive effect. A number of parts are finished in bright lustrous chromium for decorative trim. Dull or "Buter" chromium may also be used.

Aluminum.—Aluminum die-castings are most generally finished by polishing, enameling, or anodically oxidizing and coloring. Polished aluminum die-castings retain their luster for long periods of time under ordinary atmospheric conditions. It is because of this property that most aluminum applications are finished simply by polishing and buffing to a high luster. Aluminum can be finished with the same organic and novelty finishes described under zinc.

Magnesium.—Magnesium alloy die-casting surfaces are protected against tarnishing by a suitable organic coating. Protection and decoration can be obtained together by selecting the proper paint materials and paint schedules. A definite procedure has been established which, if followed, will secure lasting protection to the magnesium surfaces. Once the surface has been cleaned properly, chemically treated, and a good baked primary coat applied, any of the regular finishing enamels and novelty effects can be used to produce final finishes having both sales appeal and utility.

THE DIE-CASTING PROCESS

The three major requirements of the die-casting process are:

(*1*) The use of a casting machine to hold and operate a die.
(*2*) A properly designed and constructed die.
(*3*) A suitable alloy.

Successful die-casting depends upon the careful coördination of all the details of each of these factors, and requires an organization trained in all branches of engineering and metallurgy to affect this coördination.

To make die-castings render their full value, close coöperation between the designer and the die-casting engineer is essential. Early

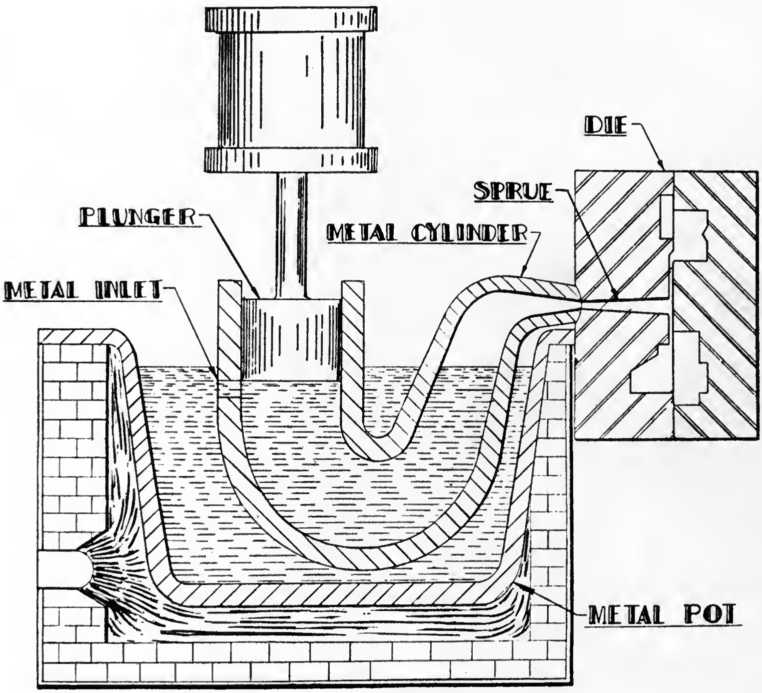


Fig. 5. Principle of zinc-base alloy die-casting machine.

contact between these persons, especially during the formative stage of the design of a part, will result in applying die-castings to the best advantage. The die-casting engineer can advise how to design a part that will minimize die costs and production difficulties; how to save weight where weight is not necessary; what alloy will best meet the functional requirements of the part; how to minimize plating and finishing costs; and how to design to reduce assembly costs. These factors must be considered to derive the best results for both producer and consumer.

The buyer must be assured that his source of supply of die-castings is thoroughly dependable. The alloys used must be subjected to chemical and metallurgical control in the preparation and in casting operations, and kept within the limits set by standard specifications. The control of accuracy and uniformity of castings during the casting operation and the elimination of defects by rigid inspection methods are, of course, also necessary.

Strength, accuracy, and uniformity are fundamental factors of quality of die-castings. By proper design, careful selection, and con-

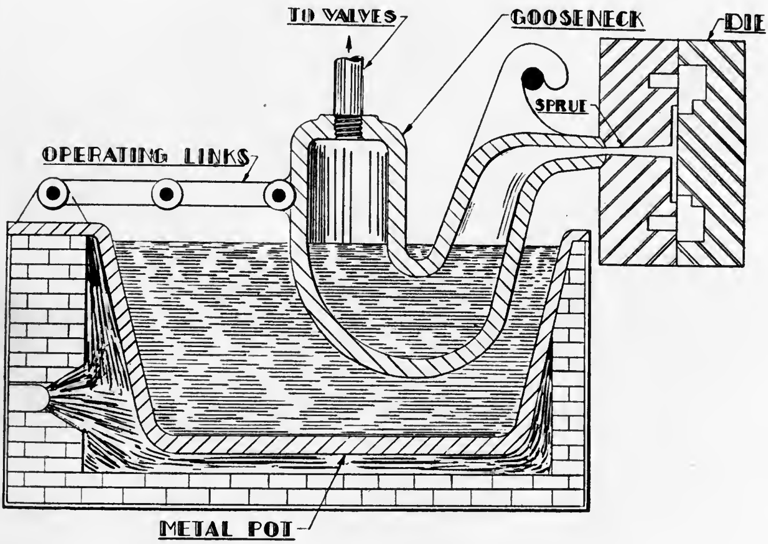


FIG. 6. Principle of aluminum die-casting machine.

trol of the alloy, strength is maintained. Accuracy is obtained by careful calculation of shrinkage and by accurate die construction. Uniformity depends upon complete coördination of all factors and upon the elimination of variables.

DIE-CASTING MACHINES AND METHODS

Die-casting machines can be divided conveniently into three major divisions: (*1*) plunger type machines; (*2*) air type machines; (*3*) High-pressure hydraulic ram types.

Die-Casting Methods.—The lower melting point metals, tin, lead, and zinc base alloys, are usually cast in what is termed a plunger type machine. In principle, this machine consists of a melting pot in which is submerged a plunger pump (Fig. 5). The inlet orifice to the pump is beneath the level of the metal, and the outlet orifice is connected to the sprue or gate of the die. When the plunger is raised, molten metal fills the pump cylinder, and when the plunger is depressed, the molten metal is forced into the die cavity.

A piston operated by compressed air is usually employed to actuate the metal pump plunger. A system of toggle linkages connected between the air cylinder and the metal plunger is generally employed to increase the pressure at the end of the stroke.

Aluminum Die-Casting.—Aluminum die-castings can not be made commercially on the plunger type machine just described for the following reasons:

Aluminum has a tendency to dissolve or wash away the ferrous metal of which the metal pump is constructed, thus quickly wearing away the piston fit and resulting in a loss of pressure; also, oxides of aluminum are formed, which tend to impart to the piston a binding action and quickly make it inoperative.

The method employed in casting aluminum alloys is as follows: Submerged in the molten aluminum alloy is a specially shaped cast-iron container known to the industry as a "gooseneck" (Fig. 6). This gooseneck might be compared to a tea-kettle suspended by the handle. A pipe from a compressed-air supply is connected to the lid opening. The gooseneck is mechanically suspended on a system of links so that it can be submerged sufficiently below the surface of the melting pot to bring the orifice of the spout below the surface of the molten metal in the pot.

The linkage is so arranged that the gooseneck can then be raised so that the spout can be brought out of the molten metal, and moved into contact with the sprue or gate of the die, at which point it is mechanically locked in place.

The operations are as follows: The gooseneck is lowered into the molten alloy. The compressed-air connection to the lid is opened to the atmosphere by means of a valve, and the air-pressure is shut off by means of another valve. This allows the molten metal to flow into the gooseneck through the spout. The gooseneck is then mechanically lifted from the melting pot, allowing the surplus metal to drain from the spout. It is then tilted backward slightly to prevent dripping and the continuation of the stroke brings the spout into contact with the die orifice where it is securely locked.

The valve leading to the atmosphere is then closed and the valve from the compressed-air supply is opened. Approximately 500 lbs. per square-inch of air-pressure is applied to force the molten metal into the die impression. The compressed-air supply is then shut-off and the valve to the atmosphere is opened, after which the gooseneck is allowed again to drop back into the melt to receive a fresh charge.

All the operations are generally performed automatically in syncronism with the rest of the die-casting machine. The other principal function of a die-casting machine consists in opening and closing the dies, pulling the cores, and ejecting the finished castings.

Brass Die-Casting.—Neither the plunger nor the gooseneck types of machine can be used for die-casting brass alloys. Brass when die-cast is handled in small charges, and is forced into the die at unusual speed and pressure (Fig. 7); whereas zinc is cast at pressures up to 1800 lbs. per square-inch, and aluminum 500 lbs. per square-inch. Brass is cast at pressures up to 10,000 lbs. per square-inch.

The Design of Dies.—The design of the dies is the first and most important step in the manufacture of die-castings. A die that is improperly designed can not produce satisfactory castings, and frequently a die so constructed can not be corrected. There are many vital factors to be considered by the die designer before deciding upon the construction of any die, some of which are as follows:

The location of the gate or metal inlet is of vital importance to the user of die-castings. The gate location is decided upon not only from the standpoint of casting production, but also from the user's viewpoint of the finished casting. The designer of a die is much better able to locate the gate properly if he is thoroughly familiar with the service application of the die-cast part.

Since all die-casting dies are made of steel it is evident that methods must be provided for the exit of air in the die cavity when it is displaced by the metal entering into the die. Failure to provide proper vents in the die will naturally result in unusual porous castings. Many methods of venting are employed. The size, contour, and section of the casting determine the method of venting that is most applicable.

Proper means must be provided in every die for rapidly ejecting the casting from the die after the casting operation. This is usually accomplished by means of ejector pins. In the process of ejecting the casting, the ejector pins make a slight impression in the casting. These ejector pin marks are frequently quite visible. It is the task of the die designer to place these ejector pins in such position on the casting that they eject the casting rapidly without distortion, and, at the same time, the ejector pin marks must not be objectionable from the user's viewpoint.

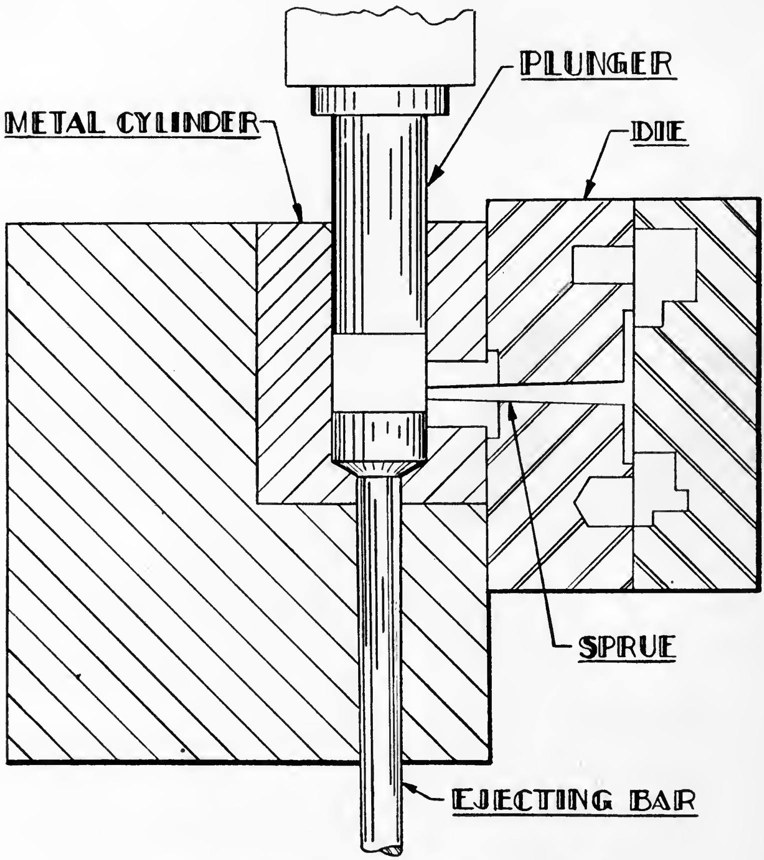


FIG. 7. Principle of brass die-casting machine.

Die Steels.—The difficulties met in die-casting practice increase and multiply with advancing melting and casting temperatures of the alloys used. The life of die-casting dies varies with increase of melting and casting temperatures. For instance, dies for lead and zinc base alloys with casting temperatures not exceeding 800°F may be made of ordinary machine steel (S. A. E. 1040) and without heat treatment are capable of long use before becoming unserviceable.

For aluminum alloys with casting temperatures around 1300°F, the greater heat absorption makes it necessary to use a high-grade alloy steel composition for the dies. Furthermore, proper heat treatment of the alloy steel die is essential in order to obtain a life of 100,000 casting cycles before replacement is necessary.

Brasses and bronzes having still higher casting temperatures and greater heat absorption values naturally present more difficulties than aluminum.

ALLOYS

The important qualities of a suitable die-casting alloy may be listed as follows:

(*1*) Physical properties: strength, ductility, hardness, *etc.*
(*2*) Permanence of properties and dimensions in service.
(*3*) Fluidity.
(*4*) Strength and ductility at elevated temperatures of solidification.
(*5*) Solidification range.
(*6*) Low liquid and solid shrinkage.
(*7*) Machinability.
(*8*) Polishing, plating, and finishing properties.
(*9*) Corrosion resistance.
(*10*) Weight and cost.

The alloys used in modern die-casting practice may be classified into six main groups, namely:

(*1*) Tin base alloys: tin alloyed with antimony, copper, and lead.
(*2*) Lead base alloys: lead alloyed with tin and antimony.
(*3*) Zinc base alloys: zinc alloyed with aluminum, copper, and magnesium.
(*4*) Aluminum base alloys: aluminum alloyed with copper, silicon, nickel, and magnesium.
(*5*) Copper base alloys: copper alloyed with zinc, tin, silicon, aluminum, nickel, manganese.
(*6*) Magnesium base alloys: Magnesium alloyed with aluminum, manganese, and silicon.

A description of the general properties and applications of typical alloys of each group follows:

Tin and Lead Base Alloys.—Tin and lead base alloys represent only a small part of the total die-casting production, although for some uses these alloys are indispensable. Because of their corrosion resistance, tin base alloys find considerable application in parts for soda fountains, milking machines, syrup pumps, dental appliances, and surgical instruments.

Lead base alloys are usually employed where a cheap non-corrosive metal is required, and where strength and hardness and other mechanical properties are unimportant. Parts that must withstand the action of strong mineral acids, as in fire extinguishers or other chemical apparatus, are produced in lead base alloys. X-ray equipment employs lead die-castings, because of the resistance lead offers to the passage of x-rays.

TABLE I

Chemical Composition of Zinc Base Alloys

	A. S. T. M. Alloy XXI S. A. E. 921 (Per Cent)	A. S. T. M. Alloy XXIII S. A. E. 903 (Per Cent)
Copper	2.50–3.00	Max. 0.10
Aluminum	3.50–4.30	3.50–4.30
Magnesium	0.02–0.05	0.03–0.05
Iron	Max.–0.10	Max.–0.10
Lead	Max.–0.007	Max.–0.007
Cadmium	Max.–0.005	Max.–0.005
Tin	Max.–0.001	Max.–0.001
Zinc (99.99+% purity)	Remainder	Remainder

TABLE II

	Alloy XXI	Alloy XXIII
Tensile strength (lbs./sq. in.)	48,000	40,000
Charpy impact strength (ft. lbs.)	18	20
Elongation (% in 2″)	5	5
Brinell hardness	83	74
Compressive strength (lbs./sq. in.)	93,000	60,000
Shearing strength (lbs./sq. in.)	45,800	31,000
Melting point	715°F	718°F
Specific gravity	6.7	6.6
Thermal conductivity (cal./sec./cm.^{3}/°C)	0.25	0.27
Thermal expansion (per °C)	27.7×10^{-6}	155,000

Zinc Base Alloys.—Of all the types of alloys used in die-casting the zinc base alloys are used in the majority of cases, chiefly because of their low cost, their ease of casting, their physical properties, the stability of these properties, and their excellent finishing qualities.

In Table I are listed the zinc base alloys in most common use today. These conform to specifications issued by the American Society for Testing Materials (*B–86–33–T*), and the Society of Automotive Engineers (Nos. *921* and *903*).

TABLE III

Chemical Composition Limits of Standard Aluminum Alloy Die-Castings

	No. 1 Alloy	No. 2 Alloy	No. 3 Alloy	No. 4 Alloy	No. 5 Alloy	No. 6 Alloy
Copper	Max. 0.60	Max. 0.60	2.50–3.50	3.50–4.50	6.50–7.50	1.50–2.00
Silicon	4.00–6.00	11.50–12.50	7.50–8.50	4.50–5.50	2.50–3.50	Max. 1.00
Iron	Max. 2.00	Max. 2.00	Max. 2.00	Max. 2.00	Max. 2.25	Max. 2.25
Zinc	Max. 0.30	Max. 0.30	Max. 0.50	Max. 0.50	Max. 1.50	Max. 0.20
Magnesium	Max. 0.10	Max. 0.10	Max. 0.10	Max. 0.10	Max. 0.10	Max. 0.10
Manganese	Max. 0.30	Max. 0.30	Max. 0.30	Max. 0.30	Max. 0.30	Max. 0.20
Nickel	Max. 0.25	Max. 0.25	Max. 0.50	Max. 0.50	Max. 0.50	1.50–2.00
Total other metals	Max. 0.20	Max. 0.20	Max. 0.20	Max. 0.20	Max. 0.20	Max. 0.20
Aluminum	Balance	Balance	Balance	Balance	Balance	Balance

Physical Properties of Standard Aluminum Alloy Die-Castings

	No. 1 Alloy	No. 2 Alloy	No. 3 Alloy	No. 4 Alloy	No. 5 Alloy	No. 6 Alloy
Ultimate tensile str. (lbs./sq. in.)	26,000–28,000	30,000–34,000	28,000–32,000	28,000–31,000	29,000–33,000	26,000–28,000
Yield point (lbs./sq. in.)	10,000–12,000	13,000–15,000	12,000–14,000	13,000–15,000	16,000–18,000	10,000–12,000
Elong. (% in 2")	3.50–4.50	1.50–2.50	1.50–2.50	1.50–2.50	0.50–1.50	3.50–4.50
Charpy impact str. (ft. lbs.)	4.0–5.0	1.50–2.50	1.50–2.50	2.00–3.00	1.00–2.00	4.0–5.0
Brinell hardness No.	65–70	75–80	75–80	65–70	75–80	60–65
Weight (lb. per cu. in.)	0.097	0.095	0.099	0.100	0.103	0.099
A. S. T. M. *B-85-33-T* Spec.	No. IV	No. V		No. VII	No. XII	No. VIII
S. A. E. spec.	304	305		307	312	
Al. Co. Amer. spec.	43	13		85	81	92

The American Society for Testing Materials and the Society of Automotive Engineers exact the following minima of physical properties from these alloys:

	A. S. T. M. Alloy XXI S. A. E. 921	A. S. T. M. Alloy XXIII S. A. E. 908
Minimum tensile strength (lbs./sq. in.)	44,000	35,000
Minimum charpy impact strength (ft. lbs.)	6	12
Minimum elongation	2	3

In Table II physical properties and constants capable of these two alloys as cast from die-cast test-bars made in accordance with A. S. T. M. specifications are given.

TABLE IV

Nominal Composition of Standard Copper Base Die-Casting Alloys

	I (Doler Brass)	II (Doler Brastil)	III (Doler Nickel Brass)
Copper	65	81.0	44
Zinc	34	14.75	40
Silicon	1	4.25	
Nickel			14
Manganese			2
Tensile strength	70,000	85,000	70,000
Elongation (% in 2″)	25	10	0.10
Yield point	40,000	60,000	55,000
Brinell hardness	120	170	140
Specific gravity	8.50	8.25	8.55

Aluminum Base Alloys.—Aluminum base alloys are used chiefly for their characteristic properties, which may be summed up as follows:

(*1*) Low specific gravity.
(*2*) High thermal and electrical conductivity.
(*3*) Corrosion resistance.
(*4*) Freedom from any dimensional changes.
(*5*) Stability of properties at subnormal temperatures.
(*6*) Ability to hold a polished luster for long periods of time.

It is because of these properties, especially lightness and corrosion resistance, that aluminum die-castings are used extensively for portable equipment such as vacuum sweepers, typewriters, photographic equipment, and many others.

The standard aluminum base alloys used for die-castings are essentially those covered by A. S. T. M. specifications *B-85-33-T.*

These alloys, which are listed in Table III with their physical properties, may be classified into three main groups:

(*1*) Copper-aluminum alloys.
(*2*) Copper-silicon-aluminum alloys.
(*3*) Silicon-aluminum alloys.

Copper Base Alloys.—Pressure die-casting copper base alloys (brass) is relatively new, but progress is proceeding steadily under a definite program of research and development (see Table IV).

The salient qualities of brass die-castings, great strength and corrosion resistance, demand attention from design engineers. The die-casting of brass alloys opens to industry a source of engineering parts of exceptionally great strength and accuracy, intricacy, and stability not readily obtained by other means of fabrication. It is difficult to limit the potential market of materials having such a combination of properties. Brass die-castings have already found use in a number of motion picture camera and projector assemblies.

TABLE V

Magnesium Base Alloy

	Doler Mag. No. 2	Doler Mag. No. 6	Doler Mag. No. 10
Aluminum	2.00	6.00	10.00
Manganese	0.10	0.10	0.10
Tensile strength (lbs./sq. in.)	23,500	24,000	28,000
Yield point (lbs./sq. in.)	15,500	16,000	21,000
Impact strength (ft. lbs.)	6.0	3.0	1.0
Elongation	% in 2″		
	8.0	3.0	1.0
Brinell hardness	42	52	65
Weight (per cu. in.)	0.064	0.065	0.066
Melting point (°F)	1175	1155	1100

Magnesium Base Alloy.—The standard magnesium base alloy used for die-casting has the chemical composition and physical properties shown in Table V.

DISCUSSION

MR. CRABTREE: Can you die-cast the stainless steels?

MR. FOX: Not as yet. The development of the die-casting art has proceeded from the casting of alloys of low melting points to those of higher ones. At first tin and lead base alloys, with melting points up to 700°F were cast. Then followed in order zinc base alloys with melting points up to 800°F, aluminum base alloys with melting points up to 1200°F, and copper base alloys with melting points up to 1600°F. The highest melting point materials, such as the bronzes, cast iron, and steel will be the next tried, but shall await development of better die materials.

MR. CRABTREE: When casting magnesium how do you prevent oxidation?

MR. FOX: We use an inert gas atmosphere over the molten magnesium. Sulfur dioxide gas is most generally used for this purpose.

MR. PALMER: What are the relative costs of magnesium and aluminum?

MR. FOX: The specific gravity of magnesium is about 1.8 as against 2.8 for the lightest aluminum alloy. Although the cost per pound of magnesium is higher than that of aluminum, the difference in the densities makes the cost per volume of magnesium less than that of aluminum.

MR. PALMER: Are there any practical difficulties in using magnesium for die-casting which would make it unsatisfactory?

MR. FOX: Aside from the care necessary to prevent oxidation of the melt, there are no more difficulties in die-casting magnesium than in die-casting aluminum alloys. There are certain precautions that the supplier or consumer may take in machining magnesium which concern the inflammability of finely divided magnesium. Magnesium does not take fire until the melting point is reached. The fine chips take fire readily because they can not conduct the heat away fast enough. It is only when large accumulations of chips are carelessly left in the open that any fire hazard is found.

MR. CRABTREE: But the metal oxidizes very readily in a moist atmosphere, does it not?

MR. FOX: That is right.

MR. CRABTREE: And you have to protect it with a suitable lacquer.

MR. FOX: Yes. It is important that proper procedure and proper materials be used in finishing magnesium castings. A properly cleaned casting, and a suitable baked primer coating followed by the color coatings is the usual procedure. One concern makes a complete vacuum sweeper that is so finished and has proved its practicability in every respect.

MR. SWARTZ: Is the magnesium more brittle than the aluminum?

MR. FOX: Magnesium is about the same as aluminum in that respect. Of course, the compositions of both aluminum and magnesium alloys control this property. A 10 per cent aluminum-magnesium is comparable with the standard aluminum casting alloys, such as the commercial No. 12 alloy. With lower aluminum content, in magnesium alloys, the ductility is increased.

THE ACTIVATED ALUMINA SYSTEM AS APPLIED TO AIR-CONDITIONING AND DRYING PROBLEMS*

G. L. SIMPSON**

Summary.—*The phenomenon of adsorption is discussed. Some of the properties of the solid adsorbent, activated alumina, are given, including a dynamic characteristic curve. This dynamic characteristic is utilized industrially to dry air and gases to dewpoints as low as −76° C (0.0004 grain per cu. ft.; 0.0009 milligram per liter). Apparatus utilizing activated alumina in this way is described and pictured.*

Uses of the system include drying controlled atmospheres and bottled gases, and in chemical processing when water-vapor would promote corrosion or adversely affect the processes. Compressed-air lines are kept free of water to prevent freeze-up in winter or spoilage of work.

In industrial and comfort air-conditioning, comparatively large quantities of partially dried air are required. A continuous dehumidifier to meet these requirements is described and illustrated.

It is pointed out that performance is a function of machine design as well as of the fundamental characteristics of the solid adsorbent used. Depending upon the factors of first cost and economy of operation, a wide range of performance may be obtained. A curve shows the present-day characteristic of a line of machines that is commercially available.

The phenomenon of adsorption is not thoroughly understood. It can, however, be described in sufficiently accurate terms to form a useful mental image of it and its practical application.

Attention will be confined to the adsorption of gases by solids, since water-vapor is essentially a gas and its removal from mixtures of other gases is becoming an increasingly important process.

It has been found that an affinity exists between certain surfaces and the molecules of certain gases that causes gas to cling to the surface. We may say in effect that the gas is then condensed to a liquid, and a heat equivalent to the latent heat is given off. Furthermore, the application of heat releases this bond, and frees the adsorbent of its adsorbed gas.

---

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received September 9, 1937.

** Vice-President and General Manager, Pittsburgh Lectrodryer Corp., Pittsburgh, Pa.

Since the adsorbability of different gases by any given adsorbent is roughly proportional to the boiling point of the gases, this process of adsorption affords a means of separating certain gases from others in a mixture. Adsorption is probably a universal phenomenon, but certain substances can be so prepared as to show adsorption to a marked degree.

To be of commercial value such an adsorbent must have a high removal efficiency, a high adsorptive capacity, and freedom from

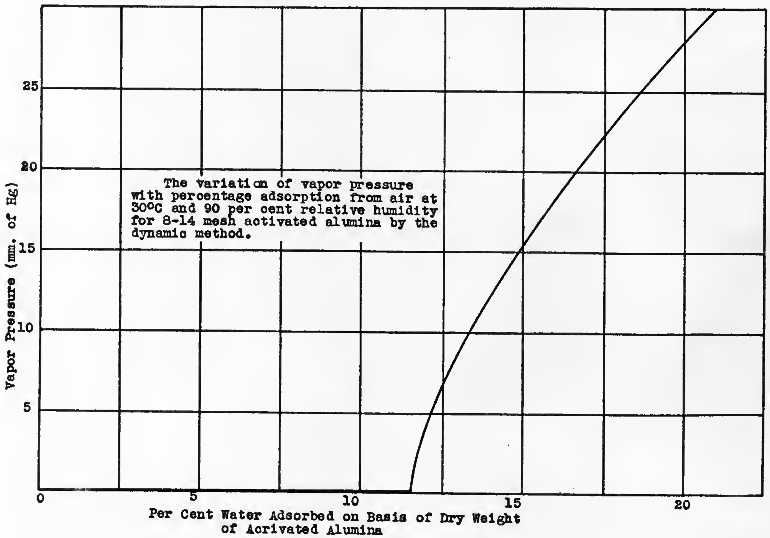


FIG. 1. Characteristic curve showing adsorption efficiency of activated alumina.

chemical reactions with the gases to be treated. It must also be available in large quantities at a price that can be warranted by the results attained through its use. Such a solid adsorbent is activated alumina.

Chemically this material is largely aluminum oxide. Physically its structure is such that a large adsorptive surface is available per pound of material. Since this material exhibits marked capacity to adsorb water-vapor from air and gases, it has wide commercial application.

Gases passed through beds of this material can be made extremely dry. A dryness equivalent to dewpoints below −76°C has been obtained. Fig. 1 shows the characteristic curve of the material under the conditions stated on the chart.

Taking advantage of this characteristic of activated alumina, air for the manufacture of liquid air is dried to extreme dryness in equipment similar to that shown in Fig. 2. Apparatus of the same type is used for drying carbon dioxide, ethylene, carbon monoxide, hydrogen, oxygen, and, in fact, practically all the commercially known gases.

More and more chemical and metallurgical processes are being conducted in controlled atmospheres. Sheet steel and strip in the past always had to be pickled after annealing to remove the scale formed through oxidation of the metal surface. This practice is now being discontinued. Great tonnages of sheet steel and strip are now coming out of the annealing furnaces with the same bright finish that they had when they entered. This is accomplished by the control of the chemical nature of the gases with which the heated steel comes in contact. Often this control requires reduction of the water-vapor content. Apparatus shown in Fig. 3 is utilized for drying the controlled atmospheres for annealing metals, to prevent the decarburization of high-carbon steel in heat treatment; and to prevent discoloration in the drawing furnaces.

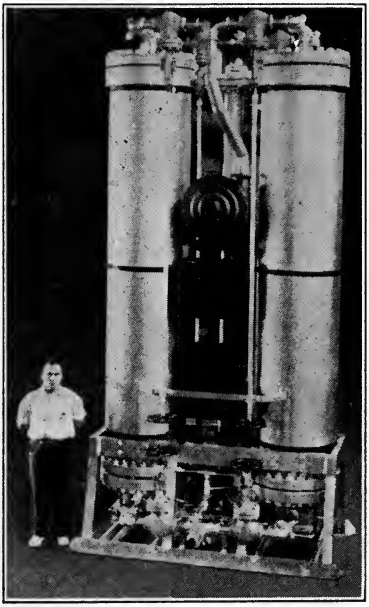


FIG. 2. Apparatus for drying air and other gases at high pressure.

Protective atmospheres are used also in the manufacture of paints and varnishes and other chemical products. This control again often involves the reduction of the water-vapor content.

Compressed air is freed from water-vapor in apparatus of this type so that it will not precipitate or freeze pipe lines or blow condensed water onto the work in spray booths or when testing or merely blowing the dust off parts in the process of manufacture.

We believe, however, that the motion picture industry will be more interested in applications involving comparatively large quantities of air partially dehumidified for the control of humidity in air-conditioning and in drying operations. In this instance factors of economy dictate a different method of attack in the utilization of a solid adsorbent.

Where continuous drying of the air and gas is desired, two or more adsorbers are used so that one may be reactivated before the

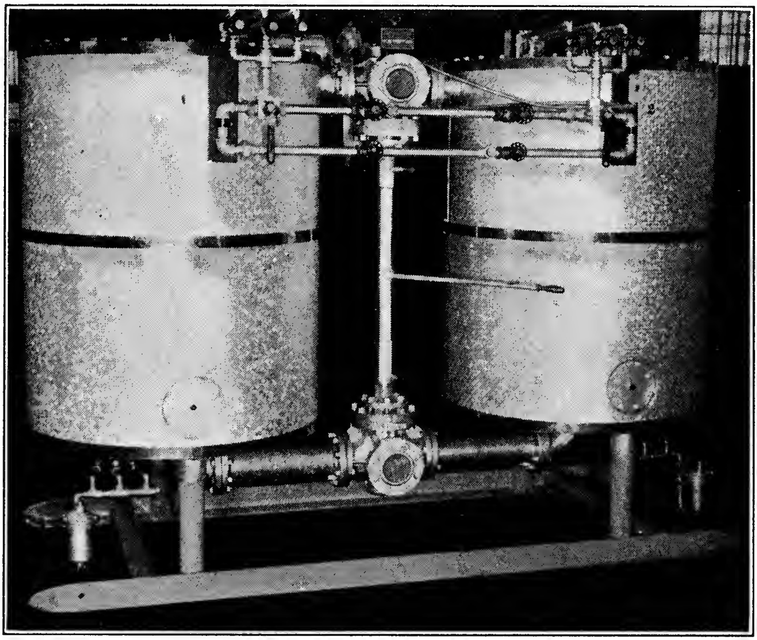


FIG. 3. Apparatus for drying controlled annealing atmospheres.

other has played out. The air-conditioning equipment we shall now discuss has eight adsorbers. Four of these adsorbers are on duty removing moisture from the air-stream; three are on reactivation; and a fourth is on the cooling or purge stage just prior to putting it back into service. As each adsorber plays out, it is put on reactivation and a fresh adsorber cut into the circuit. This is done by means of a rotating central distributor, the only moving part in the apparatus except the motor and blowers. Reactivation of the spent adsorbers is conducted continuously by means of a stream of heated air, and the purge serves to cool the heated adsorbers prior to putting them back into adsorption.

The performance of such apparatus is a function of machine design based upon the properties of activated alumina. A characteristic curve of these machines as now built is shown in Fig. 4.

This "Lectrodryer," as it is known in the trade, is essentially an apparatus for the reduction of the water-vapor content of the air. Air passed through this machine by its self-contained blower comes out dehumidified in accordance with the characteristic curve shown

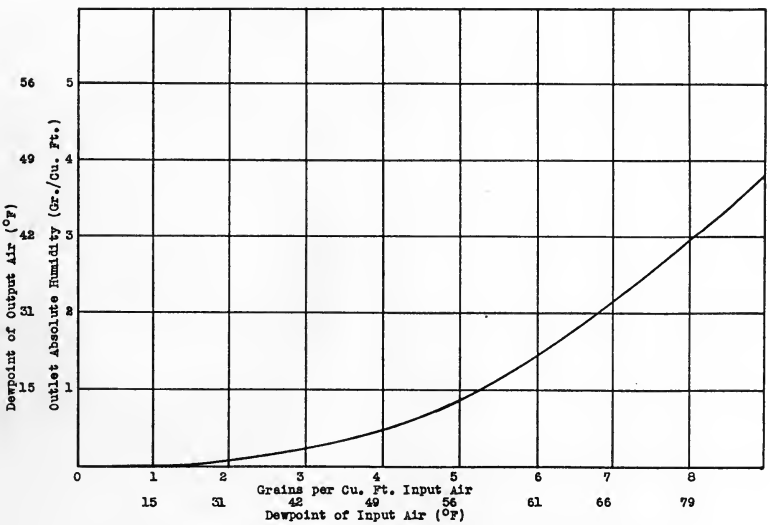


FIG. 4. Characteristic curve showing dryer performance.

above. In its passage through the machine this air is raised to a temperature of about 150°F. This is caused in part by the heat of adsorption but includes also some of the heat stored in the adsorbers during the reactivation stage.

In some applications this heated air is of use; for instance, where warm, dry air is needed for a drying operation. In other cases, as in air-conditioning, the heat must be removed before the dry air is used for dehumidification. This is then accomplished by after-coolers in the outlet stream, where either well water or city water or auxiliary refrigeration may be used.

In such a machine the heat energy required for reactivation will amount from $2^1/_2$ to 4 times the latent heat of the water adsorbed, depending upon the size of the machine and the moisture content of the input air.

Removal of water-vapor alone is often the most important single problem in industrial air-conditioning. A dehumidifier in the room to dry the air by recirculating it through the machine or an arrangement to feed partially recirculated and some fresh air through the dehumidifier, is utilized.

Fig. 5 shows a very simple case involving reduction of the water-vapor content in a storage room. No attempt is made to control the temperature. Materials stored here are highly hygroscopic, and large quantities were ruined by the weather annually until this apparatus was installed. Note the simplicity. The machine is placed right in the same room or in an adjoining room if more convenient. A single duct leads the dry air into the room and another duct returns it to the machine for redrying. The humidistat in the room turns on the machine automatically when the moisture content of the room rises above a predetermined figure, and shuts it off when the room is dry enough. In summer air-conditioning applications this dehumidifying unit may be combined with circulation, filtering, and sensible heat removal.

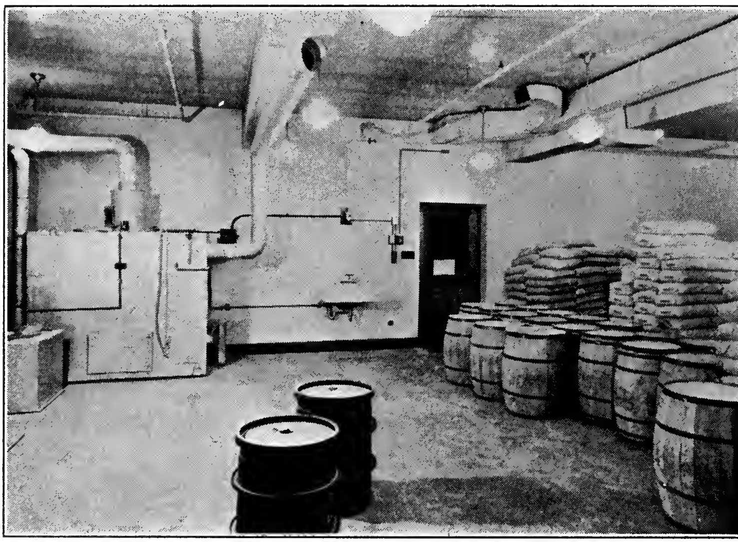


FIG. 5. Dryer for lowering water-vapor content of storage room.

Drying of most materials can be accomplished by simply using heated air. Some products, however, are affected by temperature so that it is not desirable to heat the material above a certain range. In these instances the humid summer air contains so much moisture that sufficiently low relative humidity for properly drying these products can not be obtained. This is either because the process is unduly prolonged or sufficient dryness can not be obtained during

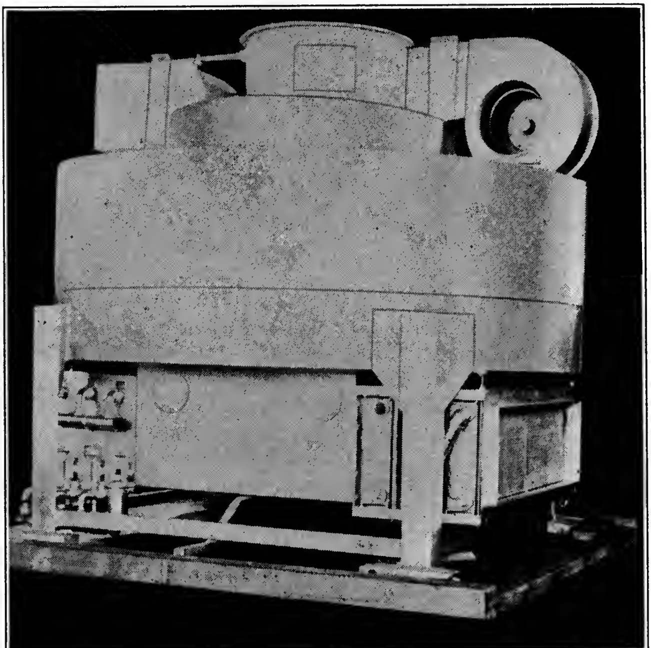


FIG. 6. Large apparatus for prevention of condensation of moisture due to evaporative cooling effect of solvents.

periods of high atmospheric humidity. In such instances the dehumidification of atmospheric air fed to drying cabinets, tray dryers, and drying lofts forms a very interesting solution to this problem. It is particularly important in such cases to remember that the normal output of an adsorption dehumidifier is warm, dry air. In considering the overall cost of dehumidified air due credit should be given to the heat energy available in the air dried this way.

In the manufacture of film base, water-vapor may be deposited in the material by cooling due to solvent evaporation. This may be avoided by using dehumidified air in the atmosphere surrounding the "wheels." Fig. 6 shows a machine used to condition over 15,000 feet of air per minute for just such an application.

In other applications the evaporation of solvents in the manufacture of mica insulation caused local cooling which precipitated water from the atmosphere; this was corrected by the installation of equipment for controlling the dewpoint of the air in the room in which the material is manufactured.

Hundreds of activated alumina dehumidifiers have been installed. They range in operating pressures up to as high as 3500 pounds per square-inch and in capacities in excess of 15,000 feet per minute. Frankly, we do not know for what purposes some of these machines are used. Engineers are investigating more and more the effects that water-vapor may be having on their processes or on their product.

DISCUSSION

MR. CARVER: In the diagram showing the rotary air switch you indicated that the air was passed through one of the driers in the opposite direction to get it ready. How is that done?

MR. SIMPSON: We did not draw the details in the lower part of the drawing. The distributor up to the mid-point is composed of three sections: the main stream, the reactivating stream, and a little stream that feeds air into the adsorber getting ready to go back into service. The latter purges the beds of the products of combustion and gas-burning equipment, and serves to take some of the moisture out of the bed. The stream of heated air is then returned to the reactivating stream.

MR. BRADLEY: Is there any self-contained unit suitable and practicable for studios and rooms having no outside outlet? I am thinking of human beings rather than of goods.

MR. SIMPSON: The machines made by my company are not yet developed for household or office installations.

MR. BRADLEY: Are such machines on the market?

MR. SIMPSON: I believe there are.

MR. CRABTREE: How frequently must the alumina be renewed? Is it poisoned in any way by use?

MR. SIMPSON: Anything that will paste up the structure or shut it off will poison it—sugar dusts, *etc.* With the inlets properly filtered, these machines have run for four and one-half years on the same charges. It is simply a question of keeping the dust and dirt out of the machine. The usual chemicals that will not poison men will not poison this material. Nitrous oxide and some of the other oxides of nitrogen, for instance, have some effect upon the material, but the quantities available in the normal processes are not enough to have any effect commercially upon the application of the machine. As a matter of fact, we are using just that property to remove nitrous and other oxides of nitrogen from certain controlled atmospheres where otherwise we would get very distinct corrosion of pipe lines due to the moisture content.

MR. CARVER: Must you use gas for reactivation, or can you use steam? Is it cheaper to use gas?

MR. SIMPSON: We want a stream of heated air. If it is cheaper to use gas, that equipment is available. If it is cheaper to use steam, that equipment is also available. In some cases we use electricity, where the fire hazard and the lack of steam make electric operation desirable. Many of these machines are running on gas, which is a particularly effective fuel and in many cases provides a distinctly inexpensive way to operate the equipment.

MR. BRADLEY: Is it possible to remove oxides of nitrogen in any great quantity? I am thinking about film fires, where the fumes and smoke represent a definite hazard to human health and life. Would it be possible to direct these fumes through such a machine and neutralize their toxic effects in large quantities?

MR. SIMPSON: That is a thought I certainly shall follow up. The concentrations with which we have dealt have been a matter of 1 and 2 per cent, cumulative, however, in pipe lines, and very corrosive. We shall certainly look into the possibility of removing much larger concentrations from air streams.

NEW MOTION PICTURE APPARATUS

During the Conventions of the Society, symposiums on new motion picture apparatus and materials are held in which various manufacturers of equipment describe and demonstrate their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.

THE SOUND-LEVEL METER IN THE MOTION PICTURE INDUSTRY*

H. H. SCOTT AND L. E. PACKARD**

Although sound-level meters have been commercially available for some time, it is only within the past year that they have attained their present high degree of popularity. One of the main reasons for this sudden acceptance by industry is, doubtless, the availability of new and improved models combining convenience of operation, low weight, and, in some cases, low price.

Probably few industries have as many important uses for a sound-level meter as the motion picture industry. Noise meters, as they were formerly called, have long been used for measuring the noise-levels in studios and theaters, the sounds made by various mechanical and electrical devices such as ventilators, cameras, projectors, arc lights, *etc.*, and for checking the volume of reproduction and the background noise-level from reproducing systems. Recent improvements in microphones, however, have made possible sound-level meters having reasonably smooth frequency characteristics, so that such instruments, unlike the earlier noise meters, are suitable not only for measuring complex noises, but are also quite satisfactory for many kinds of single-frequency measurements. Naturally, this has expanded the usefulness of the sound-level meter to include measurements of the overall frequency response of reproducing systems and variations in frequency response throughout a theater or auditorium.[1]

One of the newest sound-level meters is the General Radio Type *759-A*, which incorporates many features hitherto unavailable in even the most expensive instruments (Fig. 1). Aside from meeting the tentative specifications of the American Standards Association, the design of this new instrument stresses portability and convenience of operation, which characteristics are of utmost importance to the user. Among its many features are a non-directional sound-cell microphone, a high-gain stabilized amplifier, the absence of all battery adjustments, a practically linear decibel meter, and a simple system for resetting the calibration.

To mention the features in more detail, the sound-cell microphone provides a rugged and sensitive sound pick-up device with a smooth, nearly flat frequency

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received October 1, 1937.

** General Radio Company, Cambridge, Mass.

response over the important frequency range, practically free from directional effects. Such a device is unaffected by ordinary changes of temperature and humidity, and even unusually low temperatures produce only a small change of sensitivity, for which correction can easily be made, if desirable.

In the interests of convenience the microphone is mounted upon a folding bracket on the top of the sound-level meter, and turns down into a compartment cast in the panel when not in use. This makes it unnecessary to unwind any cables or plug in the microphone each time a measurement is made, since, under normal conditions of use, the microphone is always connected directly to the instrument. Provision is made, however, for removing the microphone from the

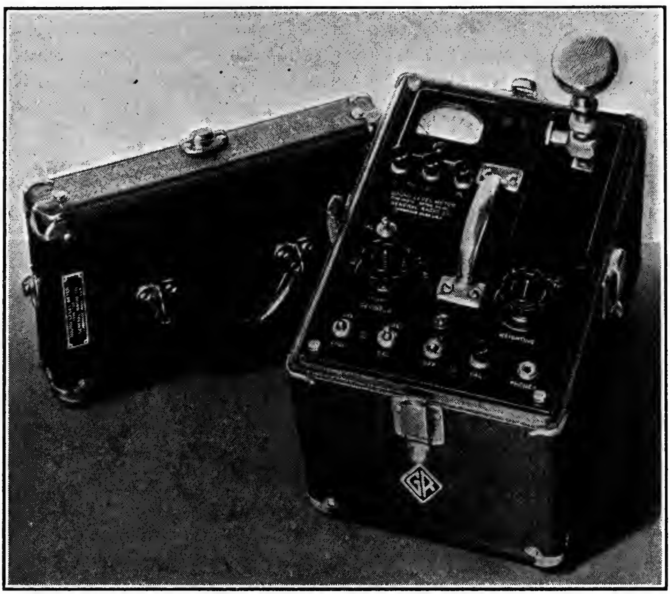


FIG. 1. Type *759-A* sound-level meter.

sound-level meter and using it on a cable, for the few applications where such an arrangement is desirable. A special cable and tripod are available for this purpose.

The amplifier circuit itself is of the resistance-capacitance coupled type, using pentodes. By proper design of the screen-supply circuits an unusually high degree of stability of gain has been achieved, so that it is seldom necessary to reset the calibration control as the batteries wear out. Another feature of the amplifier circuit is the extremely low battery drain, the total plate current being only 2 milliamperes. Naturally, this allows the use of very small batteries. Also, an amplifier circuit of this type requires no transformers or other heavy components.

The use of a ballast tube in the filament circuit and of the stabilized amplifier circuit makes all filament current or battery adjustments quite unnecessary. This is a great convenience, since it is not necessary to adjust any battery controls when putting the instrument into operation. Push-buttons are provided on the panel for indicating directly on the "Decibels" meter the condition of the batteries—a red line on the meter indicates when the batteries should be replaced. Accordingly, except for occasionally pushing the battery-test buttons to be sure that the voltages are sufficiently high to provide stable operation, it is never necessary to pay any attention to the batteries. When it does become necessary to change the batteries, the change is accomplished easily and quickly, since the battery-box cover is provided with spring contacts that automatically make the proper connections to the batteries when the cover is fitted in place.

The use of small batteries and an amplifier circuit requiring no transformers results in an unusually light instrument. The elimination of transformers also minimizes the possibility of inductive interference. The main panel and microphone housing are a single aluminum casting which is light but rigid. The whole instrument is housed in an "airplane-luggage" case made of light-weight plywood covered with leatherette and completely shielded electrostatically. The resulting instrument is small and light, and attractive in appearance.

Because of the high gain of the amplifier (approximately 140 db.) it is naturally necessary to make some provision for insulating the vacuum-tubes against mechanical shock in order to minimize microphonic pick-up in the tubes themselves. This is accomplished by special rubber bushings which support the complete amplifier assembly. All the heavier parts of the amplifier, such as by-pass condensers, *etc.*, have been mounted on this assembly, and the rubber mountings have an extremely low deflection rate for small deflections, thus providing a long natural period of oscillation for the sub-assembly. The rubber mountings are so designed, however, that the deflection rate increases rapidly as the deflection is increased, thus providing a snubbing action and making it impossible to damage the instrument in ordinary handling or jarring.

Convenience of operation has been considered of paramount importance in the design of the new sound-level meter. The main attenuator is adjustable in 10-db. steps, and, as previously mentioned, the indicating meter, which actually covers a range of 16 db., has a scale that is practically linear, which is achieved by the use of shaped pole-pieces. Three weighting networks are provided, in accordance with the A.S.A. standards, including the 40-db., 70-db., and flat networks. The first two of these networks are used for low-level and medium-level measurements, respectively, while the flat network is used generally for high-level measurements and for measuring frequency response. Fig. 1 shows the general appearance of the instrument. In particular, the arrangement of the panel, the clear lettering on the panel and on the meter scale, and the novel microphone mounting should be noted. All necessary operating instructions are fastened permanently inside the lid of the cabinet.

One extremely convenient feature of the new instrument is the method of resetting the calibration. Although the amplifier used in this device has an unusual degree of stability, it was not considered desirable to rely upon this factor entirely for maintaining the permanence of calibration. Accordingly, provision is made so that the amplifier gain may be reset quickly and easily at any time. The arrangement consists essentially of applying a voltage through an attenuator to the input of the amplifier. The magnitude of this voltage and the output of the amplifier are indicated alternately on the "Decibels" meter when the calibration button is pressed. If the readings are alike the gain is correct. If the readings are not alike a screw-driver control may be adjusted to reset the calibration to its factory value. Ordinarily the alternating voltage for making this test is obtained from commercial power lines, a connecting cord being provided for the purpose. In the absence of a-c. power lines, however, an audio-frequency oscillator or other similar device may be used.

In order to test the sound-level meter under actual field conditions, a large number of measurements have been made, including most of the important problems to which the sound-level meter is applied (Fig. 2). The following information is not presented as an exhaustive survey of theater conditions, but merely to give an idea of conditions in what seems to be a typical suburban theater. The measurements were made in the University Theater at Cambridge, Mass., which has a seating capacity of about 2000 persons.

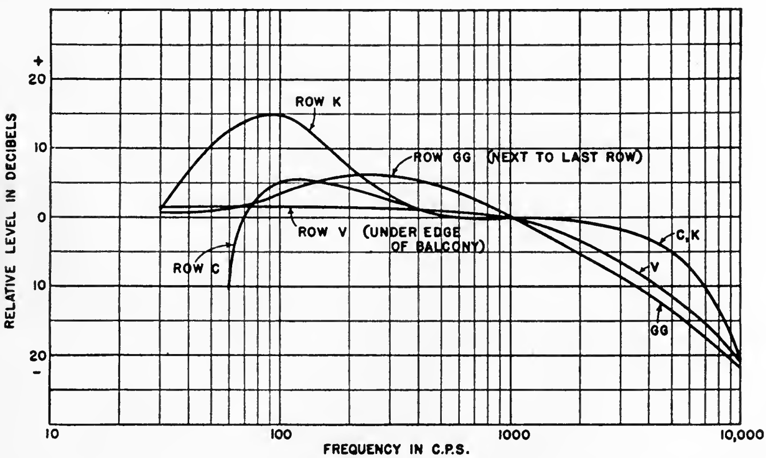


FIG. 2. Variations of frequency response in center seats of motion picture theater.

The initial noise-level in this theater—that is, with all air-conditioning and mechanical equipment shut off—is about 26 db. A loud street noise, such as a pneumatic drill, may raise the level to as high as 32 db., which, as will be noted later, is considerably below the normal noise-level within the theater when the air-conditioning equipment is in operation. Accordingly, it appears that the theater is quite satisfactorily insulated from outside noises.

Turning on the air-conditioning equipment raises the noise-level in the theater by nearly 20 db. in some locations. For instance, in the front orchestra seats the total noise-level with the air-conditioning equipment in operation is approximately 45 db. The level, however, decreases toward the back of the theater, reaching a minimum of approximately 37 db. in the rear rows and 41 db. in the balcony.

Measurements made of the loudness of reproduced speech and music in this theater seem to be about average.[2] Speech sounds, for instance, were around 70 to 72 db., while music reaches 80 db. or higher. The background noise in the theater during the program, which includes, aside from the noises previously mentioned, the audience noise and the noise from the reproducing system, is approximately 54 db.

Frequency characteristics were taken at various positions in the theater in order to determine the changes in frequency response with location. Some of these data are shown in Fig. 2, which indicates clearly how the frequency response changes in the center of the theater between the front seats and the rear seats. The effect of the balcony upon the high frequencies is particularly noticeable and readily accounts for the decrease in articulation under the balcony.

Data such as these are invaluable to the theater owner or operator, since they show readily how well the various portions of the audience are actually hearing the reproduced sounds. As a result of such measurements it is frequently possible, by proper acoustical treatment or by changes or additions in the speakers or tweeters, to improve noticeably the quality of reproduction throughout the theater.

The data shown here were obtained by merely connecting a beat-frequency oscillator to the input of the amplifying equipment. Obviously, similar runs may be made when using a constant-frequency film in the projectors, thus obtaining an overall measure of the reproduction, including the optical equipment. No particular difficulties were encountered due to standing waves when making measurements at the higher frequencies, but there was some trouble from this source at the lower frequencies. Accordingly, it would be desirable, where extreme accuracy was warranted, to use a warble tone to minimize the effects of standing waves.

The authors wish to express their appreciation to Messrs. S. Sumner and C. W. Parshley for the use of the University Theater during these tests and to Mr. O. B. Asten of Electrical Research Products, Inc., for his coöperation in carrying out the tests.

REFERENCES

[1] "The Technique of Noise Measurement," Bulletin 20, *General Radio Co.*, Cambridge, Mass.

[2] WOLF, S. K., AND SETTE, W. J.: "Factors Governing Power Capacity of Sound Reproducing Equipment in Theaters," *J. Soc. Mot. Pict. Eng.*, **XV** (Oct., 1930), No. 4, p. 415.

WOLF, S. K., AND SETTE, W. J.: "Progress in the Acoustics of Sound Recording and Reproduction for Motion Pictures," *Rev. Sci. Instr.*, **VII** (Sept., 1936), No. 9, p. 323. Note that the decibel ratings mentioned in these papers are referred to the threshold of audibility. The new sound-level meters use 10^{-16} watts per sq. cm. as reference level. Accordingly, for any given sound a new standard sound-level meter will read approximately 7 db. higher than if the measurement were referred to the threshold of audibility.

DISCUSSION

MR. KELLOGG: To what level are the decibels referred; to the threshold of hearing or some arbitrary level.

MR. SCOTT: The American Standards Association has, within the past year or so, set a new standard reference level, which is about 7 db. below what we used to regard as the threshold. The new level is 10^{-16} watt per sq. cm. Compared to earlier sound-level meters, this one reads about 7 db. higher.

MR. RICHARDSON: What are supposed to be the practical benefits of the instrument in a theater? Does it in any way aid the projectionist in adjusting the sound-level?

MR. SCOTT: In some theaters the instruments have been found quite useful for checking the level of reproduction as well as for making other measurements as described in the paper. It is possible to mount the microphone anywhere in the auditorium and run an extension cable to the instrument, which can be in the projection room, and thus to keep an actual acoustical check on the level in the auditorium.

COMPLETE CUE-MARK ELIMINATION AND AUTOMATIC CHANGE-OVER*

S. A. MACLEOD**

The change-over system described here has been developed for the purpose of eliminating faulty change-overs in the process of projecting motion picture film. This equipment makes instantaneous, precise, automatic change-overs from one projector to another, and never fails to make the complete change-over at exactly the correct moment.

The system eliminates necessity for visual cue marks of any type, such as are now placed on film by projectionists and by producers in processing the film, and consequent replacements by the exchanges due to such marking and mutilation are avoided. The system also reduces fire hazard considerably.

Change-overs done by this system are not visible to the eye. Faulty changes from one projector to the other are entirely eliminated. Not a single frame of the picture or one spoken word of the sound record is lost. Fade-out changes are properly timed, and perfect continuity of both picture and sound is assured.

More efficient use of curtains, lights, and other effects used in modern motion picture theaters is afforded by relieving the projectionist of much eye-strain and tension in his work and permitting him to devote more attention to the actual management of his projection room and to the supervision and maintenance of his equipment.

Projectionists have often been unjustly criticised for their inability to see the indistinct and mutilated cues placed upon the films. Under the best of conditions, cues can be missed. The cues inserted by the producers are often indistinct because of the background. Many films, therefore, are mutilated by the projectionists in their many efforts to create satisfactory cue marks. These cues may consist of grease pencil marks, sticker, punches, scratches with sharp instruments, notches cut out of the edges, or tinfoil glued to the film. They may

---

* Presented at the Spring, 1937, Meeting at Hollywood, Calif.

** Automatic Change-Over Company, Los Angeles, Calif.

be placed at various distances from the end of the film, and the last projectionist running such film is left with the alternative of calculating and interpreting the previous timing, or of adding a new mutilation or cue-mark of his own.

The equipment is fully automatic in operation. It is not necessary for the projectionist to operate any switch, or otherwise assist in the functions of starting the projector motors, or of timing and operating the dowsers and fader in their proper order. The electrical circuit is so arranged that the regular motor switches, dowser switches, and sound change-over device (fader or key) may be used at any time independently of the A. C. O. Upon installation, the regular controls usually employed in the projection room need not be changed, removed, or altered in any way.

The equipment consists of the following units which combine to render the device completely automatic:

FIG. 1. Mounted film cue clips, finger up.

Film cue-clips are attached by means of a side-plate to the film reels. When set by the projectionist when the film is rewound, these clips predetermine the exact time at which the desired change-over shall take place. The unwinding film releases each finger or cue-clip at the proper time. The release of the finger or cue-clip actuates plunger shafts within the spindle and operates mercury switches contained within the top-magazine switch housing. The mechanical features of this arrangement have been thoroughly tested over a period of several years and have proved to be dependable and satisfactory.

The system includes a pair of top-magazine spindle assemblies and mercury switch housings, one of which is installed on each projector in place of the regular spindle on the top-magazine bracket. The assembly is easily mounted on the top-magazine hanger casting with two set-screws. The A. C. O. spindle takes the place of the old one. No electric wires, contactor, switches, *etc.*, are used inside the upper film magazine. The spindle shafts are standard for use on any 35-mm. projection equipment. Spindles are fitted with a specially designed brake mechanism, permitting exact adjustment of film tension at any time even while the projector is in operation.

Economies that the A. C. O. can be expected to effect are noticeable in the saving of carbons and electric power. No long period of waiting is required for visual motor-start and change-over cues to appear upon the screen, during which time the operator must necessarily burn both projector arcs.

The A. C. O. System performs three distinct operations, automatically:

(*1*) At a proper predetermined point the A. C. O. takes its cue from the film being projected, and, automatically actuates a switch, starting the oncoming projector motor. This motor-start may indicate to the projectionist that he should strike the arc on the incoming projector.

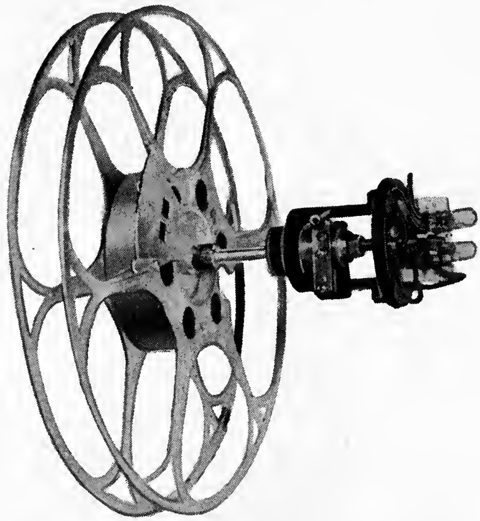


FIG. 2. Top-magazine spindle (*open*) mounted on reel.

(*2*) At the next predetermined point the A. C. O. takes another cue from the film being projected, and actuates the switch that controls the dowsers.

(*3*) At the second predetermined point the switch controlling the sound change-over is actuated. Both the dowsers and the sound change together.

There can be neither black nor white screens, nor the loss of a single spoken word. Being electrical and mechanical in operation, change-overs made by the A. C. O. are not subject to human failure or error and leave nothing to chance.

The control cabinet unit (115 volt a-c. 3 amp.) is mounted on the projection room wall, usually between the projection machines, conveniently accessible to the projectionist. It comprises a centralized control, through automatic mechanical-electrical interlocks, which governs the operations of starting and stopping the motors and making the various changes of dowsers and sound. A convenient switchboard enables the projectionist to operate the equipment at will with the greatest flexibility and selectivity.

The dowsers are designed to fit each projector head and are a standard part of the equipment. They are small and compact, neatly designed, durably constructed, and very efficient in operation. The dowser shutter travels only $^3/_4$

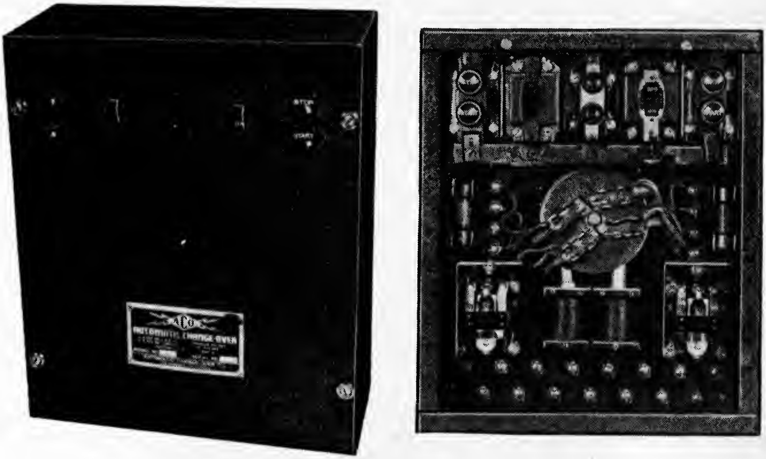


FIG. 3. Main control cabinet; (*left*) exterior; (*right*) interior.

inch and its action is very fast and practically noiseless. The magnetic coils have a large overload capacity and all fittings are extra-heavy. The dowsers are specially designed to operate with the A. C. O. change-over equipment, but may also be operated separately and independently if desired. Any other

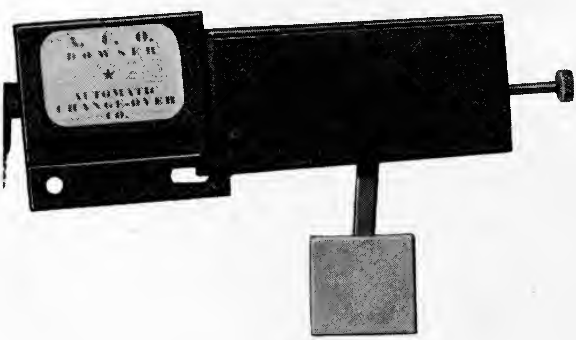


FIG. 4. A. C. O. dowser.

standard dowser will also operate satisfactorily when used in conjunction with A. C. O. equipment.

The A. C. O. equipment has been thoroughly tested in actual theater operation over a period of six years, and has proved conclusively that it meets all of the essential requirements.

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 copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C.

British Journal of Photography

85 (Jan. 14, 1938), No. 4054

Reducing Projector Noise (16-mm.) (p. 25). — T. E. Langlands

Communications

18 (Jan., 1938), No. 1

Design of Resistance-Coupled Amplifiers (p. 11). — E. J. Rhoad

Amplification Problems of Television (p. 15). — F. A. Everest

Production Development of Television Tubes (p. 24).

Electronics

11 (Jan., 1938), No. 1

Reviewing the Video Art (p. 8).

Wide-Band Television Amplifiers (p. 16). — F. A. Everest

Cathode-Ray Phasemeter (p. 24). — S. Bagno and A. Barnett

Home Facsimile Recording (p. 26). — S. Ostrolenk

Filmtechnik

13 (Dec., 1937), No. 18

Aufgaben des Kinoverstärkers (Motion Picture Amplifier Problems) (p. 205–6) — R. Wigand

International Projectionist

13 (Jan., 1938), No. 1.

Analyses of Modern Theater Sound Reproducing Units (p. 14). — A. Nadell

Film Aperture Decision Rests Ill with Rest of Experts (p. 20). — H. Griffin

Projecting Hi- and Low-Range Prints; Standard Fader Setting Data (p. 24).

Journal of the Acoustical Society of America

9 (Jan., 1938), No. 3

An Improved Magnetostriction Oscillator (p. 185). — G. W. Pierce and A. Noyes, Jr.

Theoretical and Experimental Investigation of the Transmission of Sound over Reflecting Surfaces (p. 193). — G. W. PIERCE AND A. NOYES, JR.

Variations in Sound Absorption Coefficients as Obtained by the Reverberation Chamber Method (p. 234). — R. M. MORRIS, G. M. NIXON, AND J. S. PARKINSON

The Predetermination of Speech Levels in Auditoria with Coupled Spaces (p. 244). — G. E. MORISON

Journal of the British Kinematograph Society

1 (Dec., 1937), No. 1

The Design of Special Telephoto and Wide Aperture Lenses (p. 3). — K. J. HABELL

The Functions of a Director in the Making of a Film (p. 8). — V. SAVILLE

The Standardization of Camera Exposure in Kinematography (p. 20). — P. E. SMETHURST

Studio Control Systems (p. 33). — M. F. COOPER

Kinematograph Weekly

251 (Jan. 13, 1938), No. 1604

All Facilities Offered by the Denham Laboratories (p. 163).

Beauty of Negative-Positive Dufaycolor (p. 165).

Kinematograph Weekly

251 (Jan. 20, 1938), No. 1605

A Survey of Last Year's Technical Progress (p. 63). — R. H. CRICKS

New Camera and Disk Recorder (p. 68).

Kinotechnik

19 (Dec., 1937), No. 13

Zur Theorie des Donnereffektes und seiner Abhängigkeit vom Gammawert (Theory of the Donner Effect and Its Dependence on the Gamma Value) (p. 305). — A. NARATH

Einfluss der photographischen Behandlung auf den Donner-Effekt von Tonaufnahmen in Zackenschrift (Influence of Photographic Treatment on the Donner Effect on Sound Exposures in Variable-Width Recording (p. 311). — H. HÖRMANN AND A. KÜSTER

Motion Picture Herald (Better Theatres Section)

130 (Jan. 8, 1938), No. 2

Relative Characteristics of Low- and High-Intensity Projection Light (p. 30). — E. R. GEIB

130 (Feb. 5, 1938), No. 6

The Practical Theater Man's Approach to Acoustic Problems (p. 23).

A New Maintenance Weapon; Electrostatic Air Cleansing (p. 30).

What to Do While Waiting for the Sound Service Engineer (p. 35). A. NADELL

Photographische Industrie

36 (Jan. 12, 1938), No. 2

Rückblick auf die Kinotechnik 1937 (Glance at Motion Picture Technical Progress for 1937) (p. 45).

RCA Review

2 (Jan., 1938), No. 3.

Direct-Viewing Type Cathode-Ray Tube for Large Television Images (p. 289). I. G. MALOFF

Television Cathode-Ray Tubes for the Amateur (p. 297). R. S. BURNAP

A New System of Remote Control (p. 303). C. N. KIMBALL

Effects of Space-Charge in the Grid-Anode Region of Vacuum Tubes (p. 336). B. SALZBERG AND A. V. HAEFF

Television

11 (Jan., 1938), No. 119

A New Emitron Camera with Greatly Increased Sensitivity (p. 11).

Projection Tubes (p. 13). V. K. ZWORYKIN AND W. A. PAINTER

How Cossor Television Receivers are Tested (p. 24).

ABC of Magnetic Scanning (p. 26). G. PARR

SPRING, 1938, CONVENTION

WARDMAN PARK HOTEL
WASHINGTON, D. C.
APRIL 25th–28th, INCLUSIVE

Officers and Committees in Charge

W. C. KUNZMANN, *Convention Vice-President*
J. I. CRABTREE, *Editorial Vice-President*
G. E. MATTHEWS, *Chairman, Papers Committee*
W. WHITMORE, *Chairman, Publicity Committee*
E. R. GEIB, *Chairman, Membership Committee*
N. D. GOLDEN, *Chairman, Local Arrangements Committee*

Local Arrangements and Reception Committee

N. D. GOLDEN, *Chairman*

D. BENNETT
J. G. BRADLEY
H. T. COWLING
A. A. DETITTA
R. EVANS
N. GLASSER
C. L. GREGORY
N. C. HAEFELE
A. MUTO
R. F. NICHOLSON
W. K. PETTUS
J. A. PRATT
R. T. SCHLOSBERG
C. S. STODTER

Registration and Information

W. C. KUNZMANN, *Chairman*

E. R. GEIB
S. HARRIS
F. HOHMEISTER

Ladies' Reception Committee

MRS. R. EVANS, *Hostess*
assisted by

MRS. J. G. BRADLEY
MRS. H. T. COWLING
MRS. A. A. DETITTA
MRS. N. GLASSER
MRS. N. D. GOLDEN
MRS. S. B. RIDDICK
MRS. N. C. HAEFELE
MRS. A. MUTO
MRS. J. A. PRATT

Banquet Committee

R. EVANS, *Chairman*

J. G. BRADLEY
H. T. COWLING
A. A. DETITTA
N. GLASSER
N. D. GOLDEN
N. C. HAEFELE
W. C. KUNZMANN
A. MUTO

Publicity Committee

W. WHITMORE, *Chairman*

J. R. CAMERON
A. A. DETITTA
J. J. FINN
S. HARRIS
F. HEARON
G. E. MATTHEWS
P. A. MCGUIRE
A. MUTO
F. H. RICHARDSON

Convention Projection Committee

H. GRIFFIN, *Chairman*

G. FRIEDL, JR.
N. C. HAEFELE
H. F. HEIDEGGER
W. HOLZ
W. K. PETTUS
J. FRANK, JR.
J. A. PRATT
F. J. STORTY

Officers and Members of Washington Projectionist Local 224.

Apparatus Exhibit

S. HARRIS, *Chairman*

J. FRANK, JR.
O. F. NEU
J. H. KURLANDER

Membership Committee

E. R. GEIB, *Chairman*

J. G. BRADLEY
R. EVANS
S. HARRIS
J. A. PRATT

Hotel and Transportation Committee

J. G. BRADLEY, *Chairman*

D. BENNETT
F. HEARON
C. A. LINDSTROM
R. F. NICHOLSON
R. T. SCHLOSBERG
C. S. STODTER

Headquarters

The headquarters of the Convention will be the Wardman Park Hotel, where excellent accommodations are assured. A reception suite will be provided for the ladies, for whom also is to be arranged an interesting program of entertainment.

By special arrangement with the Hotel Management, special breakfast, luncheon, and dinner service will be provided on the Continental Room Terrace, for SMPE delegates only.

The following daily hotel rates, European plan, are guaranteed to SMPE delegates attending the Convention:

One person, room and bath	$ 3.50
Two persons, standard bed	5.00
Two persons, twin beds	6.00
Parlor suite, one person	9.00
Parlor suite, two persons	11.00

Room reservation cards will be mailed to the membership of the Society in the near future, and those who plan to attend the Spring Convention should return their cards promptly to the Wardman Park Hotel to be assured satisfactory accommodations. Local railroad ticket agents should be consulted with regard to trains and rates.

For those who will motor to the Convention ample free parking space is available on the Hotel grounds. For those who prefer parking in the Hotel garage a special rate of 75 cents a day has been arranged.

Technical Sessions

An attractive and interesting program of technical papers is being assembled by the Papers Committee. All technical sessions, apparatus symposiums, and film programs will be held in the *Little Theatre* of the Hotel.

Apparatus Exhibit

An exhibit of newly developed motion picture apparatus will be held, to which all manufacturers of equipment are invited to contribute. No charge will be made for space. Information concerning the exhibit and reservations for space should be made by writing to the General Office of the Society.

Apparatus displayed should be newly designed or developed, or should have features of technical interest for the engineers attending the Convention.

Registration and Information

The Convention registration headquarters will be located at the entrance of the *Little Theatre,* where all the technical sessions will be held. The members of the Society and guests attending the Convention are expected to register and receive their badges and identification cards for admittance to special evening sessions. These cards will also be honored at several *de luxe* motion picture theaters in Washington during the four days of the Convention.

Informal Luncheon and Semi-Annual Banquet

The usual informal Luncheon will be held at noon of the opening day of the Convention, April 25th, in the Continental Room of the Hotel. On the evening of Wednesday, April 27th, will be held the Semi-Annual Banquet of the Society, also in the Continental Room, at 8:00 P.M. Addresses will be delivered by prominent members of the industry, followed by dancing and other entertainment.

Motion Pictures

Delegates registering at the Convention will be supplied with complimentary passes to the following motion picture theaters in Washington during the dates of the Convention:

By courtesy of Mr. J. J. Payette: Warners' *Uptown* and *Earle* Theaters.
By courtesy of Mr. H. Meiken: *RKO Keith's* Theater.
By courtesy of Mr. C. Barron: Loew's *Capitol, Palace,* and *Columbia* Theaters.

Ladies' Committee

A number of interesting events are being planned by Mrs. R. Evans, *Hostess,* and the Ladies' Committee. On Monday, April 25th, at 5 P.M. Mrs. Franklin D. Roosevelt has kindly consented to receive the ladies of the Convention at the White House. All those who intend to be present at the reception should transmit their names as early as possible to Mr. W. C. Kunzmann, *Convention Vice-President,* at the General Office of the Society, Hotel Pennsylvania, New York, N. Y.

Recreation

The Wardman Park Hotel management is arranging for golfing privileges for SMPE delegates at several courses in the neighborhood. Regulation tennis courts are located upon the Hotel property, and riding stables are within a short distance of the Hotel. Trips may be arranged to the many points of interest in and about Washington.

Points of Interest

To list all the points of interest in and about Washington would require too much space, but among them may be mentioned the various governmental buildings, such as the Capitol, the White House, Library of Congress, Department of Commerce, U. S. Treasury, U. S. Bureau of Standards, Department of Justice, Archives Building; and other institutions such as the National Academy of Sciences, the Smithsonian Institution, George Washington University, Washington Cathedral, Georgetown University, *etc.* In addition may be included the Lincoln Memorial, the Washington Monument, Rock Creek Park, The Francis Scott Key Memorial Bridge, Arlington Memorial Bridge, the Potomac River, and Tidal Basin. Mt. Vernon, birthplace of Washington, is but a short distance away and many other side trips may be made conveniently *via* the many highways radiating from Washington.

ABSTRACTS OF PAPERS OF THE SPRING CONVENTION

AT

WASHINGTON, D. C.

APRIL 25–28, 1938

The Papers Committee submits the following abstracts of papers for the consideration of the membership. It is hoped that the publication of these abstracts will encourage attendance at the meeting and facilitate better discussion of the papers.

Report of the Progress Committee; J. G. Frayne, *Chairman.*

The outstanding event in cinematography during the past year was the development of the high-speed panchromatic emulsions by the Agfa Ansco Corporation. Other interesting advances in the emulsion field are the development of two fine-grain duplicating film stocks by the Eastman Kodak Company. Of interest also is the new sound emulsion developed by Dupont in which the periodic variation in sensitivity brought about by the present emulsion-drying methods has been eliminated.

In the sound-recording field, items of interest are the introduction of linear decibel volume indicators by United Artists Studio and the introduction by RCA of the modulated high-frequency method of determining optimal processing conditions.

"Sound Stages and Their Relation to Air-Conditioning"; C. M. Wert and L. L. Lewis, *Carrier Corp.*, Syracuse, N. Y.

The development and growth of the modern motion picture sound stage has almost paralleled that of sound pictures. Weather and advancement of lighting technic undoubtedly brought about original need of enclosed stages. Advent of sound recording brought about requirements not originally considered. Modern sound stages have increased not only in quality but in size. The modern sound stage must have structural strength to withstand the elements, including earthquakes. It must meet requirements of set construction, sound-proofing, and occupancy. Sound treatment makes necessary other treatment for satisfactory occupancy. Lighting on the sound stage is the greatest contributor of heat gain within the stage. Lighting is variable as to amount and duration, and must be controlled correctly. Size and number of sets are very variable and create their individual problems. Both the number and types of persons present on a sound stage play their parts in the relation between air-conditioning and the sound stage.

Construction that retards the flow of heat in either direction through walls necessitates the addition and removal of the heat. Lighting on a sound stage is of such magnitude that its effects must be removed. High-salaried personnel, often in costume, demand comfort while working. Management is obviously economically in better position if personnel is comfortable; less time is lost due to make-up retouching and less delay brought about by perspiration dampened costumes.

An air-conditioning system should have the ability to provide heating, cooling, ventilation, and cleaning. Heat in the air rising to the top of the stages should be removed by an exhaust system. Stages are generally maintained at 75°F and 50 per cent relative humidity, with temperature settings above and below at the option of the occupants. Floor distribution of air has the advantage of more economical removal of rising heat but has the practical disadvantage of placing set construction and personnel too near source of cooling. Overhead distribution has the advantage of better temperature distribution but is less economical in the removal of rising heat from lights.

Sound treatment of an air-conditioning installation is necessary for continuous operation of the system. If the system does not operate continuously the heat load builds up to the point where the system can not adequately regain comfortable conditions during non-shooting periods. Treatment is accomplished by both isolation and absorption of generated sound, and can be so accurately determined that a guarantee of the increase in noise level can be given in decibels and in relation to frequency ranges.

"Motion Picture Projection from Metallic Film"; R. W. Carter, *Taylor-Sloane Corp.*, New York, N. Y.

A brief history is given of the various processes for putting photographic images on metallic surfaces and the evolution from flat surfaces to flexible metal ribbons is discussed. The subject of metal films is traced under the following headings: The physical and mechanical difficulties in the development of a metal strip suitable for projection. The physical, chemical, and mechanical properties necessary for the photographic emulsions and photographic developers. The effect of mechanical strain and the heat of the projection machine upon the metal film. The relative wearing quality of metal film as compared with that of cellulose film. The possibilities of coating both sides of the metal strip and the development of printing machines to print thereon. Making original master negatives on standard photographing equipment. Dubbing positive prints from the master metal negative. The optical system best adapted for getting the highset possible reflection from the polished surface of the metal film. The comparison of light transmission from celluloid and metal films. The effect of heat upon the image on a metal film. Can a metal film be joined rapidly if it comes apart? A comparison of shrinkage between metal film and cellulose film. What evidence have we of the permanence of metal film? Will it be possible to develop color on metal film, and will the use of prisms make it possible for successful projection? What changes will the operator have to make in technic and general practice? Why will the sound be more accurate from a reflected image? Will it be possible in the future to use a series of sound-tracks in various languages on the metal film? With the elimination of the fire hazard, shrinkage, and the introduction of less weight and positive permanence, what are the chief defects to be expected in metal film, and what is proposed to overcome these defects?

"Documentary Film Study—a Supplementary Aid to Public Relations"; A. A. Mercey, *School of Public Affairs, The American University*, Washington, D. C.

Documentary films are proving of increased importance as a factor for informing and mobilizing opinion. The marked success of two U. S. documentary films, *The Plow That Broke the Plains* and *The River*, both written and directed by Pare Lorentz, has focused new attention upon this type of film. The school of Public Affairs of American University conducts an "in-service" training school for government employees whereby registrants obtain instruction in courses and subjects from experts in various Federal departments. Included in these curricula are a series of courses on public relations. The film as a factor in public relations is an important one. In answer to requests for some information and instruction in this new field, a course in "Documentary Films Today" was instituted.

The film course included an eight-week study with screenings, film analyses, and discussions conducted by visiting experts in film-making and film use. The subjects covered were: The newsreel as contemporary historian; the *March of Time* as a document; federal, educational, and scientific films; U. S. Government documentary films; documentary aspects of Hollywood films; foreign documentaries; industrial, sales, and domestic propaganda films. During the eight-week period, visiting experts included a government producer, an industrial film user, an educator, and others. Technical aspects with reference to advances in film production were discussed.

In addition to regular film discussion and study, a number of reports were made on documentary film activities. Among the most important was one on a federal film survey. For the first time, a complete survey of all U. S. government films is being made that will compile in one place the data on motion pictures. A standardized type of procedure was outlined.

"The Determination of Correct Exposure in Photography"; L. A. Jones, *Kodak Research Laboratories*, Rochester, N. Y.

Many treatments of this subject, some dealing with certain specific phases, and some fairly complete, are to be found in various textbooks and scientific journals in the field of optics and photography. In spite of this, however, there seems to be some uncertainty in the minds of some relative to the correct manner of dealing with the problem. The present treatment is distinctly of a tutorial character, an endeavor being made to present the problem in a clear and systematic fashion. Much of the existing confusion is doubtless due to the multiplicity of photometric units found in the literature of photometry, and to a certain amount of ambiguity in the current definitions relating to these units. An attempt is made to present a considerably simplified conception of the minimum number of photometric quantities required for dealing with the exposure problem. The relation between image illumination and object brightness is dependent upon several physical characteristics of the image-forming system. Quantitative information relating to specific image-forming systems and a general average image-forming system useful for computing the relation between object brightness and image illumination are given. The relation of the sensitivity of photographic materials to the problem is considered in some detail, as well as the photometric and contrast characteristics of various types of photographic subjects.

"Latent-Image Theory and Its Application to Low-Intensity Photographic Exposures"; W. J. Albersheim, *Electrical Research Products, Inc.*, New York, N. Y.

In a previous paper by the writer, it was shown that the photographic exposure characteristics are in agreement with the assumption that a photographic grain must absorb two photons of visible light in order to become developable. In the present paper, this theory is compared with recent physical research by other authors. It is assumed that a film grain is "sensitized" by the first absorbed photon and fully "exposed" by the second absorbed photon.

Reciprocity-law failure at low-intensity exposures can be explained by the assumption that the sensitized state of film grains is unstable and that the number of sensitized grains decreases with time in an exponential manner unless fixed by activation. The half-time of this fading for certain emulsions is deduced from Kodak publications on reciprocity-failure characteristics.

Conclusions from this theory are drawn with regard to the contrast improvement for low-intensity photography, such as astronomical work or newsreel photography under unsatisfactory lighting conditions, by pre- or post-fogging. The theoretical conclusions are checked with test results.

"Effect of Aeration on the Photographic Properties of Developers"; J. I. Crabtree and C. H. Schwingel, *Eastman Kodak Co.*, Rochester, New York.

Unseasoned elon-hydroquinone developers of relatively high alkalinity (*p*H 10.0 to 10.5) showed a rapid decrease in activity after aeration for $1^1/_2$ hours while elon-hydroquinone-borax developers of low alkalinity (*p*H 8.4 to 8.8) showed increased activity (due to the liberation of alkali resulting from oxidation) which then remained constant for prolonged periods.

In general, the alkalinity of developers containing hydroquinone increased on aeration, while those containing only elon showed little change.

Practical tests with processing machines equipped with air agitation devices have shown that very constant developing conditions can be maintained with both positive and negative types of developers.

"Solution Agitation by Means of Compressed Air"; C. E. Ives and C. J. Kunz, *Eastman Kodak Co.*, Rochester, N. Y.

In the development of motion picture film, the developer in the emulsion undergoes exhaustion and thereby loses activity. Agitation of the developing solution in the vicinity of the film is required to assure sufficiently rapid and uniform renewal by relatively fresh developer brought from the remainder of the bath.

The present work is concerned with a method of bringing about this agitation by means of compressed air which is released at one or more points in the developer, through which it rises to the upper surface creating a generally turbulent condition and setting up rapid streaming effects.

The effectiveness of the stirring is limited by the tendency of the induced stream to form a narrow channel in one portion of the tank with relatively low velocity in the remainder of the tank.

Various means have been tried in an effort to direct the rapidly moving stream along the film surface, and this was accomplished by means of a gridwork of conducting pipes extending from top to bottom of the rack and parallel to the sides of the racks. Tests for uniformity of development made by means of uniformly flashed film showed the benefit conferred by the various improvements in control of the agitation. Dimensions and details of construction are given for making up the distributing grid.

"Maintenance of a Developer by Continuous Replenishment"; R. M. Evans, *Kodak Research Laboratories*, Rochester, N. Y.

By a series of simple assumptions that do not depart appreciably from current practice it is shown that the concentration of any ingredient in a developer solution that is continuously replenished during use may readily be calculated. The equations for the equilibria and rates of growth of the various substances are derived and application is made to a practical case. The benefits of chemical analyses for developer constituents both for maintenance of quality and for economy are pointed out, and the analytical methods published by Lehmann and Tausch are briefly outlined.

"The Effect of *p*H upon the Washing of Processed Films"; S. E. Sheppard and R. C. Houck, *Kodak Research Laboratories*, Rochester, N. Y.

Advantages stated to be obtained by adjusting fixing baths and wash-water to the isoelectric point of gelatin have been claimed. The advantages are said to be shorter washing time, less swelling and retention of water, with consequent improvement in the jelly strength of the wet emulsion, and reduced drying time. In the present investigation the conditions as to *p*H of the solutions, and wash-water, rate of flow of water, residual thiosulfate, *etc.*, were controlled accurately. The results indicate that with a regular acid fixing and hardening bath (*F-25*) there is no advantage, but rather a disadvantage in washing at the isoelectric point (ca *p*H 4.9) rather than at *p*H 7 to 8, since the time required to remove hypo to the same degree is increased, nor is less water retained. In a non-hardening acid fixing bath, there was little difference in washing time, but some gain in drying time for the isoelectric wash because of reduced water absorption.

"A New Densitometer"; H. Neumann, *Klangfilm G. m. b. H.*, Germany.

Density measurements of variable-width sound records should cover a large range of densities, and the measuring area should be as small as possible, so as to make it easy to find a suitable area on normal sound records.

The densitometer described, which is intended mainly for use in studios and laboratories but which is so accurate that it may be used also for scientific research, is capable of measuring densities of 0.01 to 2.5 of areas 2.5 mm. long and 0.03 mm. wide, limited by a mechanical slit. The absorption of light by the object is determined by means of the current set up in a blocking layer photoelectric cell which is measured by a very sensitive galvanometer giving direct density readings. The calibration of the light-source can be checked very simply by a separate light path without making necessary removal of the object during the check. A special arrangement is provided for visual observation of the measuring area under the slit.

The density values are determined with parallel light, and from these data the values for diffuse light may be easily calculated.

"The Transmission of Motion Pictures over a Coaxial Cable"; H. E. Ives, *Bell Telephone Laboratories*, New York, N. Y.

The transmission of television signals over wire lines a number of years ago used signals corresponding to images of coarse detail, and required frequency bands accommodated by existing types of circuits. The television images now considered necessary correspond to frequency bands of greatly increased width, and will require special wire networks and transmission means.

The coaxial conductor recently in operation for experimental purposes between New York and Philadelphia can transmit a band of frequencies of approximately 1000 kc. While designed primarily for multiple telephone channels, it offered the possibility of transmitting a single wide band as required for television.

The experiment consisted in providing television-type terminal apparatus for producing signals falling within the available band, and of developing and utilizing methods of transmission that would make most complete use of the frequency band available. For convenience in the experimental work, the signals were generated from motion picture film. The film was scanned mechanically by means of a lens disk containing 240 lenses. The film was moved continuously at 24 frames per second, and its motion, together with the motion of the lenses in the disk, swept each frame of the film in 240 juxtaposed lines. Light passing through the film was received on a photosensitive surface; the resulting photoelectric current was amplified and by means of modulating and demodulating apparatus transmitted as a single sideband lying between approximately 150 and 950 kc. At the receiving end the single sideband signal was restored as a signal from zero to 800 kc.

For reception, special cathode-ray tubes were used in which particular attention was paid to the definition of the spot and the linearity of response. Synchronism between the two ends was obtained by sending a single frequency over a separate channel and using it to operate sweep circuits at the receiving end. The use of mechanical scanning and the high-definition receiving tubes resulted in pictures of very satisfactory quality within the limitations set by the frequency band. (Illustrated with slides and motion pictures.)

"The Inter-Relationship of the Various Aspects of Color"; L. A. Jones, *Kodak Research Laboratories*, Rochester, N. Y.

An understanding of the subject of color and color measurement involves a knowledge of many and diverse phenomena. Pursuit of this knowledge leads into many fields of physical or objective science, such as physics, physiology, biology, chemistry, *etc.*, as well as into the domain of a subjective science, psychology.

While it may not be possible or even desirable to attempt to draw sharp lines of demarcation between all the various aspects of the problem, it does seem desirable, for the sake of orderliness and clear thinking, to suggest a certain division of the subject into a few definite categories and to attempt to define the relations that exist between the various aspects of the problem as a whole.

The present treatment of the subject is designed largely as a means of establishing orientations in the general field. An attempt is made to develop a logical and unambiguous nomenclature that will enable us to discuss various aspects of the subject without the confusion that exists so generally at the present time when individuals of diverse trainings and viewpoints attempt to discuss the subject of color. The subject-matter divides itself rather logically into three clear-cut categories, which may be referred to as the physical, psychophysical, and psychological. Attention is drawn to the relation existing between the correlated aspects in each of these three categories. An attempt is made to clarify the purely physical factors involved and to discuss certain sensory and perceptual aspects of color and the relations existing between them and their physical and psychophysical correlates.

"The Theory of Color Reproduction"; A. C. Hardy, *Massachusetts Institute of Technology*, Cambridge, Mass.

All methods of three-color photography are the outgrowth of a suggestion made in 1855 by Clerk Maxwell, the illustrious British physicist. The method that he suggested would now be classed as an additive process, since the final reproduction was effected by projecting three lantern-slides in register on the same screen; one lantern being supplied with a red filter, one with a green filter, and one with a blue filter. Maxwell suggested further that these lantern-slides be prepared from three negatives, each negative being exposed through the same filter that was to be used in projecting the corresponding lantern-slide. An extension of Maxwell's reasoning to subtractive processes leads to the conclusion that the dyes used in the production of the positive images should each be complementary in color to the corresponding taking filter.

Despite Maxwell's intimation that his process was theoretically incapable of perfect reproduction, the basic features of Maxwell's reasoning have been incorporated into the commonly accepted theory of color reproduction. The recent progress in the science of colorimetry has made it possible to investigate the relation that should obtain between the characteristics of the taking filters and the colors of the reproduction primaries. Such an investigation shows that the taking filters required for perfect reproduction have characteristics that are very different from those in common use.

The paper is concerned with the establishment of the conditions that lead to faithful reproduction by any three-color process. Examples of the application of these fundamental conditions are given for both additive and subtractive processes.

"Screen-Film Negative-Positive Process"; T. T. Baker, *Dufaycolor, Inc.*, New York, N. Y.

Progress in two directions has greatly simplified the making of prints from screen-film negatives. The study of emulsion characteristics and of the mechanics of development with silver bromide solvents has led to the avoidance of color dilution in copying one screen material from another. Sodium thiosulfate in a metol developer has been shown to localize development in the lower strata of the film, so that the silver image is formed in close contact with the reseau, largely eliminating scatter at the boundaries of differently colored units; the crystalline structure of the silver salts and grain-size frequency also assists in preventing scatter. Residual color dilution as the result of the 45-degree oriented reseaux is explained, and the way in which this has been counteracted by suitable choice of gammas in the negative and positive material. The production of a vapor-lamp emitting the line spectra of mercury and cadmium without appreciable spectral background, combined with a liquid didymium chloride filter has provided a triple monochromatic light-source, the spectral lines of which coincide with the peaks of the reseau transmissions, thereby eliminating dilution of color due to overlap, such as has always previously been present with color filters of the narrow-cut type. The Dufaycolor contact printing machine with automatic control of both hue and printing light is described. The technics of printing, and development with standard equipment, are described with lantern-slides and projections of recent 35-mm. cine prints (which are at present circulating in English theaters).

"Problems Involved in Full-Color Reproduction of Growing Chick Embryo"; E. S. Phillips, *New York State College of Agriculture, Cornell University*, Ithaca, N. Y.

Attempts to record on 16-mm. color film the physiological changes that take place during the 21-day incubation period of the hen's egg presents problems varying with each day's growth. Because the author was working with living subjects that required strict adherence to narrow tolerances in order to maintain normal embryological development and even life itself, it was necessary to adapt photography to the problem.

Development of the embryo is shown in three different ways, *i. e.*, (*1*) transmitted light, with shell entire; (*2*) removal of part of the shell, and subsequent photography by reflected light; and (*3*) removal of the entire shell, and placing the embryo in a watch crystal, thus showing all parts in their relative sizes.

In all three methods, temperature, humidity, and light control constitute the major problems.

"The Multiplane Camera"; W. E. Garity, *Walt Disney Productions, Ltd.*, Hollywood, Calif.

In line with the policy of continued improvement in cartoon technic, it was recognized that several developments could be undertaken which if successfully adapted, would add much to the power and charm of animated motion pictures. By confining cartoon photography to a single plane in front of the camera, the expense and difficulty of creating a convincing illusion of depth and a real-life appearance of camera movement made the consideration of a several-plane technic imperative. The out-of-focus diffusion and the differential movement of foreground and background elements of scenes can be attained most easily by separating those elements on different planes in front of the camera. The problem resolved itself into the adaptation of glass-shot technic to cartoon production. In separating the scene elements into several planes, many other advantages were gained, such as the lighting control of single-scene elements, the ease of using special-effects equipment, and the possibility of using backlight and process backgrounds.

The answer to the problem was a permanent machine, the multiplane camera, which was built to use the standard cartoon technic of animated characters in connection with several plane backgrounds. The machine was built with the view of accuracy of control, complete flexibility of scene set-up, and efficiency of operation. This required plane elements that could be quickly and accurately assembled, an accurate indication system, and an interlocked system of control.

Because the light level on each plane is an important part of every set-up, a sensitive quick-reading light-measuring system had to be devised. The number of machine adjustments involved was so large that a master control sheet was laid out, giving complete operation information for each frame of film. As a final check before exposure, a periscope type of finder was devised so that the chief operator could give the set-up a visual check before each exposure. To write out the master control sheets it was necessary to develop a scene-planning group of artists and technicians to control and plan the use of the machine in creating the desired illusions.

The results in giving increased power to animated motion pictures have been very satisfactory, as can be best illustrated by viewing the screen results. The adaptability of the multiplane technic to animation photography has proved to be so flexible that its complete possibilities will come only with experience.

"A Method for Determining the Scanning Loss in Sound Optical Systems;" E. D. Cook, *General Electric Co.*, Schenectady, N. Y., and V. C. Hall, *Eastman Kodak Co.*, Rochester, N. Y.

The usual methods of evaluating the frequency characteristic of sound records have been satisfactory for the determination of the required correction for overall losses. However, the losses due to aperture and optical effects are not known with sufficient precision to permit an inferior limit to be assigned to film loss only.

The method described was chosen in connection with a high-fidelity development, and consists in comparing direct measurements made on images formed by contact printing of a geometrically shaped test-object on the film with measurements of frequency records made using the recorder optical system. While the results obtained can not be applied generally, the method is capable of segregating film loss from other losses for the specific conditions under which the test is conducted.

"An Optical System for the Reproduction of Sound from 35-Mm. Film"; J. H. McLeod, *Kodak Research Laboratories*, Rochester, N. Y., and F. E. Altman, *Hawk-Eye Works, Eastman Kodak Co.*, Rochester, N. Y.

An optical system has been designed and tested for use in 35-mm. sound reproducers. It is the slitless type of optic, and gives a scanning image that is 0.001 inch wide when used with an exciter lamp having a coil diameter of 0.055 inch. A toric lens is used to form a curved-line image of the filament of the lamp. This curved image is then re-imaged by a highly corrected objective lens of numerical aperture 0.28. The objective lens has inherent curvature of field, but this curvature is compensated for by the curvature of the line-image formed by the toric lens so that the final image is flat. The toric lens also acts as a condenser lens to throw an image of the filament into the objective lens. Careful tests of samples show that the final image is flat, straight, and of uniform width and intensity.

"Sound Recording by Color Modulation (Van Leer System)"; A. L. W. Williams, *Brush Development Co.*, Cleveland, Ohio.

A method of recording sound is described in which advantage is taken of the variation in sensitivity of photographic film to light of different wavelengths. On standard film there is a portion of the sensitivity-wavelength curve in which the sensitivity changes linearly over a wide range with a small change in wavelength or color. An optical system and apparatus are described, designed to vary the color of the recording light over this narrow band and capable of wide-range recording. By this system very small deflection of the recording galvanometer is required, enabling a simple crystal oscilloscope to be used for the purpose. Chromatic aberration is almost eliminated. Large errors in exposure or development may easily be corrected so that minimum distortion occurs.

Report of the Standards Committee; E. K. Carver, *Chairman*.

The tentative drawings that have received initial and final approval by the Standards Committee have been published in the March issue of the JOURNAL of the Society. The uncompleted items at present under consideration are:

(*1*) Drawings for standard cores for cine film.
(*2*) Further consideration of the proper separation distance between the two halves of the push-pull sound-track.
(*3*) Drawings of sprockets for 16-mm. sound-film.
(*4*) Revision of the standard release print to correspond with the revisions made by the Academy.
(*5*) Review and possible revision of the glossary of technical terms.
(*6*) Carrying out actual tests on the new sprocket perforation for 35-mm. film, which, it is hoped, will displace the old Bell & Howell perforation.

"An Ultraviolet Push-Pull Recording Optical System for Newsreel Cameras"; G. L. Dimmick and L. T. Sachtleben, *RCA Manufacturing Co., Inc.*, Camden, N. J.

Recent advances in sound recording technic, notably exposure with ultraviolet and the class *B* push-pull track form, are incorporated in a variable-width recording optical system of extraordinary compactness, for newsreel work. The overall dimensions are approximately 6 inches long by 4 inches wide by 3 $^7/_8$ high, and the weight complete is about 3 $^1/_4$ pounds. This compact form is made possible by the development of a new galvanometer window lens of very special form, and of an objective lens of 7.6 mm. E.F. and $f/2$ speed which will cover the sound-track width satisfactorily. The power drain of the exposure lamp is 21 watts at 4.9 volts, and the galvanometer input at full modulation is about 30 milliwatts.

The class *B* push-pull track inherently provides ground-noise reduction without the use of special equipment. Response of the print at 6000 cps. is 3 db. below that at 1000 cps. with ultraviolet light, and 6 db. below it with white light. The turn of a lever and the reduction of the lamp current to 3 amperes prepare the system for white-light recording when battery power must be conserved and quality is less important.

"Processing Ultraviolet Recording on Panchromatic Films"; J. O. Baker, *RCA Manufacturing Co., Inc.*, Camden, N. J.

The necessity in newsreel work of making the original sound recording on panchromatic film has always meant a serious sacrifice in quality and ground-noise ratio, as compared with the results that can be attained when sound is recorded on a separate film. While ultraviolet recording materially increases the fidelity of response, with panchromatic as well as with standard sound negative film, the low contrast and inherently high base fog of panchromatic film when processed for negative picture development produce noise and considerable reduction in volume range.

The track density on the panchromatic film is rather low, of the order of 1.0 to 1.2, when recorded with a practical optical system for a single-film system. When this track is printed upon commercial release print stock the dense portion of the negative track will print through, producing a fog density in the clear portion of the printed track. This fog in the clear portion tends to produce noise and reduces the volume range. When the panchromatic negative and print are processed in accordance with commercial practice, the reduction in volume range is of the order of 6 decibels.

Printing the panchromatic negative upon a high-contrast emulsion improves both the noise and volume range. Since the release prints must be on standard picture positive stock and not on high-contrast film, it is here proposed to make a master positive on high-contrast emulsion and to re-record from this to a standard sound negative, which would be used in the ordinary way to make the release prints. An improvement in release print ground-noise of 8 to 12 decibels is obtained by this method, and the volume range is increased by 6 decibels. Briefly, the proposed method is a means for increasing the density contrast of the final release print track when the original is recorded on panchromatic film.

"Design and Operation of Theater Loud Speaker Systems"; J. F. Blackburn, *Lansing Manufacturing Co.*, Los Angeles, Calif.

Although really satisfactory loud speakers have been commercially available for only a comparatively short time, all the essential elements of a good loud speaker have been at hand for many years, so that the reasons for the late appearance of suitable units must be sought in the economic rather than the technical field.

The loud speaker with its horn and other adjuncts is considered analogous to the antenna and plate circuits of a radio transmitter. It is pointed out that probably only in acoustics and in radio transmission do we have to be so wavelength-conscious, since only in these cases do the wavelengths of interest range from very small to very large, compared with apparatus dimensions. This wide range at once denies the use of the types of simplifying assumptions that are so convenient in other fields, and introduces several sets of mutually contradictory requirements for the apparatus. To date, apparently no one has succeeded in fulfilling all these requirements in a single piece of apparatus, so that it becomes necessary to use multi-channel systems with appropriate frequency-dividing networks.

One solution to the requirements just outlined is discussed in detail from the engineering point of view. The comparatively meager published design data are reviewed and commented upon in the light of the author's experience with the units described. Some information is given regarding possible modifications of performance by minor changes in the units. Experiences in the application of these units in the field are discussed and suggestions are given to users.

"Push-Pull Recording with the Light-Valve"; J. G. Frayne and H. C. Silent, *Electrical Research Products, Inc.*, Hollywood, Calif.

Push-pull recording on film is accomplished by means of a double light-valve having four ribbons. Distortions introduced by the recording medium which are represented by second-order harmonics balance out in reproducing, as do also the frequencies introduced by the action of the noise-reduction system. As a result, push-pull recording not only eliminates certain defects of conventional recording, but permits the application of new technics that allow further extension of the volume range and improvement in the naturalness in the final product.

"The Educational Value and Preparation of U. S. Army Training Films"; R. T. Schlosberg, *Capt., U. S. Army Signal Corps*, Washington, D. C.

Problems encountered, considered incident to the preparation of army training films, and teaching principles and their application to instruction through the medium of sound-films are discussed. The method employed and the criteria for the selection of subjects are outlined, as also the general method by which such film subjects are produced.

"New Uses for Instructive Motion Pictures"; H. Roger, *Rolab Photo-Science Laboratories*, Sandy Hook, Conn.

Problems are described that were encountered during the production of several motion pictures with sound for the New York State Department of Health. These films represent a type that has found new uses in instructing physicians and nurses, as well as the general public, in the treatment of pneumonia patients. They represent a part of a nation-wide campaign program against the spread of pneumonia. One or two films will be demonstrated.

"Making an Industrial Film"; J. A. Norling, *Loucks & Norling Studios*, New York, N. Y.

Industrial films can be classified as sales films, which are made for the purpose of putting a sales message across to the prospective consumer; sales-training films, which are devised to train salesmen and are not planned for public use; educational films, which may contain some sales-promotional material; advertising films, which are usually very short bits released in theaters. Of the many industrial pictures made in the last few years, by far the most important are those classified as sales, sales promotional and sales-training.

Problems that arise in the production of these films are discussed. The increasing demand for color has set up many new problems for the producer of industrial motion pictures and slide-films. Growing appreciation of high production quality among industrial clients has also increased the difficulties and expense of the producer. These matters are touched upon but the main portion of the paper is devoted to one typical film—a detailed case history of its making, from the original scenario to the ultimate use of the film in reaching the market. (The presentation will close with a demonstration reel.)

"An Industrial Visual Instruction Laboratory"; J. G. T. Gilmour, *General Electric Co.*, Schenectady, N. Y.

The history, methods of operation, equipment, and types of work are described of the section of the General Electric Co. that prepares, produces, and distributes the pictures used by the Apparatus and Supply Division of the Company.

"A Higher-Efficiency Condensing System for Motion Picture Projectors"; F. E. Carlson, *General Electric Co.*, Cleveland, Ohio.

In motion picture projection optical systems for tungsten-filament sources, the condenser design is such that the source is imaged well ahead of the picture aperture. This position is dictated by considerations of uniformity of screen brightness. It is not the optimal position from the standpoint of utilization of light, for it entails losses at the aperture. At the best position for efficiency, the degree of brightness uniformity is inacceptable because of the non-uniform brightness of the source. The paper describes a method for reducing such losses without sacrificing picture quality.

"A Water-Cooled Quartz Mercury Qamp"; E. B. Noel and R. E. Farnham, *General Electric Co.*, Cleveland, Ohio.

The structure of the water-cooled quartz mercury lamp, its operation, quality of radiation, brightness, and source size limitations are first described, followed by a discussion of the power-supply equipment, both a-c. and d-c. Applications of the lamp are as follows:

(*1*) Motion picture projection, both with single lamps and with several sources.

(*2*) Motion picture photography, both black-and-white and color. This part of the paper tells also of an application to very high-speed motion picture photography. For black-and-white photography the lamp is quite satisfactory. For color work the relatively limited red radiation may call for external methods, either in the use of fluorescent reflectors or a highly red-sensitive emulsion, to make up for this deficiency.

(*3*) Film printing. Because of the relatively high output in the blue-violet and ultraviolet regions this lamp may prove a very satisfactory source, especially where advantage is taken of the ultraviolet radiation.

The following additional applications, of secondary interest to the motion picture industry, are also discussed: photo-enlarging, photoëngraving, and searchlights.

"Theory vs. Practice"; F. H. Richardson, *Quigley Publishing Co.*, New York, N. Y.

Attention is directed to the discredit heaped upon the splendid work accomplished by scientific men in designing apparatus employed in projection, and upon the praiseworthy accomplishment of construction engineers in carrying those designs forward into completed equipments. Apparatus can not be made to function efficiently in theaters while men are in charge who lack practical and theoretical knowledge. The public, for the most part, is unable to form intelligent opinion as to where the fault for poor functioning lies, and almost invariably will credit it to imperfect equipment. Suggestions are offered looking toward placing theater projection equipment in the hands of thoroughly capable men, to the end that the equipment may be made to produce results of which it is capable and to last a maximum length of time in service without excessively high operating expense.

"Good Tools Pay for Themselves"; J. R. Prater, *Congress Theater,* Pabouse, Washington.

The average projectionist does not equip himself with an ample supply of good tools, and the average theater management refuses to stock the projection room with anything more than a scant supply of tools of poor quality. After listing the tools that are known to be useful in the projection room the paper points out that were such tools available to the projectionist they would return their original cost in a relatively short space of time by enabling proper testing and alignment of equipment in addition to facilitating minor repairs of the equipment.

"A Technic for Testing Photographic Lenses"; W. C. Miller, *Paramount Productions, Inc.,* Hollywood, Calif.

Different makes of lenses have different properties and characteristics which may render a lens ideal for one purpose and totally undesirable for another. Lenses of a given make and series often vary in quality among themselves. To obtain the best type of lens for a specific purpose it is necessary to subject the various makes obtainable to tests that will reveal the characteristics in such a way that they can be reduced to numerical quantities for comparison. Once the type of lens for a specific purpose has been chosen, it is of great importance to be able to select the best of that type from a group submitted by the manufacturer.

Equipment and technic used in tests that make such discrimination possible are described. A few general hints and precautions are given that will aid in determining the characteristics most desirable for various purposes. Special emphasis is placed upon the tests for lenses intended for use with standard 35-mm. equipment. It is a simple matter to apply the methods and principles to other classes of lenses.

"Some Unusual Adaptations of 16-Mm. Equipment for Special Purposes"; J. L. Boon, *Development Department, Eastman Kodak Company,* Rochester, N. Y.

A casual observer, looking over the existing standard amateur photographic equipment, would probably be of the opinion that there is little need of altering a camera to do a special job. However, closer observation of the various problems that photography serves reveals that the standards of practice have been chosen merely to suit the needs of a common majority of users, and the minority are almost forgotten. Further observations show that an alteration to a standard camera to make it fit a specific purpose usually precludes its usefulness for many of the purposes for which it was originally designed, and also its utility for other special purposes.

An attempt has been made in this paper to make known some of the unusual adaptations of 16-mm. motion picture equipment, each to fulfill a definite purpose, and to show that industry is becoming more conscious of the utility of such photographic equipment as a tool in solving some of its problems.

"A New 16-Mm. Projector"; H. C. Wellman, *Camera Works, Eastman Kodak Company,* Rochester, N. Y.

The new projector is housed completely in aluminum die-castings, and to provide quietness of operation, the pull-down gears are individually adjusted in assembly by means of an eccentric sleeve. To facilitate threading, the location of the pull-down claw is designated by the threading knob, the position of which can be detected by touch as well as by sight. Throwing a single lever engages the rewind mechanism and at the same time releases the lower reel.

A threadlight is built into the projector, so positioned as to be most effective for threading the gate and the sprockets. The single control switch, a new and unique feature, has four positions: the first is the *off* position; the second turns on the threadlight so that the machine may be easily threaded in a darkened room; the third turns on the motor (the threadlight remains on so that the operator can momentarily see that the loops are properly formed and that the projector is functioning properly); and the fourth turns on the projection lamp and turns off the threadlight.

"The Shrinkage of Acetate-Base Motion Picture Films"; J. A. Maurer and W. Bach, *The Berndt-Maurer Corp.,* New York, N. Y.

A simple direct-reading film-shrinkage gauge has been constructed with which shrinkage readings may be made in a few seconds. The accuracy of the instrument is such that the maximum variation in a series of readings made upon a particular film will not be more than 0.02 per cent of the predetermined length measured. Readings have been taken systematically with this instrument over a period of five months to determine the shrinkage behavior of acetate-base films under various conditions of storage and use.

The results indicate that the safety-film base made by each of the three American manufacturers has a characteristic value of shrinkage that is ordinarily reached within a few days after processing. Subsequent shrinkage is slow but continuous over a long period of time. The ultimate value of shrinkage is of the order of 1.25 per cent except in the case of films that have been projected many times on projectors using high-wattage lamps. The bearing of this shrinkage information upon equipment design is discussed briefly.

"A Criticism of the Proposed Standard or 16-Mm. Sound-Film"; J. A. Maurer and W. H. Offenhauser, Jr., *The Berndt-Maurer Corp.,* New York, N. Y.

It has been proposed that the standard dimensions of 16-mm. sound prints be changed, principally by widening the sound record and scanned areas. The question is reviewed from the standpoint of the cumulative effects of film shrinkages and mechanical inaccuracies in the steps leading to the final sound print and in the projection of that print, following the method described by R. P. May in the April, 1932, JOURNAL.

A film having sound records of various widths will be demonstrated to support the contention that increased width of sound-track is not needed, and that if any change from the present standard is to be made, it should be in the direction of a narrower track to provide a wider margin outside the sound-track and a wider safety area between the sound-track and the picture.

"A Continuous Optical-Reduction Sound-Printer"; M. G. Townsley, *Bell & Howell Co.*, Chicago, Ill.

Optical-reduction printing from 35-mm. negative to 16-mm. positive has come into wide use. A new printer has been developed for making optical-reduction prints. The printer departs from conventional design in that the film rolls are horizontal, making possible oil-damped filters and flood lubrication without friction-producing oil-seals. The printer operates in either direction and stops automatically at the end of the negative. A three-phase, 220-volt synchronous motor drives the main worm shaft from which all the working parts are driven at a printing speed of 60 feet of 35-mm. film per minute. Uniform film motion is achieved by a heavy flywheel and independently filtered drive to each film drum.

The self-contained optical unit produces on the 16-mm. film an image of the 35-mm. track moving in synchronism with the 16-mm. film, with longitudinal and transverse mangifications of 0.40 and 0.84, respectively. Provision is made for printing masking lines at the edge of the track. A 10-volt $7^1/_2$-ampere d-c. lamp is operated from a pair of 6-volt storage-batteries and a full-wave charger. Lamp current is controlled by a rheostat and ammeter.

"An Automatic Camera Timer for Time-Lapse Cinematography"; H. Roger, *Rolab Photo-Science Laboratories*, Sandy Hook, Conn.

Ever since the invention of motion picture, time-lapse cinematography has been used extensively to speed up slow actions. More or less complicated devices have been constructed, mostly by the cameraman himself, to take single exposures at various time intervals. In modern cinematography, especially in the industrial and scientific field, time-lapse photography has found a great many new uses in recording slow processes. The camera timer described in this paper operates not only the camera but also the light, in synchronism with the camera shutter. The timer is the result of more than twenty years of practical experience in this field.

"A New Framing Device for 35-Mm. Projectors"; H. A. DeVry, *Herman A. DeVry, Inc.*, Chicago, Ill.

This device embodies a unique application of the silent chain drive to the motion picture mechanism, in such a way that the up or down movement of the film effected by the framer is accomplished without disturbing the synchronism between the shutter and the intermittent. Also, since the framing is done by an overhanging arm built directly onto the intermittent, the intermittent moves only rotationally, and remains always so close to the aperture that there is no room for buckling of the film. In fact, it is impossible for any buckling to occur due to framing.

"A Film Cement Pen"; R. J. Fisher, Rochester, N. Y.

The purpose of this device is to make the application of film cement in splicing film easier and neater, and allow no waste of cement by spilling or evaporation. It replaces the bottle, brushes, medicine droppers, *etc.*, and is a time-saving element where it is necessary to make many splices, as in film exchanges, studios, and laboratories.

"New Piezoelectric Devices of Interest to the Motion Picture Industry"; A. L. Williams, *The Brush Development Co.*, Cleveland, Ohio.

Devices discussed are: (*a*) phonograph pick-up with uniform response (without further compensation) 30 to over 10,000 cps. with forces so low that it will reproduce this range from soft direct recordings with negligible wear; (*b*) record cutter which, used in conjunction with the pick-up, will record over same range; (*c*) high-fidelity headphones reproducing to over 10,000 cps. with high sensitivity and high impedance (over 7500 ohms per pair); (*d*) unidirectional microphone (changeable at will to bidirectional or non-directional) using ribbon pressure gradient unit and sound cell pressure unit.

"Characteristics of Supreme Panchromatic Negative"; A. W. Cook, *Agfa Ansco Corporation*, Binghamton, N. Y.

The new panchromatic negative film is compared with earlier types of supersensitive material. It has a light-sensitivity twice as great as that of Superpan. This permits a 50-per cent reduction in set lighting, or the use of a smaller lens aperture for gaining greater depth of field with undiminished illumination. Relative color-sensitivity is substantially unaltered. The film is doubly coated, with two emulsion layers superposed upon a gray antihalation layer between the emulsion and the support. Despite increased sensitivity, Supreme negative has equally good keeping qualities, finer grain, and lower developing fog than Superpan. Development characteristics are similar and no alteration of laboratory procedure normally employed for typical supersensitive materials is suggested, although the long scale of the film allows great latitude in development. Extremes of light and shade beyond limits imposed by earlier supersensitive materials can be recorded faithfully, as indicated by the long straight-line portion of the characteristic curve, a very short toe, and a shoulder falling in the region of densities far beyond those encountered in practice. These advantages are reflected in the quality of negatives taken under adverse lighting conditions.

"A New Indicator for Sound-Level Measurements"; S. K. Wolf and S. J. Begun, *Acoustic Consultants, Inc.*, New York, N. Y.

This device consists of a long glass tube approximately 18 inches long and one inch in diameter. In the tube are three electrodes, one of which extends the entire length of the tube, and a mixture of inert gases at a very low pressure. The inside of the glass is coated with a material that fluoresces under the ultraviolet and positive ion bombardment, due to a constant voltage applied to the electrodes of the tube. The coating is of three different types, each of which will fluoresce a different color—green, blue, and red. The "blue" extends for seven inches at the lower end of the tube, next the "green" for four inches, and finally the "red" for the upper remaining seven inches.

A voltage of 250 volts is placed across the two small electrodes to produce a striking voltage and establish a zero point on the tube. Then the alternating voltage is applied to the long electrode from the output of a voltage amplifier to which a microphone is attached to pick up the sound under observation. The range of the tube is approximately 70 db. When the signal is too weak, the "blue" portion of the tube lights up; if the signal is brought up to a higher level the "green" portion lights up, representing the 3-db. change required to modulate a broadcast station from 65 to 85 per cent. If the signal is still stronger the "red" portion of the tube lights. Approximately 250 volts a-c. are required to operate the tube over its full range. The tube can be calibrated to read directly on a decibel scale, and by using a special type of logarithmic amplifier, the scale is linear. The great advantage of the tube is that the entire audio intensity range is on one scale and no switching scales need be done in operating this instrument.

As a practical example of the use of the tube, the blue region may indicate that a speaker's voice is too low, the green that it is satisfactorily strong, the red that the voice is too strong.

"The Resonoscope"; S. K. Wolf and L. B. Holmes, *Acoustic Consultants, Inc.*, New York, N. Y.

The "resonoscope" employs a special cathode-ray oscillograph in conjunction with a standard set of musical frequencies—the twelve notes of the chromatic musical scale, produced by twelve electrically driven tuning forks, which synchronize an oscillator in step with them. This oscillator provides a *horizontal* sweep circuit for the cathode-ray tube. A voltage amplifier picks up music or any single musical tone, through a crystal microphone, and energizes the *vertical* plates of the cathode-ray tube. This gives a visual picture of the wave-form of the musical note under observation. If the note is of the same pitch (or frequency) as the standard, or any harmonic of it, the wave-form will appear stationary on the screen of the cathode-ray tube. If the note is flat, or lower in pitch, than the horizontal sweep standard, the wave-form will appear to be moving to the left; if higher in pitch than the standard, or sharp, the wave-form will move toward the right. The movement indicates to the musician whether he is playing in tune or is sharp or flat. The speed with which the wave-form moves across the screen is an indication of the extent to which the instrument is out of tune.

Any of the twelve standard frequencies in the instrument may be selected by turning a control on the panel of the instrument, and each setting of the control accommodates all octaves of the particular note. One of the special features of the circuit is that the horizontal sweep circuit is automatically changed in frequency to compensate for the change in frequency in going from one note to another. This allows the sweep circuit to be synchronized at all times by the standard frequency of the tuning forks and assures the observer that the number of wave-forms on the screen of the cathode-ray tube is a direct indication of the octave he is playing or tuning. The frequencies of the standard chromatic scale are calculated for a true tempered scale, which has the most practical use for all types of tuning. The pitch of the scale is 440 cycles per second for *A* above middle *C*, this being the international pitch for tuning. This pitch is the one being used in the present models but any pitch can be had by substituting a new set of standards.

"A Roller Developing Rack with Stationary Drive"; C. E. Ives, *Kodak Research Laboratories*, Rochester, N. Y.

In a previous paper a rack was described that provided for continuous motion of a 200-ft. length of motion picture film during processing but could be used with the rack-and-tank equipment. The purpose of this roller rack was to give a type of treatment in processing essentially similar to that given by a continuous machine while retaining the features of batch equipment that are helpful in experimental processing.

The rack previously described included a built-in driving motor and reduction gear, an arrangement that was most feasible for a single unit. With more extensive use it became desirable to have multiple units operated from stationary drives at the tanks and at the loading and unloading stations.

A new design has been worked out in which the weight of the rack was reduced greatly by the use of stationary drives. Further reduction in weight was attained by the substitution of tensioning springs for the weighted supporting beam associated with the movable lower shaft in the earlier model. This shaft was mounted upon the frame by lever arms in such a way as to use the torsional rigidity of the shaft itself to maintain it parallel to the upper shaft while allowing it the necessary vertical movement.

"A New Projector Mechanism"; H. Griffin, *International Projector Corp.*, New York, N. Y.

This new projector is provided with synchronized front and rear shutters operating in the same direction and providing considerably greater screen illumination; an automatic fire-shutter safety trip for fire prevention; a Bijur one-shot oiling system to provide positive lubrication under pressure, together with ball bearings having sealed lubrication for extremely long service; heavier film-gate construction, the entire unit being readily removable for cleaning and having adjustable tension devices and locking positively both in the open and closed position; readily removable film-trap having edge-guiding means and provision for easily cleaning and replacing worn film runners; a new ring-type fire-shutter governor; easier threading facilities; new automatically positioned threading lamp; illuminated pearl gray enameled interior; and other distinctive improvements.

"New Safety Switch for Motion Picture Projection Rooms"; E. R. Morin, *Department of State Police*, Hartford, Conn.

An emergency switch has been designed for projection rooms, which in the event of a fire simultaneously starts or speeds up the ventilating fans, and turns on the auditorium lights. Details are given of the safety requirements for the construction of theater projection rooms in the State of Connecticut.

"A Solution of the Galvanometer Window Lens Problem in Recording Optical System Design"; G. L. Dimmick and L. T. Sachtleben, *RCA Manufacturing Co., Inc.*, Camden, N. J.

In the design of the variable-width recording optical system, the lens that images the aperture upon the slit should, ideally, be located at the galvanometer mirror. Early systems employing a vertical cutting edge permitted, with fair success, the use of a simple lens close to the mirror, but the stigmatic image thus obtained ruled the method out when oblique cutting edges were adopted. Resort was then made to a simple achromatic lens located axially between the aperture and galvanometer mirror.

The design of a very compact system for newsreel work has required that the lens be again located at the galvanometer mirror. This makes it necessary for the light to pass obliquely through the lens both before and after reflection from the mirror. Both a simple lens and a corrected lens have been designed to meet this requirement, and it is found that definite advantages in the way of image quality inhere in such a lens when the design is properly executed.

"A Study of Processing Conditions for the High-Resolution Sound Recording Emulsions"; J. O. Baker, *RCA Manufacturing Co., Inc.*, Camden, N. J.

The high-resolution recording emulsion described in the January, 1938, issue of the JOURNAL has been found satisfactory for recording as a negative provided that a sufficiently high density is obtained. With ultraviolet recording on the standard emulsions, the best value of print density is of the order of 1.4 for a negative density of 1.9.

The inherently low image-spread of the high-resolution emulsion requires a higher negative density for the same print density of 1.4. The negative density is of the order of 2.2 to 2.5. The noise is thereby reduced for two reasons: first, the inherent noise of the high-resolution emulsion is lower than that of the standard emulsions; and second, the higher negative densities give less trouble from the so-called "pin-hole" effect.

General practice at the present time is to make a master sound positive of the selected takes from which a re-recorded negative is made for use in the production of release prints. The paper discusses the processing conditions for the high-resolution emulsion when used as (*a*) an original negative, (*b*) as a master positive, and (*c*) as a re-recorded negative for final printing onto the standard release print positive.

"A New Sound System"; G. Friedl, Jr., *International Projector Corp.*, New York, N. Y.

A brief review is given of the advanced features of the new Simplex sound system, and the considerations involved in developing a high-quality system for small as well as for large theaters are outlined. The engineering requirements of high-quality reproduction are set forth, and the methods employed for meeting these requirements even in the smallest system are explained.

The development is outstanding because of its very low noise level, which insures an effectively wide volume range. The advantages of wide frequency range are preserved by the special care given to the reduction of flutter. The power of even the smallest system is sufficient to reproduce faithfully the latest improved types of recordings, such as the "Hi-Range" prints. The system employs a refined type of rotary stabilizer mechanism, with provision for dual track reproduction, such as from push-pull or stereophonic recordings. Special facilities are provided for mounting and adjusting the projector mechanism. Change-over controls are of the electronic type employing grid-biasing circuits so as to eliminate switch contacts and mechanically interlocked controls. Standardized power amplifiers of 15-watt capacity with extremely low limits of harmonic distortion are used singly or in parallel for various system combinations. Two-way loud speaker systems are employed, with special switching facilities that simplify checking loud speaker units as well as amplifier characteristics.

"The Properties and Applications of Ozaphane"; J. Holloway, *The Holloway Co.*, New York, N. Y.

Chemical and mechanical differences between Ozaphane and gelatin emulsion films are discussed. A report is made of accelerated life tests conducted by the New York Testing Laboratories and the U. S. Bureau of Standards. The duplicating properties of Ozaphane are discussed, and reference is made to the following applications: sound-track, home phonographs, radio broadcast, organ recordings, *etc.;* microphotography trends, resolution of Ozaphane; color transparencies; toy film, in black-and-white and in color.

The diazo dye process is treated as applied to bases other than cellophane; surface and complete sensitization. A spectrographic analysis is given of diazo dyestuffs and it is shown how projection and sound-track utilizations are affected. (Samples of film will be projected and a demonstration will be made of a home phonograph using Ozaphane film.)

"Tracing-Distortion in Sound Reproduction from Phonograph Records"; J. A. Pierce and F. V. Hunt, *Cruft Laboratory, Harvard University,* Cambridge, Mass.

When the spherical tip of an ideal reproducer stylus slides over a warped groove surface having a sinusoidal profile, the traced curve is not exactly sinusoidal. An analysis of the harmonic content of the traced curve, similar to that given by Di Toro (*J. Soc. Mot. Pict. Eng.*, Nov., 1937) but avoiding his approximations, is directly applicable to reproduction from vertical-cut records. These results may be applied to reproduction from lateral-cut records by taking the original groove surface as inclined approximately 45 degrees from the horizontal, projecting the traced curve upon the horizontal and vertical planes, and adding in proper phase the guidance of the stylus tip by *both* sidewalls. It is shown that there is a residual vertical component of stylus motion ("pinch" effect) and complete cancellation of all even harmonics in the tracing distortion. Computation of the remaining odd harmonics indicates that, when the ideal lateral-cut reproducer characteristics include ideal "following" for vertical motion at signal frequency, a lateral-cut record may be reproduced with one-fourth to one-tenth the rms. distortion of a similarly recorded vertical-cut record. These results are displayed for convenient reference by contours of constant distortion upon a universal chart, the dimensionless coördinates of which characterize any recording condition and allow immediate specification of the maximum permissible recorded amplitude, maximum predistortion of the frequency characteristic, and the required clearance angle of the recording stylus.

"Multiple-Channel Recording"; H. G. Tasker, *Universal Pictures Co., Inc.*, University City, Calif.

Multiple-channel recording is a device for achieving needed flexibility at the time of dubbing or re-recording orchestral music presented as such in the picture. If producers, directors, and film editors could predict for the music and sound departments which portions of the orchestra would be seen from which angles in the finally edited picture, or if the editing could be completed before the music was recorded, there would be less merit in multiple-channel recording.

The reverse is true: The music is recorded first, the musicians photographed later, synchronizing their movements to a play-back of the record. Meanwhile, the pictorial treatment has taken partial shape in the minds of producer and director. Still later it takes final shape in the hands of the film editor. Sound and action are then placed in the hands of the sound department for dubbing, but it is then far too late to do more than an ineffectual raising and lowering of volume. The violins or the woodwinds can not be lifted above the surrounding sections to match a close-up of the picture.

Multiple recording, meaning the provision of a separate recording channel, complete with microphone, amplifier, recording machine, *etc.*, for each important section of the orchestra (usually six) and all propelled in synchronism, provides an excellent solution of the problem. The resulting multiplicity of sound-tracks (recorded, of course, in advance of the photography) will afterward provide the dubbing mixer with the means of easily blending a final sound-track that will be wholly in keeping with the final edition of the picture. The application of this method to the recent production *100 Men and a Girl* is described. The use of "close-mix" tracks, separate vocal tracks, *etc.*, in conjunction with multiple recording is also described.

"Application of Non-Linear Volume Characteristics to Sound Recording"; J. O. Aalberg and V. G. Stewart, *RKO Radio Studios, Inc.*, Los Angeles, Calif.

The advisability of using a non-linear volume characteristic in dialog recording is discussed. In this connection consideration is given to the following points: (*a*) the difference of level existing between the original and reproduced speech; (*b*) the advantages of a system in which manual monitoring can be confined to overall level correction rather than to momentary peaks; (*c*) the advantage of limiting the range of all except trained voices to assure the highest possible intelligibility. An analysis is then made of the various types of compression possible and a terminology is developed.

Consideration is given to the type of device most applicable to motion picture recording. The electrical circuits and operating characteristics of a compressor that has been in commerical service for 18 months are discussed. Practical results and advantages obtained by the use of the device during this period are analyzed and the possibility of additional applications is indicated.

"The Philips-Miller Method of Sound Recording"; R. Vermeulen, *N. V. Philips Gloeilampenfabrieken*, Eindhoven, Holland.

The first attempt at mechanographic recording and reproducing was made as early as 1891 but no successful solution of the problem was applied until the invention of J. A. Miller in 1931. The principle of this invention is described as inertia-free magnification. After the introduction of the principle, the inventor coöperated with the research laboratories of the N. V. Philips Company, of Eindhoven, Holland, in order to solve the problems involved in bringing the system to commercial use.

The method of obtaining a mechanical amplification of forty times is described and illustrated. The mathematical and theoretical advantages of the sytem over photographic methods are discussed, as also the film or tape that has been specially prepared for this process of recording. Some of the difficulties or precautions that are peculiar to the system and are new to the art of recording, relating to the cutting instrument, cutting material, and the coating of the film, are described. One type of recording machine is described with drawings of the most interesting mechanical parts. A bibliography of articles on the subject is appended.

"Electrical Networks for Sound Recording"; F. L. Hopper, *Electrical Research Products, Inc.*, Hollywood, Calif.

Electrical networks are employed in sound recording for modifying and limiting the frequency-response characteristic. The necessity for their use, application, and design are described. Particular emphasis is placed upon the constant-resistance type of structure.

"The Application of Electrical Networks to Sound Recording and Reproducing"; H. R. Kimball, *Metro-Goldwyn-Mayer Studios*, Culver City, Calif.

The use of electrical networks with recording and reproducing systems to accomplish beneficial results has been steadily increasing. Two types of networks are in general use, namely, wave-filters and attenuation equalizers. This paper discusses in some detail the use of these networks with sound systems as reflected by present practices and later presents practical data for engineering the networks with a minimum of time and effort. The uses to which attenuation equalizers are put divide these networks into two general classes: first, fixed equalizers to provide fixed equalization for sound channels; and, second, variable equalizers to provide means for varying at will the relative amplitudes of the frequency components of sound signals. Although the means for engineering variable networks is far from being ideal, the review given in the paper of present practices should be valuable.

"Silent Gasoline Engine Propelled Apparatus"; J. E. Robbins, *Paramount Pictures, Inc.*, Hollywood, Calif.

Problems are discussed connected with the design, construction, and operation of electrical generators and water pumps running under full load sufficiently silently to permit satisfactory sound recording. The units described were the result of demands for silent power equipment for making shots on boats, trains, bus interiors, inaccessible canyons, *etc.* As an example of what is sometimes required, one of the largest units was installed in the hold of a windjammer used throughout the Paramount Production, *Souls at Sea,* and although the microphone was at times directly above (approximately 30 feet) the spot occupied by the generator, no noises were picked up by the sound recording equipment.

Four units are described, namely, one 144-kw. Hispano Suiza, one 57-kw. Lincoln Zephyr, and one 41-kw. Ford *V-8* generator, and one high-pressure Ford *V-8* water pump. In each case the entire mechanical unit is rubber-mounted on a sub-frame within a semi-airtight compartment constructed of an outer shell of 22-gauge auto-body steel, four inches of sound-absorbing material with an inner lining of asbestos cloth. The entire exhaust system is water-cooled, employing special mufflers also housed within the case. One radiator, mounted outside, cools the water for the engine as well as the exhaust. All are practically automatic in operation, with electrical governors, temperature regulators, *etc.* The machines have been in operation approximately fifteen months and have required very little service other than normal maintenance.

"Variable-Matte Control (Squeeze-Track) for Variable-Density Recording"; G. R. Crane, *Electrical Research Products, Inc.*, Hollywood, Calif.

A review of the relation between the width of variable-density sound-track and the signal-to-noise ratio indicates the advantages to be gained by applying a variable matte to the sound-track. To provide this facility, a sound-track matting system has been developed for application to existing standard studio equipment. By means of selsyn-type motors, a foot-operated control unit drives an indicating meter, an attenuator, and a masking device on the recorder. A new condenser lens assembly is used on the recorder and the system may be used for either single or push-pull recording.

"Permanent-Magnet Four-Ribbon Light-Valve for Portable Push-Pull Recording"; E. C. Manderfeld, *Electrical Research Products, Inc.*, Hollywood, Calif.

The general adoption of the push-pull recording technic has necessitated providing adequate modulating equipment for portable recording channels. The four-ribbon permanent-magnet light-valve herein described is an important unit in this equipment. It has been designed to provide the smallest practicable mechanical structure without sacrificing the operating and maintenance advantages possessed by the larger type of valve used in fixed channels. The magnetic field of the valve is provided by permanent magnets. The individual ribbons are so mounted as to allow spacing and tension adjustments at any time.

"Overload Limiters for the Protection of Modulating Devices"; R. R. Scoville, *Electrical Research Products, Inc.*, Hollywood, Calif.

Two types of volume-limiting devices are discussed. The first type automatically limits the envelope of a signal to a predetermined maximum amplitude in such manner that harmonics are not generated. A time factor is incurred wherein the envelope amplitude is changed when the limiting value is approached. A second type of volume limiter acts instantaneously to prevent excessive signal amplitudes, and is used primarily for the protection of equipment against damaging signals and where such odd harmonics as are generated during the limiting period can be tolerated. Equipment of this type is described in detail and compared with limiters of the first type.

SOCIETY ANNOUNCEMENTS

SPRING, 1938, CONVENTION AT WASHINGTON, D. C.

Details of the forthcoming Convention to be held at Washington, D. C., with headquarters at the Wardman Park Hotel, are given in the preceding section of this issue of the JOURNAL. The dates will be April 25th to 28th, inclusive, and many interesting features are being arranged by the Convention and Papers Committees under W. C. Kunzmann, *Convention Vice-President,* and J. I. Crabtree, *Editorial Vice-President.*

PROJECTION PRACTICE COMMITTEE

Two meetings of the Committee were held on February 17th and March 24th, and two additional meetings are planned before the Spring Convention, in order to complete the semi-annual report. The report this year will be very comprehensive, presenting an analysis of the data obtained through the theater survey conducted during the past year or so and announced in previous issues of the JOURNAL. Charts are being prepared showing the ranges of auditorium shapes, projection angles, and other important features of theater design encountered in the field. In addition, considerable work is being done in drawing up a set of recommendations to the National Fire Protection Association for revising the N. F. P. A. "Regulations for Nitrocellulose Motion Picture Film." Other Sub-Committees also will be prepared to report in addition to those mentioned.

MID-WEST SECTION

At a meeting held on March 15th in the meeting rooms of the Western Society of Engineers, Chicago, Mr. Charles Herbst, Jr., of RCA Manufacturing Company, presented a paper on "Loud Speaker Developments." The presentation included a discussion of amplifier distortion and compensation, and sound-head analysis. The next meeting is scheduled for April 12th.

ATLANTIC COAST SECTION

At a meeting held on March 23rd in the studio of RCA Photophone, Inc., New York, N. Y., Dr. S. J. Begun presented a "Symposium on the Recording and Reproduction of Speech." Particular attention was given to electromagnetic recording and reproducing, and a demonstration was given of direct recording and playback. The "resonoscope," an instrument for comparing true voice pitch values, was demonstrated, as well as an automatic volume indicator for speech level.

ADMISSIONS COMMITTEE

At a recent meeting of the Admissions Committee, at the General Office of the Society, the following applicants for membership were admitted to the Associate grade:

ASHTON, W. A.
2142 1/2 Beachwood Terrace,
Hollywood, Calif.

BOOTH, W. O.
969 So. Serrano Ave.,
Los Angeles, Calif.

CAMPBELL, R.
1010 Third St.,
Alamosa, Colo.

DUDELSON, M.
2996 Lawrence St.,
Detroit, Mich.

FELDMAN, A.
2869 Grand Concourse,
New York, N. Y.

FREITAS, E. A.
1110 E. Palmer Ave.,
Glendale, Calif.

HARNDEN, P.
909 Vine St.,
Louisville, Ky.

HIPKINS, B. H.
81 Devonshire Rd.,
Forest Hill, S. E. 23,
London, England.

KOENIG, F.
18 Rue de Sucy
Chennevieres-sur-Marne,
Seine et Oise,
Paris, France.

KUHN, J. G.
1345 Winchester Ave.,
Glendale, Calif.

LORENZ, W. W.
410 Ogden St.,
Denver, Colo.

MCARTHUR, G.
McArthur Theatre Equipment Co.,
2501 Cass Ave.,
Detroit, Mich.

MCFADDEN, W. C.
4738 Tobias St.,
Van Nuys, Calif.

MERRALLS, F. N.
725 Longwood Ave.,
Los Angeles, Calif.

MOSS, G.
1311 Second St.,
Alamosa, Colo.

RUBEN, R. L.
208 W. Montcalm St.,
Detroit, Mich.

TULLY, M.
5 Arnold Court, Truro Rd.,
Bowes Park,
London N-22, England.

WACHSMAN, L. B.
2055 Harrison Ave.
New York, N. Y.

In addition, the following applicants have been admitted by vote of the Board of Governors to the Active grade:

BROWN, L. F.
Electrical Research Products, Inc.
250 West 57th St.,
New York, N. Y.

HILLIARD, J. K.
2237 Mandeville Canyon Rd.,
Culver City, Calif.

MCNABB, L. A.
Bell & Howell Co.,
4045 N. Rockwell St.,
Chicago, Ill.

S. M. P. E.

STANDARD TEST-FILMS

These films have been prepared under the supervision of the Projection Practice Committee of the Society of Motion Picture Engineers, and are designed to be used as precision instruments in theaters, review rooms, exchanges, laboratories, factories, and the like for testing the performance of projectors.

Only complete reels, as described below, are available (no short sections or single frequencies). The prices given include shipping charges to all points within the United States; shipping charges to other countries are additional.

35-Mm. Sound-Film

Approximately 500 feet long, consisting of recordings of several speaking voices, piano, and orchestra; buzz-track; fixed frequencies for focusing sound optical system; fixed frequencies at constant level, for determining reproducer characteristics, frequency range, flutter, sound-track adjustment, 60- or 96-cycle modulation, etc.

The recorded frequency range of the voice and music extends to 10,000 cps.; the constant-amplitude frequencies are in 15 steps from 50 cps. to 10,000 cps.

Price $37.50 each, including instructions.

35-Mm. Visual Film

Approximately 500 feet long, consisting of special targets with the aid of which travel-ghost, marginal and radial lens aberrations, definition, picture jump, and film weave may be detected and corrected.

Price $37.50 each, including instructions.

16-Mm. Sound-Film

Approximately 400 feet long; contents identical to those of the 35-mm. sound-film, with the exception that the recorded frequency range extends to 6000 cps., and the constant-amplitude frequencies are in 11 steps from 50 cps. to 6000 cps.

Price $25.00 each, including instructions.

16-Mm. Visual Film

An optical reduction of the 35-mm. visual test-film, identical as to contents and approximately 400 feet long.

Price $25.00 each, including instructions.

SOCIETY OF MOTION PICTURE ENGINEERS
HOTEL PENNSYLVANIA
NEW YORK, N. Y.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXX **MAY, 1938** **Number 5**

CONTENTS

JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

Subscription to non-members, $8.00 per annum; to members, $5.00 per annum, included in their annual membership dues; single copies, $1.00. A discount on subscriptions or single copies of 15 per cent is allowed to accredited agencies. Order from the Society of Motion Picture Engineers, Inc., 20th and Northampton Sts., Easton, Pa., or Hotel Pennsylvania, New York, N. Y.

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

Publication Office, 20th & Northampton Sts., Easton, Pa.

General and Editorial Office, Hotel Pennsylvania, New York, N. Y.

West-Coast Office, Suite 226, Equitable Bldg., Hollywood, Calif.

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

A METHOD OF ENLARGING THE VISUAL FIELD OF THE MOTION PICTURE*

B. SCHLANGER**

Summary.—*Recent trends toward the smaller sized motion picture audience indicate that new considerations can be given to the possibility of a larger and differently shaped screen, retaining the 35-mm. film. The screen is pictured as completely occupying the entire forefront of the motion picture auditorium, assuming a space stage instead of an artificially framed picture.*

The first step toward making pictures lifelike was to add the effect of motion. Then sound was added, and now natural color has become a factor necessary to enhance the effect of realism of the motion picture. There are still to be considered, however, two more elements required to render the picture completely lifelike.

The first of these, that of obtaining a sense of depth or relief, is occupying the minds of many at the present time. The second is an important factor that has not received sufficient attention in the past; that is, making the picture appear to fill the field of view of the spectator in the theater, so that the spectator is no longer "picture conscious." Rather he should be made to feel that what is being unfolded before his eyes is very much the same as his natural field of vision in real life.

There are two reasons why this effect can not be achieved under the present conditions of motion picture projection. One is the limitation of size of screen and motion picture film, and the other is the artificiality of the black border, which sharply cuts off the edges of the picture. The motion picture screen as now presented occupies only a small portion of the field of vision of the spectator sitting in the theater. Surrounding the screen is not only the black masking but also wall and ceiling surfaces unrelated to the picture, the illumination levels of which are disconcerting to the viewer and irrelevant to the illumination of the screen.

---

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received October 8, 1937.

** New York, N. Y.

The artificiality of the present screen surroundings is further emphasized in the presentation of color pictures, by the sharp contrast of the gray and black surroundings against the strong colors of the screen. In the case of black-and-white pictures, at least the black of the surroundings has some relation to the blacks or grays on the screen, although the intensities of the light on the surroundings and the screen vary to a disturbing degree.

FIG. 1. Present form of screen picture, with jet black border surrounding the image.

These present unnatural screen surroundings have had the effect of establishing a kind of cinematography that is most inflexible and limited in scope. For example, the black border around the screen has a tendency to force the use of pictures having low lighting intensities at the marginal areas, to avoid glaring contrasts at the border lines. Another example of the limits imposed is the hesitancy to place images of objects or human features near the sharp cut-off borders because of the unnatural effect of splitting the images. This hesitancy to use the marginal areas of the screen for various light intensities and image placements has resulted in reducing the effective area of the screen for action portrayal. This is most unfortunate when it is realized that the working screen area is not any too large for other than close-up shots.

There are two suggested means by which this artificial limitation may be eliminated and a more lifelike projected picture be achieved. One is to project an enlarged picture upon a screen occupying a sub-

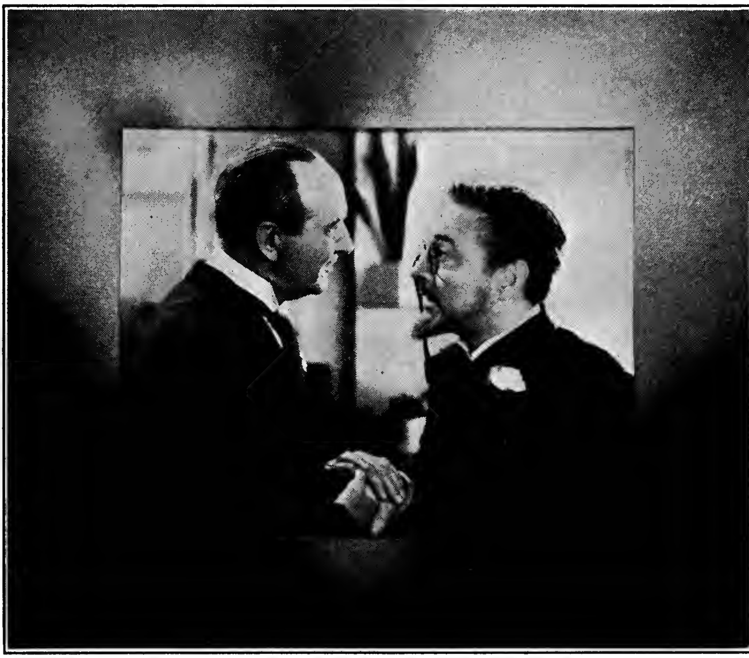


FIG. 2. Screen synchrofield, showing luminous vignetting around the image.

stantial portion of the spectator's field of vision. The other is to create an area contiguously surrounding the present screen, upon which a lighting effect can be imposed matching as nearly as possible the lighting occurring in the marginal areas of the picture. The former method apparently can not be ultilized at this time, due to limitations of the 35-mm. film and the present projection lighting and optical system, besides the difficulties encountered in the costs of producing larger settings to fill the larger screen, of which portions would necessarily have to be subdued to the main focal interest.

The second means suggested would not require any change in the film width or in the screen size. The desired effect can be attained at and around the screen. Many attempts have been made in the past to create an illuminated field in line with or forward of the screen. These have all been unsuccessful because the source of illumination used was secondary, utilizing indirect lighting troughs around the picture. Although some attempts were made to vary the color and intensity of the light, it was practically impossible to create automatically colors and light intensities that would match the ever-changing colors and intensities occurring in the marginal areas of the picture. It is evident that a screen-border illumination of a fixed intensity and color can prove to be just as artificial and frame-creating as the present black border when the marginal areas of the picture are dark compared to the contiguous illuminated border.

An illuminated field contiguous to the screen proper must not only have a constantly changing intensity of light and color, but its light and color must also vary along the four sides of the screen to match and blend the various edge conditions of the picture into the surrounding field. Fig. 1 shows a picture with the conventional black border. Fig. 2 shows the same picture with a contiguously surrounding field, having on it the various intensities nearly corresponding to the intensities existing on the picture margins. The various marginal light intensities have to blend into the background field illumination to render the physical edge of the screen as indefinite as possible.

To meet the problems herein discussed, a system* devised by J. Gilston and the author will be demonstrated for the first time in conjunction with the presentation of this paper. The system utilizes the principle of employing the projection light-beam to create an illuminated field contiguous to the picture edges. It achieves the desired result of synchronizing automatically and with great simplicity, the color and intensity of light of the marginal areas of the picture with the color and light intensity of the surrounding field. Fig. 3 is a diagram of the screen and the arrangement of diffusing and reflecting surfaces forming a "screen synchrofield." The light falling from the projector upon the marginal areas of the screen is transmitted through the marginal areas of the screen upon the diffusing and reflecting surfaces behind and beyond the screen edges. Since the lighting of the screen marginal areas and the lighting

* U. S. Pat.

of the surrounding field have but one source, the necessary blending of the picture edge into the surrounding field is assured. No attempt is made to create upon the extended field any definition or duplication of forms occurring on the screen marginal areas. The extended field appears to have vague extensions of the color and

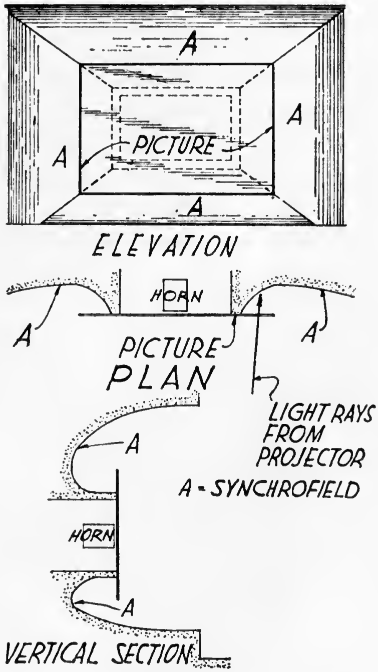


FIG. 3. Diagram of the screen synchrofield.

light intensities of the screen marginal areas, thus simulating the effect of peripheral vision in real life.

Elimination of the limiting artificial screen surroundings would help the spectator to connect himself more intimately with the space enfolded by the screen. The side walls of the motion picture theater auditorium can now be made to blend into the "screen synchrofield" surfaces, thereby making it further possible to "project" the spectator into the scene of action. For successful results, the walls must be designed to reject or receive light reflections from the screen to a proper degree. Secondary lighting must be completely eliminated from any of the auditorium surfaces at or near the screen, allowing only the carefully studied use of the screen lighting to control the lighting of the forepart of the theater.

Another advantage of this procedure is the elimination of eye fatigue caused by the necessity of adjusting the eyes to accommodate the sharp contrast of the black border and the illuminated screen. Indirectly eye fatigue will also be reduced further, inasmuch as brighter levels of screen illumination may be used for improving visual acuity without the disadvantage of the glare created by high brightness levels within dark surroundings.

The new and greater possibilities in cinematographic expression and new screen brightness evaluations resulting from the use of the "synchrofield" seem most encouraging. Eliminating the definite edge of the picture will, in effect, increase the effective area of the screen, since a freer use of the marginal areas of the screen for image placement will be possible. Panoramic views will be greatly enhanced by the apparent extension of the sky and nature's forms. The use of colored films will also be greatly enhanced by the elimination of the black surroundings that lend artificial hardness to the picture. Brilliant colors on the picture proper will appear softer when brilliant colors in subdued degree appear in the peripheral screen surroundings. Achievement of actual depth effects in the projected motion picture will further demand the elimination of a sharp picture cut-off. The more realistically life is duplicated on the screen, the less it can afford to be cut off by abrupt and dark surroundings.

DISCUSSION

MR. KELLOGG: How does the reflectivity of your translucent screen compare with that of a piece of good white paper?

MR. SCHLANGER: There is no doubt that we are losing some of the light through the translucency.

MR. KELLOGG: That is an indication of the price you pay in screen brightness.

MR. SCHLANGER: Where the incident light is the minimum possible, it would be necessary to increase the light upon the screen to compensate for the light transmitted through the screen. The screen material used in this model is not considered the most desirable, and further experimenting is necessary to determine the most efficient material.

MR. GOLDEN: Of what material is the field surrounding the screen?

MR. SCHLANGER: This happens to be a white diffusive paper. Ordinary plaster would be more suitable.

MR. KELLOGG: I was wondering whether you could not utilize some of the light reflected from the screen at angles too great to be useful for viewing the screen, say, inside of 45 degrees. I do not know whether there would be enough light reflected from the edges of the screen but it might be utilized, if sufficient, with less loss to the screen illumination, than to depend upon transmitted light.

MR. SCHLANGER: I have investigated the possibility very thoroughly, and dropped the idea because if we allow the light entering the central area to reflect to a surface at, say, 45 degrees, there will still be sharp contrast between the picture and the border. The purpose of this scheme is to blend only the edge condition into the surrounding field.

MR. RICHARDSON: The scheme has been rejected before.

MR. SCHLANGER: The conception embodied in this scheme differs fundamentally from previous proposed solutions. Earlier attempts employed fixed border illumination, while this arrangement rests upon synchronizing the field lighting with that of the screen edge.

MR. RICHARDSON: I feel that when we put light outside the screen we detract from the picture.

MR. SCHLANGER: That is true when the source of light near the picture and within the field of vision of the spectator is unrelated to the picture. But it is not objectionable if the light that appears within the field of vision is gauged to the edge light of the picture. The field illumination in this scheme operates as an integral part of the scene being viewed, and therefore does not detract from the picture.

MR. GREENE: The light that passes through the edge of the screen and is reflected to the outer edges of the border should not be regarded as light outside the screen. Psychologically, the plaster surface becomes part of the screen. However, I wonder whether the area of the screen backed up by the theater speakers will cause non-uniformity of illumination of the picture area; in other words, the dark central portion where the speakers are located might appear much darker than the border of the active screen represented by the reflective surface.

MR. MALMUTH: We manufacture a screen perforated in the center and solid or opaque at the border, and in tests we have made on a couple of hundred screens, we have found no case in which the masked area behind the loud speakers has been noticeable through the screen.

MR. SCHLANGER: I do not think that answers Mr. Greene fully. The external marginal areas of the screen will not appear sufficiently brighter than the internal area, for two reasons: First, we know that the central area of the screen has a higher illumination level due to the optical system, and second, the reflectors are so designed as to reflect the light outwardly, rather than back to the screen again. This demonstration did not show a marked contrast between the marginal area that was being used and the central area.

MR. CRABTREE: As one who has urged Mr. Schlanger in the past to proceed along these lines, I wish to congratulate him on having done something about which many of us have merely been thinking. It seems to me that the effectiveness of this scheme will be a maximum at a certain critical distance from the screen. I always like to sit close to the screen, where the margins are least conspicuous. Farther back in the theater, the margins become very objectionable, and the effectiveness of this arrangement, I should think, would be a minimum at the back of the theater. Have you tried the effectiveness at various distances?

MR. SCHLANGER: Certainly for the major portion of the theater, where the range of vision takes in only the screen plus the synchrofield, the condition should be best. Farther back the angle of vision includes not only the screen and the synchrofield but some of the walls of the auditorium as well. To complete the idea, it would be necessary to continue the effective screen area still farther, and as stated in the paper, the auditorium walls and ceiling surfaces within the field of vision could be treated with a suitable quantity of light. The objection would then be overcome and the system would be effective for the complete depth of the theater.

MR. CRABTREE: Would not this kaleidoscopic movement occurring around the screen be a little distracting? It would depend, of course, upon the general illumination level in the theater.

MR. SCHLANGER: If this scheme were shown on a full-size screen the synchronized light field would, we believe, occupy the peripheral vision of the spectator, and therefore the synchronized light movements would hold a more natural and undisturbing effect, similar to the vague feeling of peripheral movement felt in real life. In the past few years I have built quite a few theaters and have dared to leave the wall surfaces quite bright, some of them even of white plaster. There has been a feeling that auditoriums ought to be pitch black, but I have found that if the walls and ceilings are evenly illuminated (that is very important), with no interruptions of dark or light areas, an astonishingly high illumination level can be put upon the walls and ceiling without detracting from the picture. On the other hand, in a darkroom with a picture being projected, as little as a 2-watt bulb behind a shield throwing a slight glimmer of light upon a dark area is very objectionable. What is required is an even bath of illumination over the complete surface, of an intensity that will blend from the screen lighting to your position in the auditorium. Objections to light in an auditorium are due to unevenness of the light.

MR. CRABTREE: This is a matter for argument, and should be investigated. I hope you are successful in persuading someone to install this idea in a theater and I am sure it will attract a great deal of interest.

The screen is now suspended on a wire; why not cover the entire front of the proscenium with a transparent material and attach the screen in the middle? That would eliminate the black border.

MR. SCHLANGER: Several methods of more or less completely eliminating the small hair-line dark edge visible around the screen are being considered.

A HORN CONSISTING OF MANIFOLD EXPONENTIAL SECTIONS *

H. F. OLSON**

Summary.—*The expressions for the throat impedance of a horn with two rates of exponential flare have been derived. This expression is applicable to any number of sections by considering two sections at a time. The impedance-frequency characteristic of specific multiple horns shows the possibility of obtaining a large variety of impedance characteristics suitable for improving the efficiency characteristic over that possible with a single rate of flare. The efficiency of a horn type of loud speaker having a horn with three rates of flare shows an efficiency within a few per cent of the ultimate efficiency.*

The efficiency of a horn loud speaker is governed, among many other factors, by the throat resistance. To obtain the maximum efficiency at any frequency, the effective reactance of the entire vibrating system should be equal to the effective resistance. This, in general, means that to obtain maximum efficiency the throat resistance of the horn should be proportional to the frequency, since the reactance is primarily mass reactance and, therefore, proportional to the frequency. It is well known that the surge resistance of an exponential horn is independent of the frequency over its transmission range. Because of this fact, in order to obtain high efficiency over a wide range, horn loud speakers have been built using two or more units to cover the range of reproduction; that is, a relatively large throat horn for the reproduction of low frequencies and a relatively small throat horn for the reproduction of high frequencies. Obviously, the same result could be attained with a horn in which the throat resistance increased at the proper rate with respect to the frequency. Such a system would eliminate the use of two or more mechanisms, cross-over networks, phase-shift between units due to the filter, and different sound-path lengths, and other problems connected with multiple channel systems. It is the purpose of this paper to outline a method for obtaining practically any throat im-

* Received January 18, 1938.
** RCA Manufacturing Co., Camden, N. J.

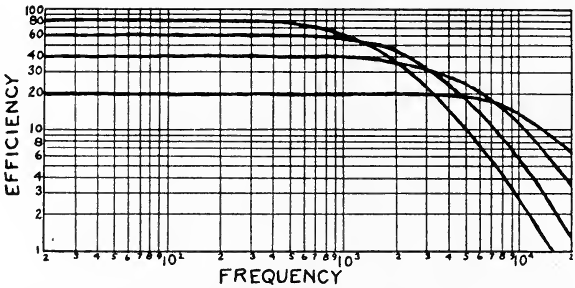


FIG. 1. Efficiency characteristics of a diaphragm coupled to a pure resistance and driven by an aluminum coil of one-half the diaphragm mass operating in a field of 22,000 gauss.

pedance-frequency characteristic by employing a horn consisting of manifold exponential sections.

The efficiency of a simple system consisting of a dynamically driven diaphragm coupled to an acoustic resistance is given by

$$Eff = \frac{r_M}{r_M + r_D} \quad (1)$$

where r_M = real part of the mechanical impedance Z_M.

$Z_M = \dfrac{(Bl)^2}{Z_T}$.

B = flux density.

l = length of voice-coil conductor.

$Z_T = AR_{A1} + j\omega m$.

R_{A1} = acoustic resistance.

m = mass of diaphragm and coil.

A = area of diaphragm.

r_D = damped resistance of voice-coil.

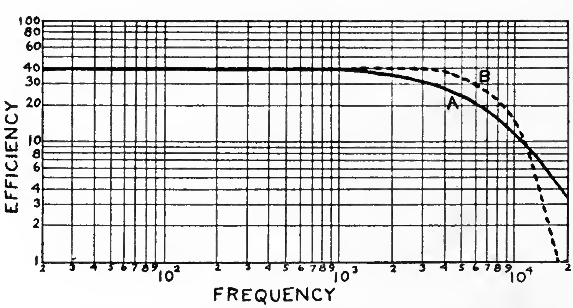


FIG. 2. Efficiency characteristic of a dynamically driven diaphragm coupled to an acoustic resistance: *A*, without air chamber; *B*, with air-chamber.

The efficiency characteristics of this system for a voice-coil of half the mass of the diaphragm operating in a gap of 22,000 gauss for various initial efficiencies is shown in Fig. 1. These characteristics show that to attain a high efficiency at the high frequencies a relatively large throat resistance is required, while to attain a high efficiency at the low frequencies a relatively small throat resistance is required.

The discussion has assumed that the system consists of only two elements, namely, the throat resistance and diaphragm plus coil mass. The stiffness of the suspension system influences the low-

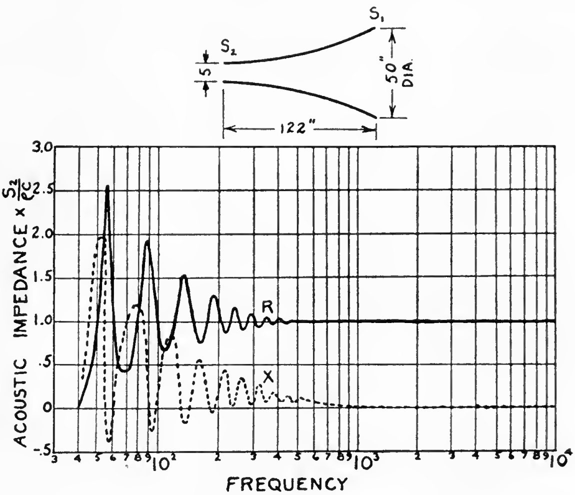


FIG. 3. Throat impedance characteristic of an exponential horn of the dimensions shown and cut off due to flare of 40 cycles: *R*, resistive component; *X*, reactive component.

frequency efficiency. In general, the stiffness is chosen so that the capacitance annuls the large positive reactance near the cut-off of a finite horn. The capacitance of the air-chamber affects the efficiency at the high frequencies. As a matter of fact, the air-chamber is extremely useful for increasing the efficiency and effecting a sharp cut-off.

The efficiency characteristics of a system consisting of a dynamically driven cone coupled to a resistance with and without an air-chamber are shown in Fig. 2. These characteristics show that it is possible to improve the shape of the efficiency characteristic by means of an air chamber.

To proceed with the subject of a method for obtaining a horn system that will make it possible to attain practically the maximum efficiency throughout the range, let us consider first a finite exponential horn. The throat acoustic impedance[1] is given by

$$Z_2 = \frac{\rho c}{S_2}\left[\frac{Z_1 \cos(b_1 l_1 - \theta_1) + \frac{j\rho c}{S_1}\sin(b_1 l_1)}{jZ_1 \sin(b_1 l_1) + \frac{\rho c}{S_1}\cos(b_1 l_1 + \theta_1)}\right] \quad (2)$$

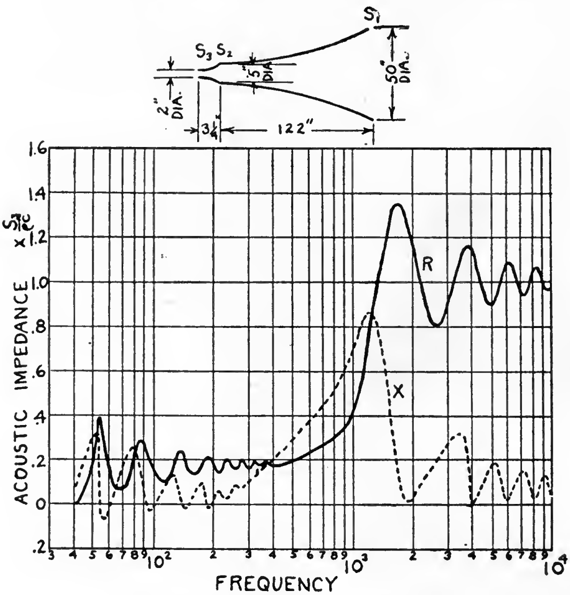


FIG. 4. Throat impedance characteristic of a multiple flare exponential horn. The large horn is the same as shown in Fig. 3. The small horn has a flare cut-off of 600 cycles: *R*, resistive component at throat of small horn; *X*, reactive component. In this example the impedance is referred to S_3 while in Fig. 3 the impedance is referred to S_2.

ρ = density of air.
c = velocity of sound.
m_1 = flare constant.
$a_1 = \frac{-m_1}{2}$,
$b_1 = \frac{1}{2}\sqrt{4K^2 - m_1^2}$.
$K = 2\pi/\lambda$.

λ = wavelength.
ω = $2\pi f$.
f = frequency.
l_1 = length of the horn.
$\theta_1 = \tan^{-1} \frac{a_1}{b_1}$
S_2 = throat area.
S_2 = mouth area.
Z_1 = mouth acoustic impedance.

A typical impedance characteristic for a horn of this type is shown in Fig. 3.

Suppose that a short horn having a high rate of flare compared to that of the large horn is connected to the large horn of Fig. 3, as shown in Fig. 4. The impedance at the throat of the small horn is given by

$$Z_3 = \frac{\rho c}{S_3}\left[\frac{Z_2 \cos (b_2 l_2 - \theta_2) + \frac{j\rho c}{S_2} \sin (b_2 l_2)}{jZ_2 \sin (b_2 l_2) + \frac{\rho c}{S_2} \cos (b_2 l_2 + \theta_2)}\right] \quad (3)$$

where $a_2 = \frac{-m_2}{2}$

m_2 = the flare constant of small horn.
$b_2 = \frac{1}{2}\sqrt{4K^2 - m_2^2}$.
l_2 = length of small horn.
$\theta_2 = \tan^{-1} \frac{a_2}{b_2}$.
S_3 = throat area of small horn.
S_2 = mouth area of large horn.
Z_2 = acoustic impedance obtained from equation *1*.

For $b_2 = 0$ equation *3* is indeterminate. To evaluate, take the derivative of the numerator and denominator with respect to b_2, and set $b_2 = 0$. Then equation *3* becomes:

$$Z_3 = \frac{\rho c}{S_3}\left[\frac{Z_2\left(1 - \frac{m_2 l_2}{2}\right) + j\frac{\rho c}{S_2}\left(\frac{l_2 m_2}{2}\right)}{jZ_2\left(\frac{l_2 m_2}{2}\right) + \frac{\rho c}{S_2}\left(1 + \frac{m_2 l_2}{2}\right)}\right] \quad (4)$$

In most cases for the frequency at which $b = 0$, the impedance at the mouth of the small horn is a constant resistance of the value,

$$Z_2 = \frac{\rho c}{S_2}$$

Then the expression for the impedance at the throat of the small horn becomes, for $b_2 = 0$:

$$Z_3 = \frac{\rho c}{S_3} \left[\frac{1 + j\,\dfrac{l_2 m_2}{2} - \dfrac{l_2 m_2}{2}}{1 + \dfrac{l_2 m_2}{2} + j\,\dfrac{l_2 m_2}{2}} \right] \tag{5}$$

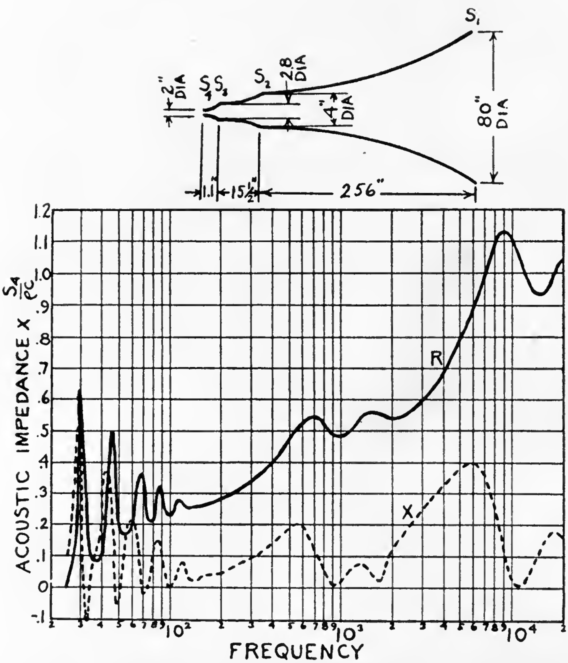


FIG. 5. Throat impedance characteristic of a multiple flare exponential horn of three sections. The cut-offs due to flare of the three horns are 25, 100, and 1400 cycles: R, resistive component at the throat of the small horn; X, reactive component. In this example the impedance is referred to S_4.

Below the frequency corresponding to $b_1 = 0$, b_1 is imaginary. This portion of the range may be evaluated by employing the standard formulas involving complex quantities.

The impedance characteristic of a horn with two rates of flare is shown in Fig. 4. The large horn is the same as that shown in Fig. 3. This characteristic shows that at the low frequencies the impedance characteristic is the same as that shown in Fig. 3. However, at the high frequencies the resistance is more than six times the resistance at the low frequencies. Employing this horn it is possible to attain practically the same efficiency characteristic as in the case of two separate horns and driving mechanisms.

Fig. 5 shows the impedance characteristic of a horn consisting of three exponential sections. The three distinct steps representing the three horns are quite evident.

The efficiency characteristic of a diaphragm and coil, having a mass ratio of 2, operating in a field of 22,000 gauss, coupled to the horn of Fig. 5, is shown in Fig. 6. This efficiency characteristic is only a

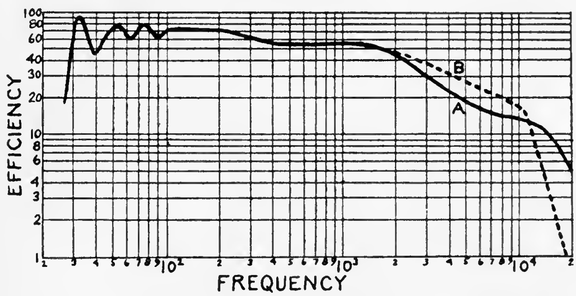


FIG. 6. Efficiency characteristic of a diaphragm coupled to the horn of Fig. 5 and driven by an aluminum coil of one-half the diaphragm mass operating in a field of 22,000 gauss: *A*, without air chamber; *B*, with air-chamber.

few per cent below the ultimate efficiency characteristic obtained from the envelope of the family of characteristics shown in Fig. 1. The characteristic *A* shown in Fig. 6 was computed assuming the capacitance of the air chamber to be zero. Of course such a condition is impossible in a practical loud speaker. The dotted characteristic *B* of Fig. 6 shows the efficiency with an air-chamber. The air-chamber increases the efficiency over a considerable range and effects a sharp cut-off at the high-frequency response limit.

High-power horn loud speakers for sound reënforcing and public address systems employing multiple flare horns have been developed by M. L. Graham.[2] The high efficiency over a wide frequency range exhibited by these loud speakers confirms the theoretical analysis outlined above.

The above examples have shown how it is possible to obtain a large variety of impedance characteristics by employing multiple exponential horns with different rates of flare. To attain maximum efficiency at any frequency, the effective reactance of the entire vibrating system should be equal to the effective radiation resistance. The principal reactance* at the high frequencies is due to the mass of the diaphragm. If the throat resistance increases with frequency as in the case of multiple exponential horns, it is possible to improve the efficiency as shown in the examples above. Of course, it is not necessary to employ exponential horns. The same results could be attained with a horn having a predetermined rate of expansion to yield the desired resistance characteristic. Multiple exponential horns have been used in this paper to illustrate the principles involved.

REFERENCES

[1] OLSON, H. F., AND MASSA, F.: "Applied Acoustics," *P. Blakiston's Son Co.* (Philadelphia), p. 188.

[2] GRAHAM, M. L.: "New High-Powered Sound Projectors," *Broadcast News* (Dec., 1937), No. 27, p. 4.

* The horn throat impedance has a reactive as well as a resistive component. In general the constants of the system can be chosen so that this reactance will not materially reduce the efficiency.

SCORING-STAGE DESIGN*

M. RETTINGER**

Summary.—*Design requirements for the construction of scoring stages are discussed, and, after a brief examination of the uses to which such recording stages are put in motion picture studios, there follows an examination of their most desirable shape and of the amount of sound-insulation necessary for their walls. The matter of optimal reverberation is investigated from the standpoints of the variation of reverberation with frequency, of accommodating different musical performances by providing control of the reverberation, and of considering the ratio of "initial" sound to generally reflected sound—an extension of the term "recorded reverberation."*

The adaptation of musical accompaniment to a motion picture may be effected in a variety of ways. Sound-tracks of vocalists accompanied by an orchestra may be made, and a print of the recording played back when the scene is photographed. Because the cameras are electrically interlocked with the sound reproducers, and picture cuts will be printed with the original sound-track, action and sound on the screen are in complete synchronism. This method is known as pre-scoring. Again, a picture may be shown upon the screen of a stage in which an orchestra is assembled. During the showing of a sequence, which might carry only a piano track, a recording of the orchestra is made while the musical director listens to the sound-track through a pair of ear-phones. Later the piano track and the orchestra track are combined by a method of re-recording, or dubbing, and then cut into a finished picture. Taking the original sequence with its piano track is known as synchronous or direct recording with incomplete accompaniment; making the orchestra track is referred to as post-scoring (sometimes also as merely scoring). There are, of course, other ways in which music may be set to a picture, but the above illustration should indicate the complexities of the task.

The studio in which the music is recorded is known as "recording" or "scoring stage," in contradistinction to a "sound-stage," which is used for recording action scenes. Only rarely is photography done

---

* Received December 28, 1937.

** RCA Manufacturing Company, Hollywood, Calif.

in a scoring stage. If dialog is recorded there, it is mostly in the form of commentation to newsreels, travelogues, and trailers. Scoring stages thus differ from the smaller radio studios used for a variety of broadcasts, although the acoustic principles underlying the design of the latter can with some modifications successfully be carried over to the design of the former.

Design Considerations.—The problems associated with the design of a recording stage are manifold. Since musical performances rendered in a scoring stage vary so widely as to type of program and

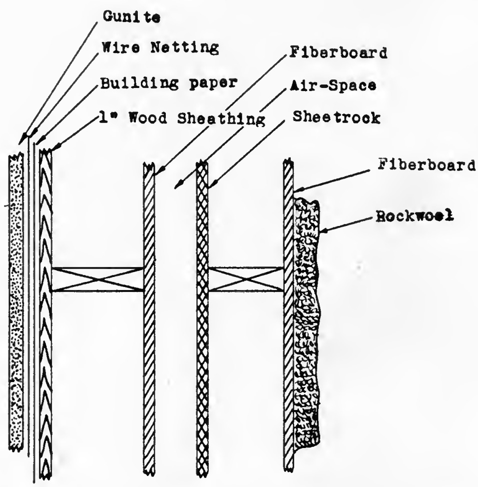


FIG. 1. Section through well insulating wall for a recording studio.

number of artists involved, such rooms should permit some control of the acoustics. The large size of the stage, necessary to accommodate symphony orchestras, requires careful consideration of reverberation, echoes, and interference. Again, the wider range of the audio-frequency spectrum recorded in such a stage necessitates provision for sustaining and distributing the higher notes as much as possible.

Several ratios for the dimensions of height, width, and length of recording stages have been proposed. Many of the larger American broadcast studios have a ratio of 2:3:5,[1] while in Germany the ratio is 1:2:3. The British Broadcasting Company[2] advocates that the length be made 25 to 75 per cent greater than the breadth, and that considerable height is a definite advantage. Of the ratios 2:3:5

and 1:2:3, *for studios of equal volume*, the writer favors the latter, first because it makes for greater ceiling height; and second, because the mean free path* is somewhat shorter. As is well known, the ratio of velocity of sound to mean free path represents the average number of reflections per second at any point in the room, so that a shorter mean free path will make for a larger number of such reflections per second, and hence for a more diffused state of sound in the room.

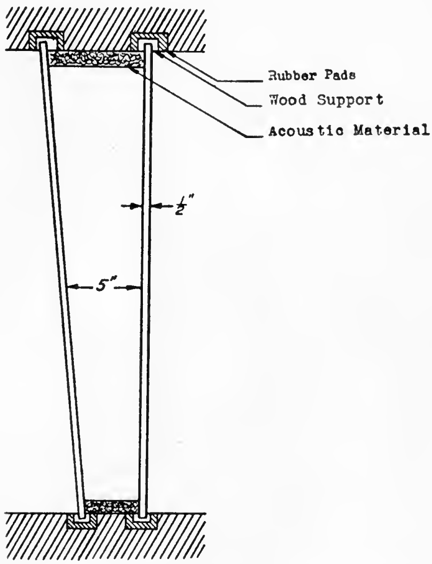


FIG. 2. Section through monitoring-room window.

Patently, for very large stages a compromise must be made as to ceiling height, to prevent its becoming abnormally high.

Next in order of design considerations may be discussed the problem of adequate insulation against outside noise, both air-borne and solid-borne. The subject is extensive, and many papers and books have been written about it. Here only special remarks pertaining to sound stages will be made, with particular attention to the present trend toward non-concrete structures.

---

* The mean free path for a rectangular room is given by $4V/s$, where V is the volume and S the total interior surface of the room.

After a noise survey has been conducted at the proposed site, a type of construction should be selected that will result in a noise-level within the stage of not more than 30 db. above the reference standard of 0.0002 dyne/cm.² as measured with a noise-level meter[3] having a 30-db. equi-loudness contour characteristic. An attempt, on the other hand, to establish an extraordinarily low noise level in the stage leads either to massive concrete or to very thick and elaborately constructed multi-layer walls, which will prove very expensive. It may be kept in mind that the thermal agitation noise of microphones is

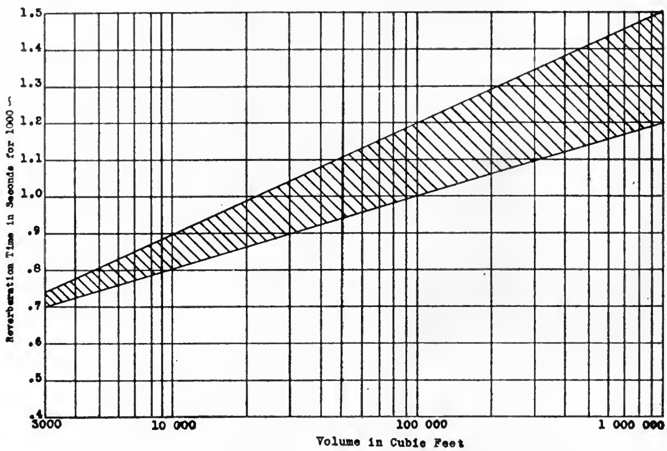


FIG. 3. Variation of reverberation time with volume for a frequency of 1000 cps.

of such order that sound levels up to some 10 db. above the threshold of audibility are masked out for many frequencies.

If we wish our stage of wood-frame construction to have an average transmission loss of 50 db., we shall probably find it most economical to employ two walls structurally isolated from each other as much as possible. A partition having inner and outer sheaths, and for that matter, a homogeneous multi-layer partition, may be likened to a high-pass filter having a cut-off of[4]

$$f_c = \frac{c}{\pi}\sqrt{\frac{p}{m\,l}}$$

where m is the mass (grams/cm.²) of a single layer, l the thickness (cm.) of the intervening air-space, p the density of air (0.0012 gram/-

cm.[3]), and *c* the sound velocity (cm./sec.). This means that for a double-layer partition having a cut-off frequency of 50 cps. and a separation between inner and outer sheaths of 10 cm. (approx. 4 inches), the wall mass per square centimeter would have to be of the order of 6 grams. This clearly indicates the desirability of employing structurally isolated double-partition walls, such as shown by Fig. 1, which have been used with satisfactory results in the construction of several large sound stages.

It has been the experience of this writer that in stages that were claimed to be insufficiently insulated it was not always the walls, floor, or ceiling that transmitted the noise so annoyingly, but openings to the stage-doors, ventilator, ducts, cable-boxes, *etc.* Double doors, of solid construction, containing a $^1/_{16}$-inch sheet of lead, are always in order. The doors must fit tightly, and the surrounding

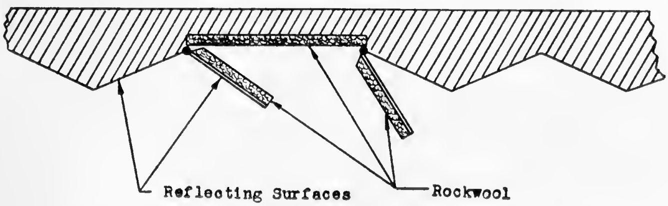


FIG. 4. Means for controlling acoustics of scoring stage.

wall space between them should be covered with a highly absorbing material. Monitoring windows should consist of two $^1/_2$-inch glass panes inclined to each other, separated by at least 5 inches, and the wall space between them treated acoustically, as shown in Fig. 2. Ventilator openings should be provided with baffles in the shape of an inverted pyramid having a sound-absorbing material on the inside. To prevent the structure-borne noise of traffic rumble, the stage foundation should be separated from the street pavement by a deep ditch filled with soft earth. The ceiling must be so designed as to prevent the patter of rain from entering, and with an eye to airplane noise, if the stage is located at the outskirts of the city.

Reverberation.—In planning for satisfactory acoustics in a room there always appear the twin questions of the most desirable time of reverberation* for a particular frequency (standard frequency now is

* The reverberation time for a given frequency is the time required for the average sound-energy density, initially in a steady state, to decrease, after the source is stopped, to one millionth of its initial value.

1000 cps.), and the variation of this time with frequency. Early experiments established that the optimal reverberation time was not constant for a given room, but depended upon the type of performance taking place in it. For that reason many broadcast stations have adopted ingenious devices for controlling the reverberation time of their studios, one station going so far as providing a movable wall.[5]

As is well known, larger rooms can tolerate a longer reverberation time than small rooms. Recording studios should have a reverberation time about $^2/_3$ of that found satisfactory for a room of equal volume used for binaural hearing. Fig. 3 gives the limits of variation of reverberation time with volume for scoring stages, and illustrates mainly that it is impossible to speak of the optimal time of reverberation of a room as a definite figure unless one mentions at the same time

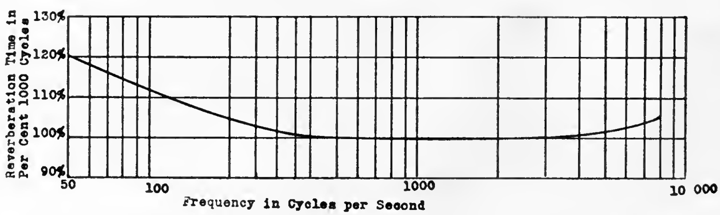


FIG. 5. Variation of reverberation time with frequency for scoring stage, expressed in per cent of the time for 1000 cps.

the type of activity for which the room is used—speech, piano recitals, songs, *etc.* The optimal time, in general, is therefore a range, with upper limit pertaining to organ oratorio and lower limit, to speech. While a variation of 0.1 second in the reverberation time of a room used for a particular activity would probably not be noticed by the majority of listeners, some adjustment of localized reverberation is well in place in a scoring stage. Fig. 4 shows a type of construction devised by the writer and used with noticeable success in a local recording studio.

The variation of reverberation time with frequency, called the reverberation characteristic, has been widely discussed in literature.[6,7,8,9] None of the criteria so far proposed for the reverberation characteristic in rooms appears to be completely tenable for scoring stages, however. Even MacNair's criterion,* which for the lower

* By this criterion the loudness level of all frequency components in speech and music should decay at the same constant rate.

frequencies makes for reverberation times shorter than those obtained by any other criterion, when applied to a scoring stage still produces recordings marred by a little "boominess." Fig. 5 shows, in per cent of 1000 cps., the average reverberation characteristic of three scoring stages having admittedly good reverberation characteristics for re-

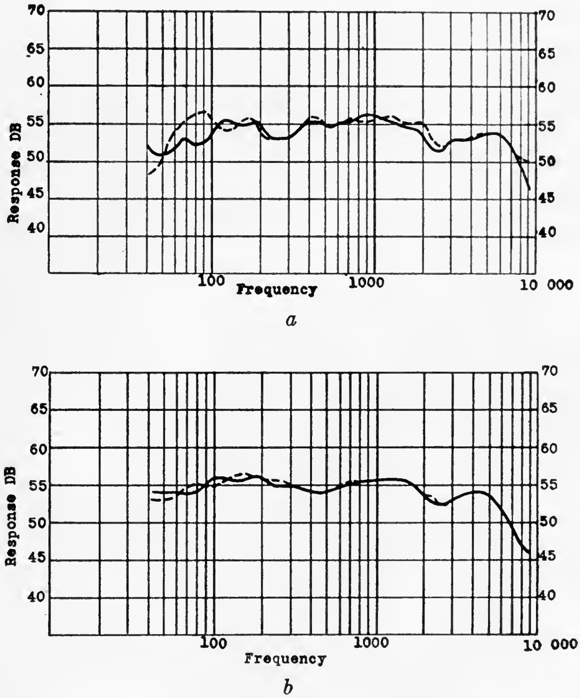


FIG. 6. Loud speaker response curves taken at two different positions near center of two equally sized rooms when the same loud speaker was positioned at one end of room: (*a*) for live, (*b*) for dead room.

cording purposes. It is important also to avoid structural resonances in a stage, which resonances always show up in the form of dips or valleys in the reverberation characteristic and produce marked frequency discrimination in the transcribed sound.

Shape of Stage.—Experience has shown that for satisfactory recording an orchestra should be placed in a "live," and the microphone in a comparatively "dead" region of the stage. A region of localized reverberation for the orchestra permits musicians, long accustomed to playing in reverberant concert halls, to keep more easily in tune, to determine without undue effort precisely the true pitch of the following note while perceiving the present one, and to retain proper balance between bass and treble. The dead region surrounding the microphone is necessary, not only to provide placement of sufficient absorbing material to give the desired reverberation period in the stage, but also to permit smoothing out whatever interference-pattern may exist at the position of the transmitter during a recording. Interference may be of the nature of a space or a time effect. The first enters most clearly during sustained passages, when the transmitter may be at a region of reduced or enhanced

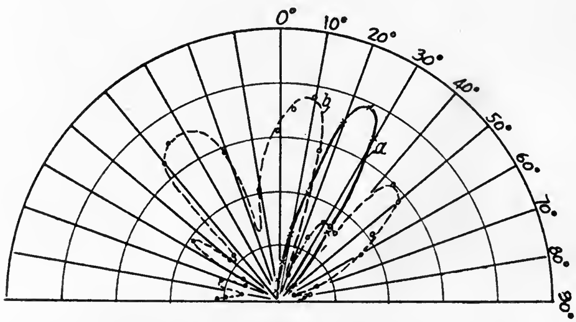
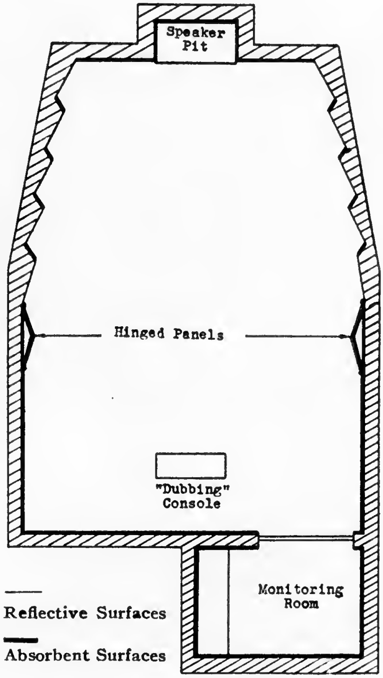


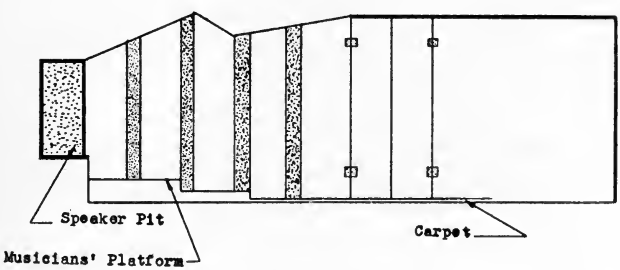
FIG. 7. Dispersion of reflected sound energy from flat surface (*solid line*) and when four semicylindrical pieces of wood were fastened to the surface (*dashed line*). Test frequency was 7000 cps. (*E. Meyer.*)

sound intensity. The second effect makes itself known in the form of irregular fluctuations of the sound pressure during growth or decay of the sound in the room. (Sound dies away in a truly exponential fashion only in a live room, and only so far as the total sound energy in the room is concerned.) The more reverberant a room, the more pronounced are the two effects, and the more disturbing do they appear in a recording. The extent to which recordings may vary in a live room because of interference in the region of the microphone may be shown by Fig. 6, which contains loud speaker response curves for two different microphone placements near the middle of two equally sized rooms, one live and one dead, when the same loud speaker was placed at one end of the room.

The reflective and absorbent areas are controlled by the shape and dimensions of the stage. The shape and acoustic treatment of the "shell" (region of orchestra) determine the amount of "initial" sound at the position of the microphone. By initial sound is meant



a



b

FIG. 8(*a*). Plan of a scoring stage.
FIG. 8(*b*). Elevation of scoring stage.

not only the direct sound, but also such first (and possibly second) reflections as will be responsible for the sudden drop of voltage in the microphone when the source or sources are suddenly stopped. The apparent "liveness" of a recording (also termed "presence" or "acoustic perspective") appears to be substantially influenced by this ratio of generally reflected to initial sound energy, known also as recorded reverberation.*[10] The larger the ratio, the more distant does the original source of sound appear to be, even when the loudness of the reproduced sound remains unchanged. This illusion of depth is also, to an extent, dependent upon the time-intervals of the initial and the generally reflected sound, for which we obtain a measure from the initial slope of the reverberation-time curve obtained with a high-speed level recorder.[11] If this steep initial drop represents too large a change of level, it may be that we associate an impression of "flatness" with the music (the impression one receives when listening to music in the open); if too small a change of level, that definition is lost, and that at least vocal music appears blurred. The desired goal evidently is to achieve small recorded reverberation in a room of moderate liveness. This means essentially that there must be reflective surfaces *near* the source or sources of sound, so that the "initial" sound will be large. Another solution is to use a directional microphone, which limits the generally reflected sound that is recorded.

There appears also to be a definite connection between the types and number of instruments recorded and the "distance" that the ear will accept as satisfactory in the reproduced sound. No thorough study seems to have been made of this factor and its influence upon the quality of transcribed sound. The writer has shown that the per cent syllable articulation of recorded sound is dependent only upon the amount of recorded reverberation in a room free from noise and echoes.[12]

Because of the reverberant character of the "shell" it becomes important to make arrangements for the prevention of echoes, and for an effective dispersion of the sound to obtain more uniform distribution in the room. Echoes are avoided by non-parallel location of the reflecting surfaces. In the simplest form, this can be done by properly splaying the side-walls of the room. Dispersion can be effected only by providing suitably oriented corrugations of sufficient depth to become effective also as diffusers of sound for the lower frequencies. Fig. 7*[13] shows the dispersion of reflected sound energy

* Olson defines recorded reverberation as the ratio of generally reflected to *direct* sound energy.

from a flat surface (solid line) and from a flat surface to which four semicylindrical pieces of wood were fastened (dashed line). The test frequency was 7000 cps. (plane waves); the area of the reflecting

FIG. 9(*a*). Corrugated ceiling of scoring stage (*Courtesy of Columbia Pictures Corp.*).

FIG. 9(*b*). Corrugated side-wall of scoring stage (*Courtesy of Columbia Pictures Corp.*).

surface, 0.25 sq. m.; and the angle of incidence, 25 degrees. As is seen, the sound energy from the corrugated wall is scattered in several directions, causing diffuse instead of geometrical or specular reflections. The dispersion becomes the more important the higher the frequency, because of the directional character of those frequencies.

Convex instead of flat reflectors could be suggested, but if it is desired to maintain a fair amount of initial sound near the center of the stage, the greater dispersive quality of such convex surfaces would not tend to accomplish this object.

A splayed ceiling is advantageous. Even as in the design of the splayed side-walls, however, it is difficult to determine accurately the angle of inclination that such reflectors should have, due to the large number of sources of sound that have to be considered in an orchestra. For that reason also it does not appear necessary to the writer to go to unusual, irregular shapes for a stage. Structural symmetry does not make for annoying sound-concentrations if the source of

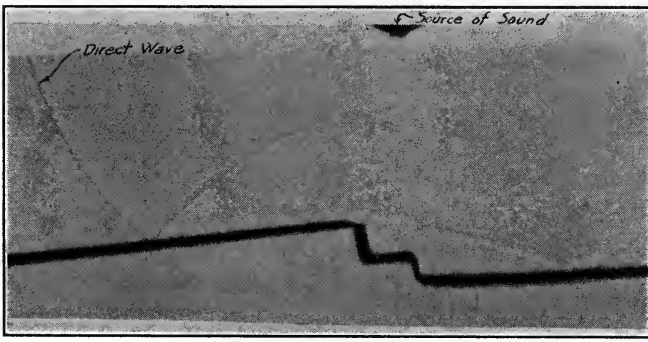


FIG. 10. Spark photograph showing diffusing effect of corrugations (*Courtesy Frank Rieber Laboratories*).

sound is not located symmetrically with respect to the walls of the rooms, and if there are no large concave reflecting surfaces. It is desirable, however, to provide absorbent surfaces at a reversed angle to the reflective parts of the corrugations in order to prevent the sound from being returned into the shell in too great measure.

There is no doubt, however, that every precaution must be taken to reduce the blurring effects of reverberation in recording. If, for binaural hearing, all the sound that comes to the listener within $^1/_{16}$ second is to be regarded as useful, and all that comes to him later is to be regarded as harmful, this limit must be reduced for monaural hearing, since reverberation appears prolonged for the latter case. This is true because the binaural hearing mechanism is capable of focusing attention upon the direct sound, thereby noticeably attenuating the troublesome effect of reflected sound.

The center sections of the side-walls should permit considerable control of the acoustics of the room. It should be possible to effect such control quickly and without disturbing the appearance of the stage. Nothing is so distracting in an otherwise well-appointed stage as the sight of dark hairfelt quilts applied directly to a wall or suspended from the ceiling at a distance from the wall, or the sight of collapsible screens that are likely to be turned over.

Figs. 8 (*a*) and (*b*) show the plan and elevation of a scoring stage incorporating the features discussed above. The entire rear wall should be treated with an effective acoustic material that can be quickly cleaned and is not easily damaged. It should particularly be very absorbent for the lower frequencies, which often enter so disturbingly in recording. One might keep in mind that an absorptivity, for instance, of 0.75 means that only 25 per cent of the sound energy but 50 per cent ($=\sqrt{0.25}$) of the sound pressure, is reflected. An acoustic treatment that has proved very effective consists of 4-inch rockwool packed between 2 × 4-inch studs, 2 ft. on centers, and covered with cheesecloth and wire netting; 1 × 1-inch wooden strips are then nailed at right angles to the studs, 16 inches on centers, and a perforated hardboard such as Masonite or Transite is applied to the construction. Such surfaces can be painted with oil paint without detracting from the absorptivity of the construction, and can be washed if necessary with soap and hot water.

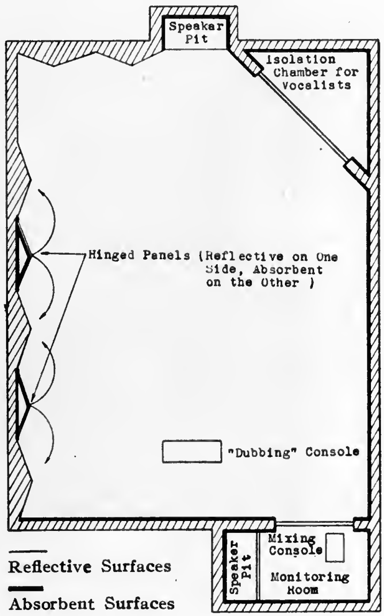


FIG. 11. Plan for scoring stage.

The corrugations may be made of 1 × 1-inch tongue-and-grooved wood, sanded to a smooth surface, and either varnished or painted in conformity with a color scheme for the room. In one scoring stage of design similar to the plan shown by Fig. 8, the corrugations consisted of 4 inches of plaster troweled to a smooth finish and painted. Such projections must be well braced, as should the construction at reversed angle carrying the acoustic treatment. Bandstands also should be of rigid construction, and a carpet always should be laid on the floor from the orchestra to the microphone. The hinged panels shown may be of the type represented in detail by Fig. 4, which can conveniently be supported by rubber-covered casters.

If the stage is large it may be that the path difference between the direct sound from a source within the shell and the reflection from the front wall (wall carrying the loud speakers) is of the order of 60

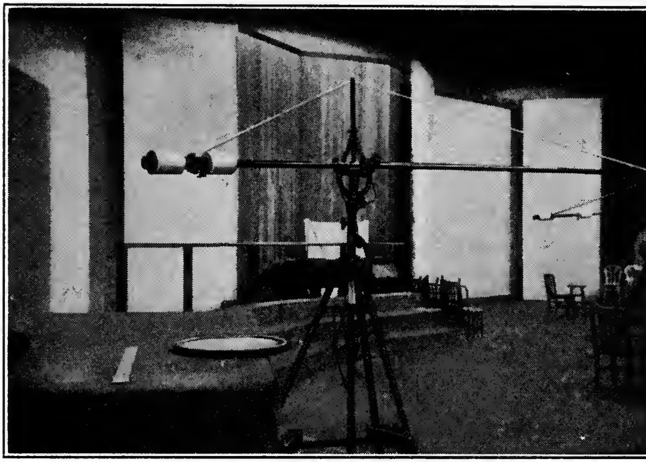


FIG. 12. Photograph showing part of scoring stage having plan of Fig. 11 (*Courtesy Warner Bros.-First National Studios*).

ft., in which case a very pronounced echo will result if the front wall is made reflective. This can be overcome either by providing the wall with corrugations or by treating it acoustically. In order to prevent the shell from becoming too reverberant it was thought desirable in one instance to provide the front wall with a sound-absorbing material, as shown in Fig. 8(*a*). The success of such treatment has been borne out by actual experience, in spite of the fact that the reverberation in the longitudinal direction was thereby decreased slightly.

Figs. 9(*a*) and (*b*) are photographs of corrugated ceiling and side-wall of a scoring stage having outlines similar to Fig. 8(*a*). Fig. 10

is a spark photograph illustrating the diffusing action of the corrugations.

Fig. 11 shows a scoring stage modeled on a somewhat different plan. Such a stage permits the placement of a very large orchestra, while the larger sound pick-up angle conveys a greater illusion of distance in accord with the more usual position of a listener at a symphonic concert. The ratio of height, width, and length of such a stage comes more nearly to 1:3:4, and a stage built on this plan has produced very gratifying results.

A ventilating system is in place in every scoring stage, where rehearsals may last for hours. Also, modern lighting fixtures do much to improve the appearance of a stage. Music, as someone has aptly said, is not one absolute tone after another, but a sequence of tone-adjustments and tone-relationships modified at every instant by the room and the players together. There is much to acoustics that is psychological.

This paper, obviously, represents a discussion of factors entering into the design of a new scoring stage. In many cases, however, compromises will have to be made. It is usually not wholly the prerogative of the acoustic engineer to select the site and size for such a stage. Again, because of obsolescence, a stage may require improved treatment, or may have to be enlarged. Whatever the case, however, the fundamental requirements discussed above must be met if satisfactory service is to be rendered. Plans made beforehand must control the outcome.

The writer takes this opportunity to express his sincere appreciation to Mr. John P. Livadary of Columbia Pictures Corporation for helpful suggestions and discussions on the subject matter.

REFERENCES

[1] MORRIS, M. M., AND NIXON, G. M.: "NBC Studio Design," *J. Acoust. Soc. Amer.*, **VIII** (Oct., 1936), No. 2, p. 21.

[2] GLOVER, C. W.: "Practical Acoustics for the Constructor," *Chapman & Hall Ltd.* (London), 1933, p. 165.

[3] WENTE, E. C.: "Instruments for Acoustical Studies," *J. Soc. Mot. Pict. Eng.*, **XXV** (Nov., 1935), No. 5, p. 389.

[4] MEYER, E.: "Transmission of Sound and Vibration in Buildings," *J. Soc. Mot. Pict. Eng.*, **XXVIII** (March, 1937), No. 3, p. 271.

[5] *Cf.* ref. 1.

[6] RETTINGER, M.: "Note on Reverberation Characteristics," *J. Acoust. Soc. Amer.*, **VI** (July, 1934), No. 1, p. 51.

[7] KNUDSON, V. O.: "Recent Developments in Architectural Acoustics," *Rev. Modern Physics*, **VI** (Jan., 1934), No. 1, p. 14.

[8] EYRING, C. F.: "The Reverberation Time in Dead Rooms," *J. Acoust. Soc. Amer.*, **I** (1930), No. 2, p. 217.

[9] MACNAIR, W. A.: "Optimum Reverberation Time for Auditoriums," *J. Acoust. Soc. Amer.*, **I** (1930) No. 3, p. 242.

[10] OLSON, H. F., AND MASSA, F.: "Applied Acoustics," *P. Blakiston's Son Co., Inc.* (Philadelphia), 1934, p. 338.

[11] MEYER, E.: "Reverberation and Absorption of Sound," *J. Acoust. Soc. Amer.* (Jan., 1937), No. 3, p. 155.

[12] RETTINGER, M.: "Note on the Velocity Microphone," *J. Soc. Mot. Pict. Eng.*, **XXIX** (Dec., 1937), No. 6, p. 629.

[13] MEYER, E.: "Über die Messung von Schollschluckstoffen in Hallräumen," *Akust. Zeitschr.*, **II** (July, 1937), No. 4, p. 179.

RECENT DEVELOPMENTS IN BACKGROUND PROJECTION*

G. G. POPOVICI**

Summary.—*The complexity of background projection is generally known. It has been widely applied in cinematography with great success. A new field offers tremendous opportunity, namely, still photography. Two types of background projector are described, one to cover screens up to 10 × 12 feet, the other up to 13 × 18 feet. The following elements of the problem are discussed:*

(1) The spot condition: what causes it and how to reduce it, even to eliminating it entirely. (2) Screen texture: nitrate or acetate base sprayed with polarizing material for diffusion (flatlight type); the new Trans-Lux screen of the high-transmission type. (3) Theory of light refraction through screen. (4) Light brightness vs. diffusion of screen. (5) Optical conditions, condensers, objective lenses, etc. (6) Light-source: brightness vs. current, behavior of different types of carbons; spectral consideration in color projection. (7) Cooling the slides with refrigerated air. (8) Electrical and optical characteristics, remote control of arc, douser, air-cooling system.

Several years ago the subject of background motion picture projection was discussed in the JOURNAL.[1] It is now proposed to describe devices for use in connection with still photography background projection, as it is believed that such information will be of interest to many in the motion picture field.

A compact projector for still projection was designed and has been proved satisfactory, both for black-and-white and for certain types of color photography. Several of its features are (*1*) an adjustable stand for holding the lamp house and rheostat; (*2*) a lamp house containing a high-intensity rotating carbon arc lamp, using 13.6-mm. carbons at a maximum current of 150 amperes, the condenser lenses being mounted on transite board within the housing; (*3*) a specially designed short-focus lens (6.25 inches), interchangeable with one of longer focus; (*4*) a holder for the slides (4 × 5 inches), which can be

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received October 4, 1937.

** New York, N. Y.

locked in any desired position; (5) a high-pressure blower for cooling the slides very efficiently, avoiding the use of liquid cells and attendant loss of light.

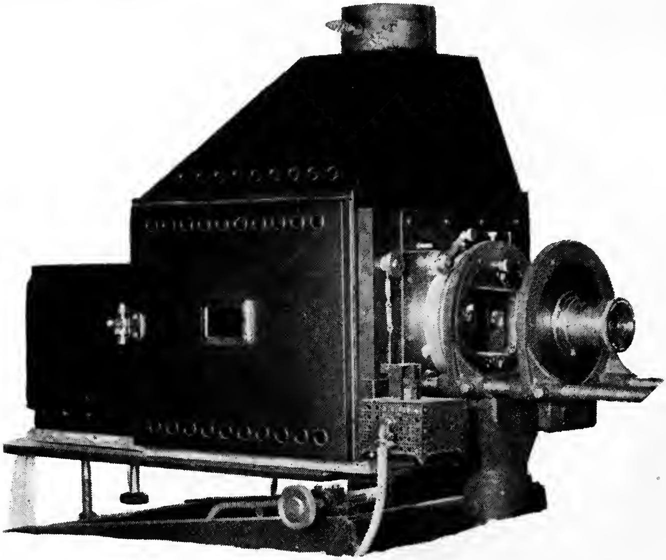


FIG. 1. Large background projector, showing lens mounting, adjustable slide holder, and air-blast tube.

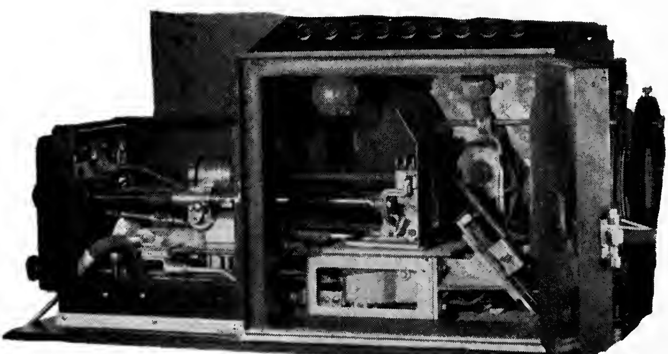


FIG. 2. Interior of projector lamp house, showing automatic control.

In response to the increased demand for color photography in illustration work, a very powerful projector has been designed, which satisfies more fully than before the requirements of the field. A re-modeled Hall & Connolly arc lamp and housing of the *HC-10* type was used (Fig. 1). The arc draws 200 amperes. The condensers are fixed in one plane but can be moved up and down or sidewise for accurate centering. They are mounted on transite, a medium that has proved to be better than cast iron. Next to the outside condenser is a casting incorporating the adjustable holder for the 4 × 5-inch slides and the nozzle through which the air flows for cooling. The casting that holds the lens is also adjustable so as to fit lenses of vari-

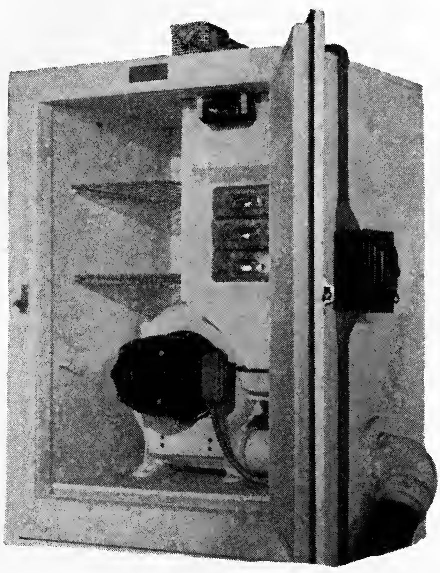


FIG. 3. Refrigerator with blower installed for supply of cold air-blast on slides.

ous focal lengths. Complete dual remote control is provided for operating the projector. Striking the arc, lifting and closing the douser, controlling the cooling system, and adjusting the rheostat can be done either from the projector or from the camera, with interlocked electrical controls (Fig. 2). Solenoids operate the douser and the air-valve of the refrigerator, in which a powerful pedal type of blower sucks from within cold air that has been cooled by passing the cooling coil (Fig. 3). The exhaust is piped to the nozzle, which distributes the air evenly over the slide. This blower delivers about 175 cubic feet of air a minute at a static pressure of $^3/_4$ pound per square-inch. The air temperature at the nozzle is about 40°F.

Two types of carbon have been tried out, namely, the French Lorraine and the National Carbon Company super high-intensity. Both have given similar results. They will carry a current of 190 amperes

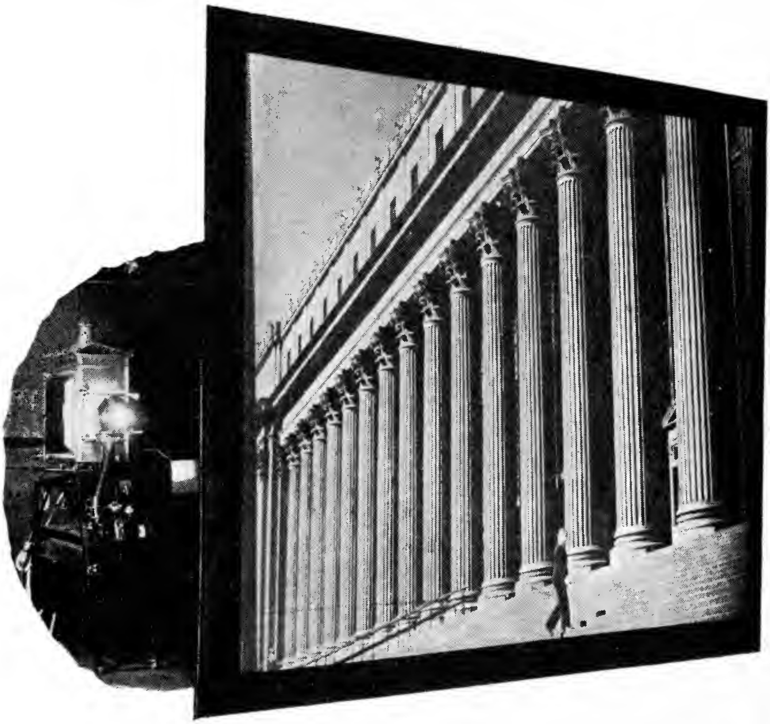


Fig. 4. Projector in operation, showing uniformity of projected image.

with an occasional increase to 200 amperes. Color projection with such equipment is very satisfactory.

Translucent screens for background projection work, to be efficient, must fulfill the following requirements:

(*1*) Transmit a maximum of incident light.
(*2*) Diffuse the transmitted light, avoiding hot-spots.
(*3*) Should have a long life and be non-inflammable.

Two general types of screen are in use today. One has as its base either cellulose nitrate or acetate which, as a fluid, is sprayed in layers, in the liquid state, upon a polished surface forming the body of the screen. Before the screen is peeled off, it is sprayed with polarizing material, such as, for instance, glass powder, to obtain the desired diffusion. Such screens have given good results, their only objection being the fire hazard.

The other type of screen is the cast screen, which is made of gelatin and silk, without seams. It is cast upon a special table, which is thermostatically controlled to insure the proper temperature. The table has prismatic ridges, which are reproduced in the surface of the

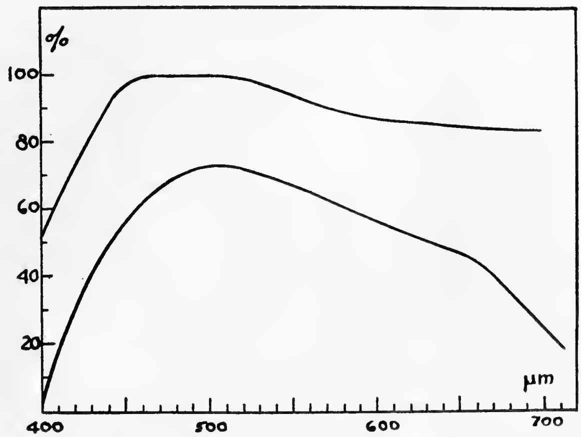


FIG. 5. Spectrograms: (*Upper curve*) H.I. arc, 140 amperes, through condensers and lens; (*lower curve*) same arc, through condensers, lens, and Translux screen (*HT* Studio type). (Carl Zeiss spectrograph; E.K. hypersensitized panchromatic plates.)

screen and thus create the required diffusion. High-transmission studio screens are produced today that will transmit 70 per cent of the incident light without causing an objectionable hot-spot, due to their texture and diffusion characteristics (Fig. 4).

A hot-spot, in studio parlance, is an emphasized brightness of an area of the projected image on the viewing or photographing side of the screen, and is always in the optical axis of the projector and camera. To understand its formation, consider the projector lens as a luminous point, forming an image on the rear of the viewing screen. If the screen were entirely transparent, all the light-rays would pass through with the exception of a small proportion due to reflection and absorption by material; hence no image would appear upon the screen and the light-source (lens) would be plainly visible. If the screen is translucent, but transmits a large percentage of the incident light, the light-source is still visible, but in the form of a diffused or "hot" spot. The illumination of the spot is given by the inverse square law:

$$E = \frac{I}{d^2} \cos i \qquad (1)$$

where I is the source intensity, d is the distance from the source to the screen, and i is the angle of incidence. When the diffusion factor D is introduced, the equation becomes:

$$E = \frac{I}{d^2 D} \cos i \qquad (2)$$

which shows that to reduce the hot-spot effect, either the distance or the diffusion must be increased. In the case of the Trans-Lux screen the diffusion is increased, thus enabling the use of shorter-focus lenses.

Fig. 5 shows two spectrograms. The upper represents the light-source (arc) direct; the lower one the same source photographed through a Trans-Lux screen. The curves show how well suited this type of screen is for color photography.

(At the conclusion of the paper, a motion picture was projected showing the equipment in operation.)

REFERENCE

[1] POPOVICI, G. G.: "Background Projection for Process Cinematography," *J. Soc. Mot. Pict. Eng.*, **XXIV** (Feb., 1935), No. 2, p. 102.

SENSITIVITY TESTS WITH AN ULTRA-SPEED NEGATIVE FILM*

P. H. ARNOLD**

Summary.—*The sensitivity of Ultra-Speed Panchromatic negative film is discussed in comparison to the speed of Superpan Negative film. A variety of testing methods, employing sensitometers, miniature still cameras, motion picture cameras, and different positive printing devices, are used in the determinations.*

The introduction of a negative material differing in speed from the familiar supersensitive panchromatic negative films more than the latter differed in speed, when introduced, from the ordinary panchromatic and orthochromatic films of the time has introduced new problems in the technical field of motion picture production. It is the purpose of this paper to discuss some of these problems in detail, paying particular attention to those that affect the cameraman and the laboratory supervisor.

When the Agfa Ansco Corporation introduced Ultra-Speed Panchromatic 35-mm. motion picture negative film early in November, 1937, the product had already been the subject of innumerable tests in the film factory at Binghamton, N. Y., over a period of several months. The production of a photographic material of unusual sensitivity necessarily entails manufacturing hazards of an extraordinary nature quite apart from those photographic considerations that affect the eventual user. The satisfaction of certain of these basic manufacturing requirements was, quite naturally, the first consideration of the makers. Tests undertaken primarily from the manufacturing point of view nevertheless produced a body of data and information both interesting and useful to the eventual user of the film.

---

* Presented at the meeting of the Atlantic Coast Section, December 8, 1937, New York, N. Y.; received March 23, 1938.

** Agfa Ansco Corporation, Binghamton, N. Y.

Ultra-Speed Panchromatic film was placed on the market with little instructional material, technical data, or descriptive literature for the guidance of the user, because of a most insistent and compelling demand, especially on the part of the newsreel companies, that forced the release of the new film for limited commercial distribution earlier than had been planned. Test-shots made under motion picture production conditions, instead of serving merely as guides for future

FIG. 1. Street scene, New York, Nov., 1937, 10 P.M. Photographed by *News of the Day*, on Ultra-Speed Panchromatic negative film in an Akeley sound camera equipped with $f/2.0$ lens.

work and accumulating a fund of information on the practical application of the new film, were actually taken into production and used for printing releases—a tribute to the courage as well as the technical skill of our American motion picture technicians.

During the four or five weeks that Ultra-Speed Panchromatic film has been used in and near New York City, the behavior of the film has been the subject of careful study by both the manufacturer and the users. No unforeseen difficulties of any great magnitude have arisen. Amazingly good results have been attained in a number of instances, and the claims of the manufacturer seem to have been borne out in practice (Figs. 1 and 2). In the light of that experience it seems appropriate now to consider systematically the problems that have arisen in the use of the new film. For convenience these problems will be considered under the following headings: (*1*) the cameraman's problem of speed rating and exposure, (*2*) the laboratory's problem of gradation and development, (*3*) problems of light-

FIG. 2. Spectators at the horse show at Madison Square Garden, New York, Nov., 1937. Photographed on Ultra-Speed Panchromatic film, under normal room illumination, by *Universal Newsreel*.

ing and color-sensitivity, (*4*) general emulsion characteristics and their pictorial importance.

The Cost of Speed.—Students of photography, in particular those who studied the characteristics and behavior of sensitized emulsions, long ago discovered that the promotion of one photographic characteristic was usually achieved at the expense of others. An increase in speed was to be attained, according to the tradition, at a sacrifice of clearness with a loss of stability or keeping quality, at the expense of brilliance, and particularly with a coarsening of the grain. The tradition persists despite the fact that several years ago the supersensitive panchromatic films demonstrated that dye sensitizers could produce emulsions of high speed without sacrifice of desirable photographic qualities. Emulsion chemists, ignoring the tradition, have so worked to perfect modern emulsions that the emulsions are today not only faster but finer-grained, freer from inherent fog, and more stable and better as to gradation characteristics than even the moderate-speed emulsions of a few years ago.

The general sensitivity of Ultra-Speed Panchromatic film presents a problem to the prospective user not only because of the magnitude of its speed advantage over existing materials, but also because of the old tradition about the cost of attaining emulsion speed during manufacture. The overall speed, which can be easily verified, exists in apparent and inexplicable contradiction to the gradation characteristics of the Ultra-Speed Panchromatic emulsion, which are manifestly good, the grain size, which is far from obtrusive, and the film's freedom from inherent fog. Moreover, the speed advantage does not appear to have been accomplished by making the emulsion over-responsive to light of certain wavelengths, a color-sensitivity condition that would produce a marked distortion of color values in the photograph.

Film-Speed Numbers.—The film-speed problem described above may be more mental than otherwise. However, there does exist a very real problem involving the proper speed rating of Ultra-Speed Panchromatic film as well as any other new film that appears on the market. The solution of that intricate problem is beyond the scope of the present paper. Nevertheless, the importance of the subject requires some discussion of its various aspects. The use of an actinometer, or exposure meter, for determining the exposure to be given a film for photographing a certain subject under a certain condition of illumination, requires a film-speed number relating the emulsion speed to the exposure calculating device.

Photographers who depend upon actinometers must be provided with film-speed numbers of some accuracy in order to use those instruments effectively. The photographer who relies upon his own skill, judgment, and experience to determine the exposure to give a film under a certain condition needs to know only how the new film differs as to speed, gradation, and color-sensitivity from the materials with which he is most familiar through repeated use. This last assertion is based, of course, upon the assumption that the photographer has been reasonably satisfied with the results he has been attaining, or that his exposures have been generally successful. It avoids fruitless discussion of the characteristics of a theoretically perfectly exposed negative.

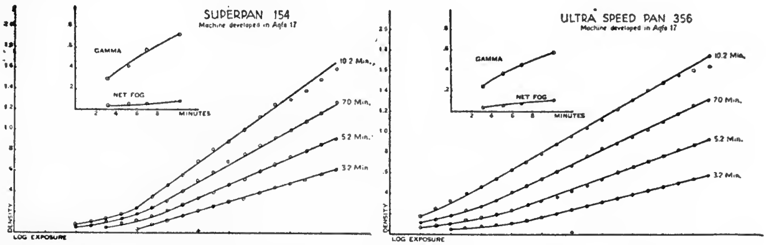


FIG. 3. Characteristic curves: Superpan *154* and Ultra-Speed pan *356*.

A Basis for Speed Comparison.—In the professional motion picture industry, for a certainty, the general characteristics of supersensitive panchromatic motion picture negative films are generally known. Avoiding hair-splitting comparisons, the high-speed negative film

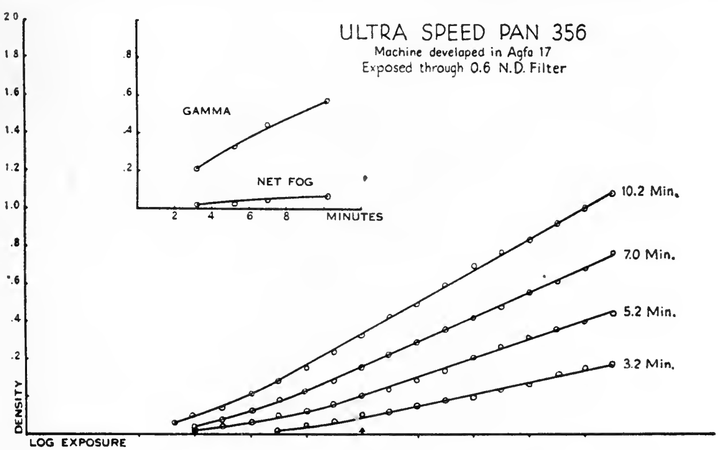


FIG. 4. Characteristic curve: Ultra-Speed pan *356*, with 0.6 neutral-density filter.

products of the several manufacturers may be regarded as a group having generally more or less similar speed, gradation, and color-sensitivity characteristics. Accordingly, any one of them, or the group as a whole, may be used as a basis of comparison for rating the qualities of Ultra-Speed Panchromatic negative film.

Agfa Superpan Negative 35-mm. motion picture film, as a familiar representative of the supersensitive panchromatic group, has been used as a type by which to measure the qualities of the new Ultra-Speed Panchromatic film. Its sensitometric characteristics are

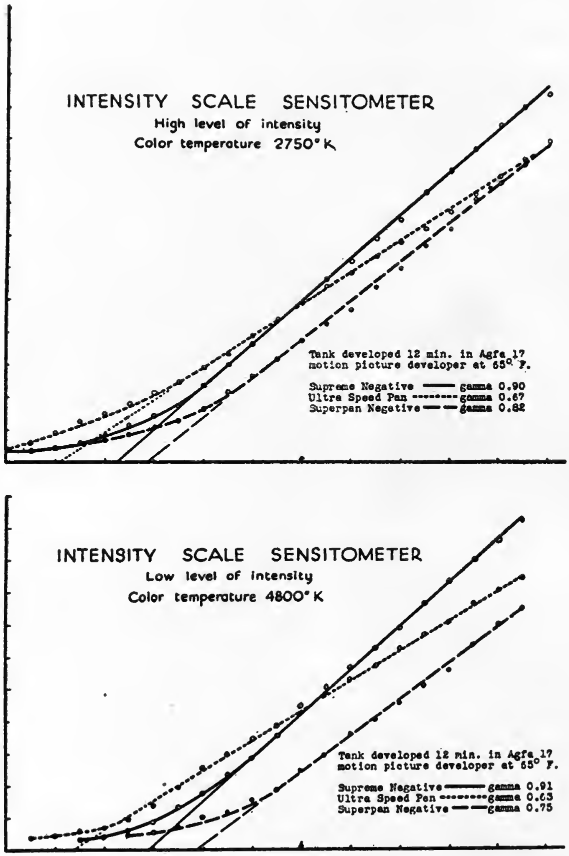


FIG. 5. Sensitometric curves taken on various types of instrument.

shown in Fig. 3. The data were obtained from film exposed on a Type II*b* sensitometer. The condition of the Agfa No. 17 (motion picture borax) developer used for these tests has been found to be approximately that of an average negative developer in use in both Hollywood and eastern laboratories.

The Ultra-Speed Panchromatic film, when exposed and developed under the same conditions as the Superpan Negative film shown in Fig. 3, did not give complete curves with times of development longer than 5 minutes or a maximum negative gamma of approximately 0.40. The minimum exposure obtained on the Type II*b*

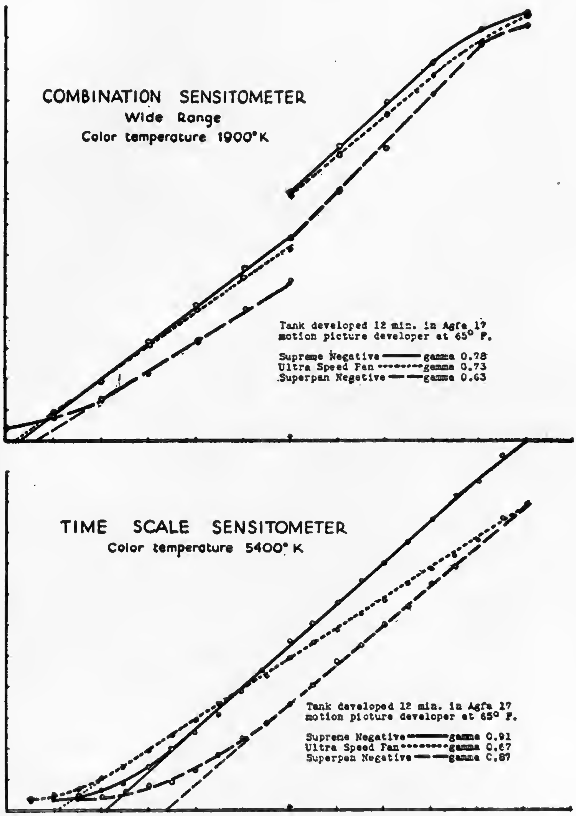


FIG. 5 (*Continued*).

sensitometer produced densities great enough to obscure the toe of the characteristic curve in the range of useful development. It was apparent that the sensitometer had been designed to accommodate films having a maximum sensitivity lower than the speed range of the Ultra-Speed Panchromatic emulsion.

In order to use the instrument on Ultra-Speed Panchromatic film without disturbing its calibration for other materials or altering the quality of the lamp, a neutral-density filter was employed. The results obtained with an 0.6 neutral-density filter are shown in Fig. 4 which affords a study of the toe or threshold sensitivity of the new film that was not possible under the sensitometric conditions shown in Fig. 3. The gamma was not changed appreciably by the use of the filter.

The Type II*b* sensitometer is highly regarded as a precision instrument, and, because of its general availability, is familiar to commercial motion picture laboratories. However, it provides only one type of sensitometric result: that produced by a time-scale apparatus operating with a certain level of illumination and exposure ratio. Access to other types of sensitometers made possible a study of the relative sensitometric characteristics of Ultra-Speed Panchromatic and other negative films under different sensitometric conditions and with somewhat different results.

A comparison of the results obtained with several types of sensitometers is shown in Fig. 5. The Ultra-Speed Panchromatic film has been given the same exposure and development as Superpan Negative film. A new panchromatic negative film, Agfa Supreme, was included in the comparison as representative of an intermediate negative-film type having a general sensitivity higher than that of the supersensitive panchromatic films but not as high as that of Ultra-Speed Panchromatic film.

Film-Speed Determination by Sensitometry.—Although some sensitometric methods of film-speed determination specify that the comparative speeds be determined from sensitometer strips developed to the same gamma, the data shown in Fig. 5 afford valid film-speed comparisons between Ultra-Speed Panchromatic and Superpan Negative, though the films have been developed for the same time and not to the same gamma. Since Ultra-Speed Panchromatic film has a lower gamma (slower rate of development) than Superpan Negative within the range of development employed for the test, its speed advantage would necessarily be increased by developing the films to the same contrast. Relative film-speed data derived from Fig. 5, therefore, must represent the *minimum* speed advantage of Ultra-Speed Panchromatic over Superpan Negative, since in practice the "flatter" film would usually be given somewhat longer relative development. Longer development would naturally increase, rather than decrease, the speed of the "flatter" film relative to the more brilliant one. The minimum relative film-speed determinations can be obtained at the points of comparison indicated for the following methods:

(*1*) Inertia speed (H&D, Wynn, Watkins, Weston).
(*2*) Threshold speed (Scheiner).
(*3*) Minimum useful gradient.
(*4*) Density 0.10 above fog (Din).

For practical purposes of relative film speed determination with the sensitometric curves shown, it was found that the points on the curves representing the density 0.10, the minimum useful gradient, and the threshold were nearly identical, so close to the margin of experimental error that the results obtained by the three methods have been grouped under the single heading "threshold." Since the Weston method is concerned solely with the straight-line portion of the curve, ignoring the characteristics of the toe that form the basis for the three most practicable and universally applied methods of film-speed determination, the ratings that result from the Weston method are related to the inertia speed and can be expressed in those terms although they are subject to the same objections that have been raised against the H&D method of film-speed rating. The relative speed advantage of Ultra-Speed Panchromatic over Superpan Negative film judged by the average of the "threshold" methods and by the inertia speed, is shown in Table I, which sums up the data presented in Fig. 5. The information is presented in terms of lens diaphragm stops divided into half-stops, since that is the practical limit of application of the information on the lens mountings in common use.

TABLE I

The Relative Speed Advantage of Ultra-Speed Panchromatic over Superpan Negative

	Threshold	Inertia
High-Intensity Sensitometer	2 stops	$1^1/_2$ stops
Low-Intensity Sensitometer	2 stops	$2^1/_2$ stops
Wide-Range Sensitometer	exceeded	$^1/_2$ stop
Type II*b* Sensitometer	2 stops	$2^1/_2$ stops
Average advantage over Superpan	2 stops	1.77 stops

Visual Methods for Sensitometry.—The foregoing is concerned with graphic methods of film-speed determination by sensitometry. The relative speed of Ultra-Speed Panchromatic and Superpan Negative film can be determined by visual methods from sensitometer strips without recourse to the data obtained in the usual way by determining the densities on the film-strips with a densitometer and plotting them against the log of the exposure. This method, which is employed frequently, requires only a modicum of skill and experience and consists of visual comparison of the film-strips. Its advantages are that the method is: (*1*) very rapid; (*2*) reduces the possibilities of error by eliminating several manual operations; (*3*) permits instant subtraction of fog by superimposing the unexposed portion of one strip over the exposed portion of the other and *vice versa;* (*4*) provides the same accuracy as pictorial comparison methods; (*5*) with sensitometer strips having a step variation of $\sqrt{2}$ speed estimates of approximately one-fourth lens stop are possible, which is at the practical limit of film-speed rating; (*6*) permits matching of toe gradients, determination of threshold or film-speed comparison by simply counting the number of visible steps.

The main disadvantages of the visual method of comparison are the lack of any permanent record, the difficulty of comparing more than two items together at the same time, and the increased difficulty of distinguishing sensitometric densities from handling marks and fog.

Camera Methods of Film-Speed Rating.—Most purchasers of photographic film use it for making pictures, not for making sensitometric strips. The chief advantage that a sensitometer has over a camera for determining the speed of a film is that the duplication of the conditions of exposure from day to day is usually easier with the sensitometer. The camera method, on the other hand, has the special advantage that it is concerned with the particular ratio of time and intensity (exposure and illumination) under which the film is used in practice, thus ruling out reciprocity failures that might be introduced through the translating of sensitometric data into practical exposure information. The camera can be regarded also as an intensity-scale instrument (time constant, intensity variable) which is its principal difference from the typical sensitometer. Most film-testing methods employed in the field of motion picture production employ both sensitometric and camera methods

Fortunately the popular miniature cameras not only operate with motion picture negative film but also are fitted with shutters of fair accuracy that can be made to approximate closely the exposure times obtained in professional motion picture cameras. The use of miniature cameras for sensitometry provides not only a convenient but an inexpensive means of testing motion picture films by the camera method, since they are rapid in use and expose a minimum amount of film. The speed ratings obtained in this way need no translation into other terms in order to be applied to projects of practical photography.

It may be considered that a maximum of photographic information about a given film is to be obtained by exposing it in a camera to a normally illuminated subject having a typical scale of light-intensities, using a series of exposures sufficient to cover the range successively from extreme underexposure to overexposure. Simultaneous consideration of two or more such strips, representing different types of film, affords a vast amount of data from which sensitometric information may be obtained, since each frame may be regarded as a complex of sensitometric densities within itself as well as a step in a series of graduated exposures.

Camera methods of testing film provide a basis for determining the relative speeds of films by a number of procedures involving either examination of the negative itself or examination of prints made from the negatives under a variety of printing conditions. Both miniature still film cameras and professional motion picture cameras are useful for these determinations. The relative speed advantage of Ultra-Speed Panchromatic over Superpan Negative film has been estimated from examination of the negatives obtained by the following camera methods of film-speed determination:

(*1*) Inspection of negatives that have received a graduated series of exposures and been given identical development.

(*2*) Inspection of negatives that have received a graduated series of exposures to the test subject and been developed in the same developer but for different times, to produce the same approximate contrast.

(*3*) Inspection or comparison of negatives on the subject films that have been exposed in a motion picture camera using lens diaphragm adjustments to compensate for their approximate speed differences.

(*4*) Inspection of positive prints made together from negatives that have received a graduated series of exposures and then developed either (*a*) for the same time or (*b*) to the same apparent contrast

(*5*) Inspection of prints made on different printer points from negatives exposed (*a*) in motion picture cameras using different diaphragm stops to accommodate roughly their speed differences or (*b*) in a miniature camera using a graduated series of exposures.

(6) Inspection of positive prints made from negatives exposed in motion picture cameras by means of Hollywood "light-testers" that give a series of different exposures to successive frames.

Negatives exposed in a miniature camera using a constant shutter speed but the entire available range of lens stops are reproduced in Fig. 6. In this case the films were developed for slightly different times to produce about equal contrast. The speed advantage of Ultra-Speed Panchromatic film over Superpan Negative film proved to be somewhat more than two diaphragm stops, judged by either shadow detail or average density. When the films were developed for the same time, the speed difference was slightly less. Ultra-Speed Panchromatic was almost exactly two lens stops faster than Superpan Negative film.

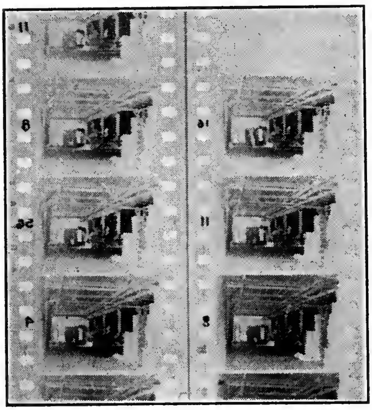


FIG. 6. Graduated exposures made in a Memo camera on Ultra-Speed Panchromatic film (*left*) and Superpan negative film (*right*). Exposures on Ultra-Speed Panchromatic film at stops 16 and 11 produce slightly greater shadow densities than corresponding exposures at stops 8 and 5.6 on Superpan Negative film.

Film-speed determination from negatives exposed in typical motion picture cameras is an indirect method accessible to the skilled laboratory "timer" who looks at the negative and judges what printer point will be required to produce a print of normal density under the laboratory conditions that prevail. Measured by this method, Ultra-Speed Panchromatic negatives given in the camera two diaphragm stops less exposure than Superpan Negatives and developed slightly longer to obtain the same contrast, have been found to require two to three printer points (20 to 30 per cent) additional exposure in printing to produce positives of the same density.

Frequently two different negatives are developed so that the same contrast is not obtained on both, particularly if differences in the response of the negative film to daylight and to artificial light are not fully taken into account. In such cases the judgment of the negative estimater is complicated by the necessity of evaluating not only density differences but contrast differences as well. Negatives on Superpan and Ultra-Speed Panchromatic film exposed under tungsten illumination of average quality and developed for the same time are shown in Fig. 7. These display the normal difference in gradation between the two stocks when exposed under that type of artificial illumination. In this case the speed advantage of Ultra-Speed Panchromatic over Superpan Negative film was estimated as slightly more than two diaphragm stops, since the Ultra-Speed Panchromatic negatives exposed at opening $f/5.6$ were slightly more dense, and exposures at stop $f/6.3$ were somewhat less dense than negatives on Superpan Negative film exposed at a relative aperture of $f/2.8$.

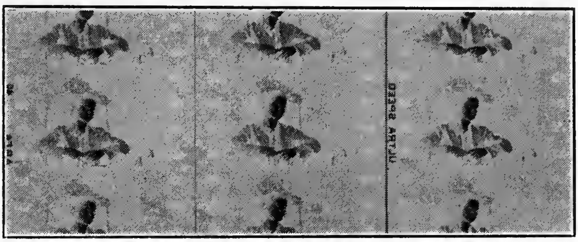


FIG. 7. Negatives obtained on Ultra-Speed Panchromatic and Superpan Negative film exposed under tungsten illumination using a professional motion picture camera. The Superpan Negative film (*center*) was exposed at a relative aperture of $f/2.8$, the Ultra-Speed Panchromatic strips at $f/6.3$ and $f/5.6$.

Although many individuals have become skillful in estimating the relative speeds of two or more films by examining the negatives themselves, most persons find it easier to make their comparisons from prints made from the negatives in question. It can be successfully argued that, although a picture negative is a substantial photograph compared to a sensitometer strip, it still is but a means to an end—which is the final print. Minute speed differences that might be measured, detected, or imagined in an examination of sensitometer strips or picture negatives are unimportant photographically if they are not apparent in the finished print.

A positive print of a Superpan Negative and an Ultra-Speed Panchromatic film negative that have been given a graduated series of exposures to the same subject illuminated by north daylight and developed to the same approximate contrast is shown in Fig. 8. The reproduction has been made from a glossy print having about the same contrast as motion picture positive printing stock. It is apparent that the Ultra-Speed Panchromatic film is more than two diaphragm

Fig. 8. Positive print of Ultra-Speed Panchromatic film negative (*left*) and Superpan Negative exposed in a Memo camera $^1/_{100}$ second at stops 16, 11, 8, 5.6, and 4, then developed to the same approximate contrast.

stops faster than Superpan Negative film under these conditions of comparison.

Positive prints from negatives that have received a graduated series of exposures in a miniature camera and have then been developed together for the same time rather than separately to obtain the same contrast are shown in Fig. 9. In this case the prints were made on a Bell & Howell printer using successive light changes, and the resulting prints matched for density. In the reproduction the Superpan Negative film frame that had been exposed in the camera using stop $f/5.6$ and printed on light No. 9 was matched with the frame on Ultra-Speed Panchromatic film that had been exposed in the camera at a relative aperture of $f/11$ and printed on light No. 12. The speed advantage of Ultra-Speed Panchromatic over Superpan Negative film, according to this method of judgment was found to be two diaphragm stops plus three printer points, or nearly two and a third lens stops.

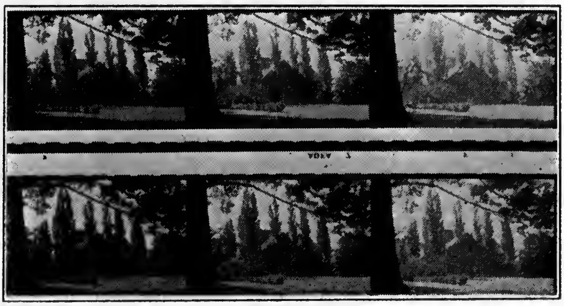


FIG. 9. Positive prints of Superpan Negative (*top*) exposed in a Contax camera $^1/_{50}$ second at stops 4, 5.6, and 8 and Ultra-Speed Panchromatic film exposed with stops 8, 11, and 16. The negatives were spliced together for development in a borax motion picture negative developer.

The relative speed of Ultra-Speed Panchromatic and Superpan Negative films was determined from prints made in a Hollywood "light-tester," an instrument that gives to successive frames of the negative a graduated series of exposures in printing. In Fig. 10 are shown parts of test-strips printed from Superpan Negative film that had been exposed in the camera using stop $f/4.5$, and Ultra-Speed Panchromatic film that had been given the same exposure and also two stops less exposure. Since the instrument that was used is calibrated to give an exposure interval of $33^1/_3$ per cent between frames, the relative speed advantage of Ultra-Speed Panchromatic over Superpan Negative was found to be about 30 per cent greater than two lens diaphragm stops determined from negatives exposed under tungsten illumination that had been developed for the same time.

Effect of Base Color upon Film-Speed.—The employment of anti-

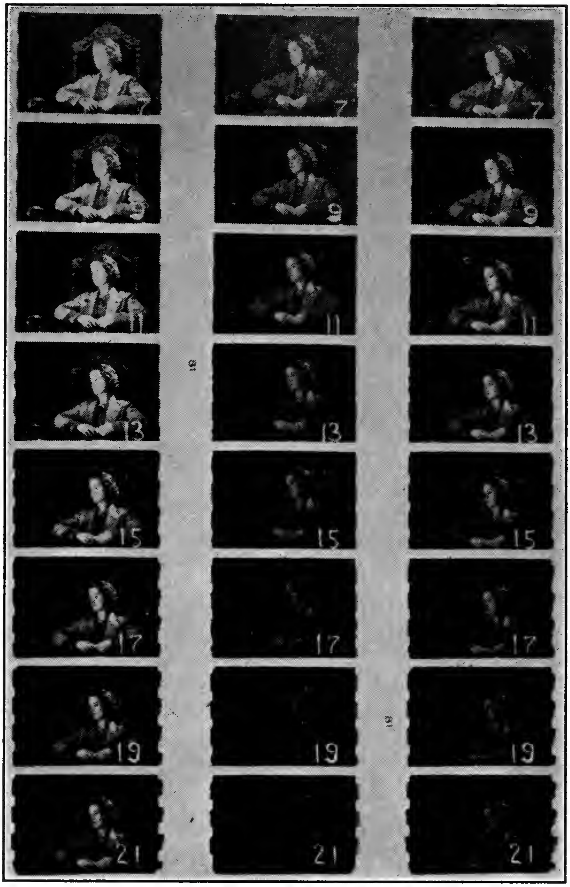


FIG. 10. Parts of three negative test-strips printed on positive film stock from (*left*) Ultra-Speed Panchromatic film exposed at stop $f/4.5$; (*center*) Superpan Negative film exposed at stop $f/4.5$; (*right*) Ultra-Speed Panchromatic film exposed at $f/9$ using a Fried light-tester.

halation procedures resulting in films having a "gray base" introduces an absorption factor in motion picture film printing that may affect the speed rating of the film. If the gray base is neutral, if it does not have selective absorption for certain light energies within the

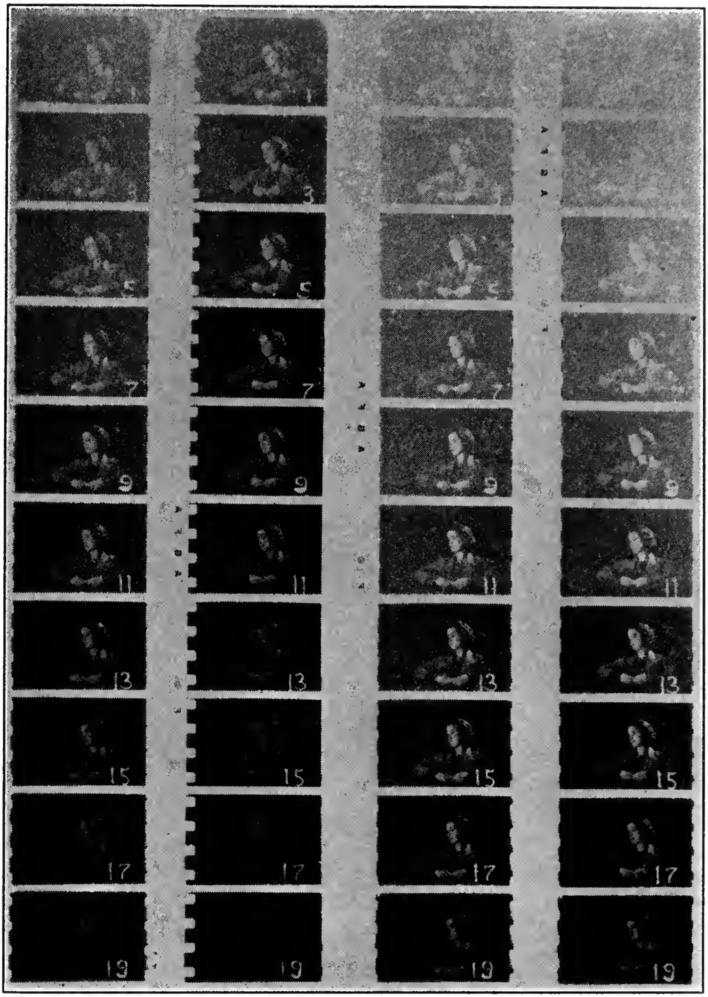


FIG. 11. Effect of tinted gray base upon apparent speed of the film. First strip from negative on lavender-tinted gray base; second strip from identical negative, except that the base was neutral gray. Strips on the right are from the same two negatives, each printed through a clear strip of the other base, showing that the films actually have the same speed.

spectral range to which the printing stock is sensitive, the apparent speed of the film will be affected only by the density of the gray layer. Gray base treatments that result in a lavender or orange, or pink tint usually do have a selective absorption that produces differences in printing speed not directly related to the measurable density of the layer. A tinted gray-base film may appear to the eye to be lighter in density than a neutral gray-base film but the former is likely to require 50 per cent (or more) greater exposure in printing to produce a positive of the same density.

Two negative film stocks can not be compared accurately for speed, using printing methods, unless they are both coated on neutral-gray base of the same density or allowances are made for the differences in color of their anti-halo bases. A simple means of canceling out the differences in gray-base absorption is to prepare strips of clear film of both stocks by running them through a fixing bath without exposure or development. Printing is then accomplished using a strip of clear film between the light-source and the positive stock so that each negative is printed by light filtered through the clear base of the other negative stock.

All the printing methods of film-speed determination in the foregoing illustrations have been concerned with films coated on neutral-gray base of the same density. In Fig. 11, however, are shown positive prints from two identically exposed and developed negatives made by coating the same emulsion on both neutral-gray base and on a lavender-tinted gray base having about the same optical density. The print from the negative having the tinted gray base apparently indicates a 50 per cent speed advantage of that stock over the neutral tinted negative stock. Prints made with compensation for the differences in actinic light absorption show the negative images on the two films to be identical.

Summary of Camera Testing Methods for Speed.—Reviewing the above results, the relative speed advantage of Ultra-Speed Panchromatic over Superpan Negative film has been determined by photographic as well as by sensitometric methods. The number of different methods involved direct inspection of negatives and the inspection of prints made from negatives. The speed differences were rated in lens diaphragm stops plus printer points calibrated so that 10 printer points were the equivalent of one lens stop. The relative speed advantage of Ultra-Speed Panchromatic over Superpan Negative film was not less than two lens diaphragm stops by any of the camera methods of comparison, and was 20 to 30 per cent greater under most of the comparison methods that employed positive prints.

REDUCTION POTENTIAL AND THE COMPOSITION OF AN MQ DEVELOPER*

R. M. EVANS AND W. T. HANSON, JR.**

Summary.—*After pointing out that photographic development is a reduction process, the terms "oxidation potential" and "reduction potential" are discussed. The methods of measuring such potentials are also discussed, as well as the condition that a system must be reversible before its true electrochemical potential can be measured. The reversibility of development in ferrous oxalate developers is referred to and some indication of reversibility in amidol developers is shown. The usual electrochemical methods of measuring potentials have been applied to organic developer solutions, and the effects of the various constituents of an MQ developer upon its "measured potential" are discussed. The true significance of these measured potentials is still not definitely known. It is shown that pH is the most important factor in determining the measured potential of a given developer solution, but that neither pH nor potential shows sufficient correlation with photographic action to be used as a "single" control variable.*

The ordinary photographic developer is an alkaline water solution of an organic reducing agent. A reducing agent is a substance which has a tendency to convert a metallic salt, such as silver bromide, mercury chloride, *etc.*, to the free metal, the reducing agent itself being oxidized simultaneously to another compound. This reduction process is the principal reaction in photographic development, and a discussion of it and the factors that influence it is of much interest and use in understanding the principles and methods of photographic development.

Various reducing agents have different tendencies to reduce salts to the free metals just as various salts have different tendencies to be reduced. For example, some reducing agents will reduce silver bromide while others will not; and correspondingly, certain reducing agents that will reduce silver chloride will not reduce silver bromide or iodide. This tendency of a substance to cause a reaction is called its potential; in the case of a reducing agent it is a reduction poten-

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received February 10, 1938.

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

tial, and for salts or other substances that react with a reducing agent, it is an oxidation potential. These potentials are expressed in volts, and are based upon a system built up by comparing each against another, with one agent being arbitrarily assigned a zero potential. The voltages are entirely analogous to the voltage ratings of a storage-battery, so the simplest way of explaining the method of measuring these potentials is by giving such an analogy.

A storage-battery is composed of two different metals, called electrodes, dipping into an electrolytic solution. One of these strips of metal is the positive pole and the other is the negative, and when they are connected externally a current flows through the system. Thus the battery is composed of two half-cell elements, each being composed of a metal dipping into an electrolyte, the two elements being connected internally by means of the electrolyte. In a similar manner, if an electrode composed of a noble metal, such as platinum, is dipped into a solution of a reducing agent, this forms a half-cell element. If this is now connected to another half-cell of the same type by means of a salt bridge (a glass tube filled with a conducting liquid), a complete battery is formed similar to the ordinary storage-battery. Its voltage can be measured by means of a voltmeter or any of the usual methods, the most satisfactory method being the use of a potentiometer. In this instrument a known battery is connected so that its voltage "bucks" the unknown voltage, and the voltage of the battery is varied in a known manner until no current flows in the system. At this point the potentials of the known and unknown are equal, thus determining the value of the unknown.

If the applied voltage is stronger than the unknown, a current flows through the unknown in the direction opposite to its ordinary tendency and reverse reactions take place in the two half-cells. This is just what happens when a storage-battery is recharged. Thus if the ordinary tendency is for the reducing agent to be changed to its oxidized form, under this condition the oxidized form is converted back to the reducing agent. If this can not occur, or as it is usually expressed, if the reaction is not reversible, its potential can not be measured. This is an important conception and will be referred to later on.

It is seen immediately that, while the potential of a pair of half-cells can be measured, it is never possible to measure one alone. To simplify matters a given half-cell (the hydrogen electrode) is arbitrarily defined as having zero potential under specified conditions (unit activity of hydrogen ion and one atmosphere hydrogen pressure), and this when measured in conjunction with any other half-cell will give a definite potential to that system. For example, the battery composed of the hydrogen electrode connected to a mercury calomel electrode has a potential of +0.25 volt, so we may say that the calomel electrode has a potential of +0.25 volt. Another very pertinent example is the silver–silver bromide system. If a half-cell composed of a metallic silver electrode, dipping into a solution containing 10 grams per liter of potassium bromide saturated with silver bromide is connected to the hydrogen electrode, the resulting voltage is +0.10 volt. This voltage depends upon the bromide ion concentration, increasing bromide ion concentration decreasing the potential. In order to get a complete picture of a battery of this type it is of interest to point out just what happens under two conditions. If the two electrodes are connected externally, by means of a wire, to a battery having a voltage less than +0.10 volt, the current will flow in such direction that the silver bromide is converted into metallic silver; and, second, if they are connected to a battery having a voltage greater than +0.10, current will flow so that metallic silver is converted into silver bromide. Similarly, if silver bromide is put into a solution having a potential less than +0.10 volt, it will usually be reduced to metallic silver, and if the solution potential is decreased to a negative value (still comparing this with the hydrogen electrode as zero), this tendency will become stronger and stronger. It is apparent, then, that this defines one of the limits of possible potentials a compound can have and still be a developer.

At this point the fact might be mentioned that all oxidation reduction reactions are electrical in nature, and in order for such a reaction to take place there must be a difference of potential between the two reactants. It does not follow, however, that the difference can always be measured readily.

Since the photographic development process is an oxidation-reduction reaction the potentials of the constituents should prove to be of a good deal of interest and usefulness. The potential of the silver–silver bromide system is easily measured but the potential of the developer solution is another matter. For many years it has been the consensus that the reduction potential of a developing solution could not be measured because the developing reaction is not considered reversible, that is, in the case of organic developing agents. The reversibility of the development reaction with the ferrous complex developers has been known for many years. In 1905 Sheppard and Mees found that a solution containing a certain ratio of ferrous to ferric complex would just develop an emulsion, while one containing a slightly lower ratio would oxidize a silver image to silver bromide. They could not measure the reduction potentials of their solutions due to the early date of their work.

In 1934, Reinders and Beukers[1] in Holland repeated the work of Sheppard and Mees, measuring the reduction potentials of the solutions. They immersed one exposed photographic strip and one that had been both exposed and partially developed (but not fixed) in each of a series of developers having potentials covering a fairly wide range.

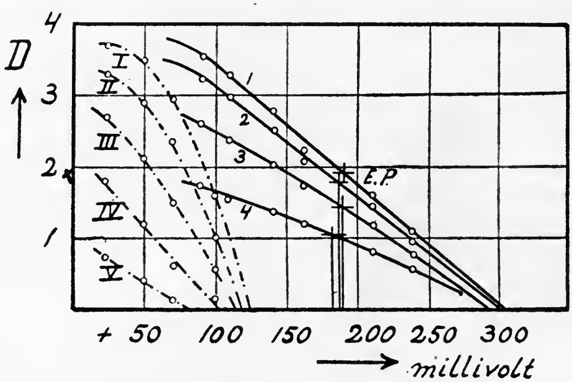


FIG. 1. Equivalence point curves (from Beukers' thesis 1934).

After six hours' time all reaction was complete and the strips were removed and fixed. Fig. 1 is reproduced from Beukers' thesis. The density of each strip is plotted against the potential of the solution in which it was placed, the dotted lines representing the exposed strips and the solid lines the predeveloped strips. Each line represents a different exposure. The short horizontal lines across the solid lines represent the density to which the strip had been predeveloped before immersion in the ferrous developer. It is shown quite clearly that to the left of this intersection the densities have been increased, or silver bromide has been reduced to silver, and that to the right the densities have been decreased, or silver has been oxidized to silver bromide. This is called the equivalence point and should agree with the known reversible potential of the silver–silver bromide system, which it does very satisfactorily.

The latent image curves are particularly interesting. The latent image does not start to develop at the equivalence point, but 60–70 millivolts to the left of it, which means that a stronger developer is necessary to develop an exposed halide grain that has not been partially developed, than one that has been partially developed. It is thus seen that the lower limit of potential that a compound must have, to be a developer, is really a little different from that mentioned previously. It is hardly necessary to say that this is a sufficient condition to make a developer, but the actual value is different for every compound and depends upon the exposure.

As was mentioned before, there has been some question about the possibility of measuring the reduction potentials of organic developers. About two years ago Evans and Bahler in the Kodak Research Laboratories found that when a platinum electrode was immersed in a mixed developer a definite and repeatable potential was set up. It was not thought that this was the true electrochemical reduction potential of the system but was probably somewhat closely related to it. However, it was a very interesting variable, and considerable work was done in order to determine just what relation it did have to the true reduction potential of the system. The complete technic of measuring this potential and some experimental data obtained by its use were published in April, 1937.[2]

The work of Reinders and Beukers was repeated but using organic developers, and static potentials were measured by the new technic. Fig. 2 is taken from this paper and is exactly similar to that reproduced from Beukers' thesis except that amidol was the developing agent. In this case the potential measurements were made using a saturated calomel electrode as the standard, rather than the hydrogen electrode. (As mentioned before, this electrode has a potential of +0.250 volt against the hydrogen electrode.) All the pH measurements have been made with a glass electrode, and sodium ion errors have been partially neglected. (*Note:* It is probable that the sodium sulfite in these solutions had been used up by aerial oxidation by the end of the reaction.)

On converting these potentials to the hydrogen system it is seen that the equivalence point checks with that obtained by Beukers within 10 millivolts. This would appear to indicate that the potentials as measured are the true reduction potentials of the solutions, but until further evidence is obtained it is best to refer to them merely as the "measured potentials."

Immediately the question arises, "What is the relation between this potential and the photographic activity of a developer solution?" The statement is frequently made in the literature that the reduction potential of a developer should be closely related to its photographic properties, and it is implied that if this quantity could be measured the problem of the control of a developer solution would be solved. As a matter of fact, the chemical theories that apply to potentials relate only to equilibrium conditions, such as were obtained in all the previously mentioned work in which all the strips were left in the developer at least six hours. They do not have any connection at

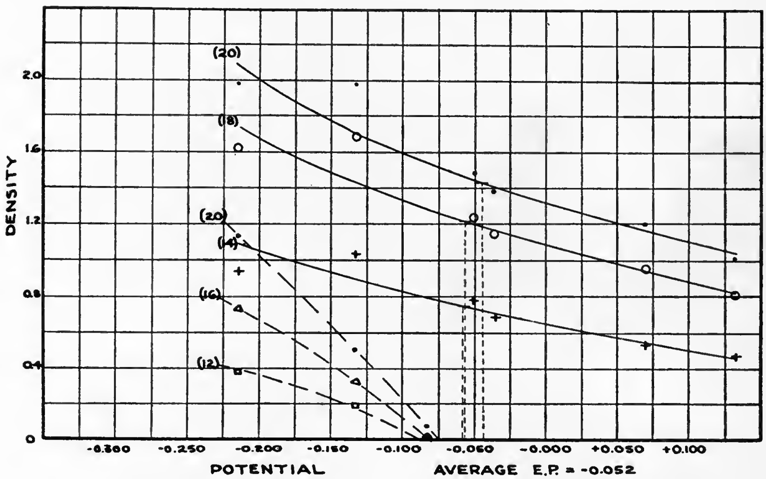


FIG. 2. Equivalence point curves: amidol 10 grams per liter.

all with velocities, and since it is the velocity conditions with which we are concerned in development, too much should not be expected of the potential.

Since the *MQ* type of developer is the one most used commercially, it is of interest to investigate the effects of the various constituents upon this potential.

In the first place, it has been found that *p*H affects the potentials of developer solutions to a large extent. *p*H is a measure of the concentration of hydrogen ions in the solution or is an expression of the acidity or alkalinity of a solution. A neutral solution has a *p*H of 7, and values down toward 0 represent increasing acidity while values increasing toward 14 represent increasing alkalinity. Fig. 3

shows the relation between the pH and potential of a hydroquinone and of an elon solution. It is seen that at a pH of about 8.6 the two have the same potential, and it is interesting to note that at this pH, hydroquinone will just barely develop a latent image after prolonged action, while elon is a very good developer.

Sulfite also affects the potential of an elon, a hydroquinone, or an *MQ* developer. The first small amounts of sulfite cause an increase

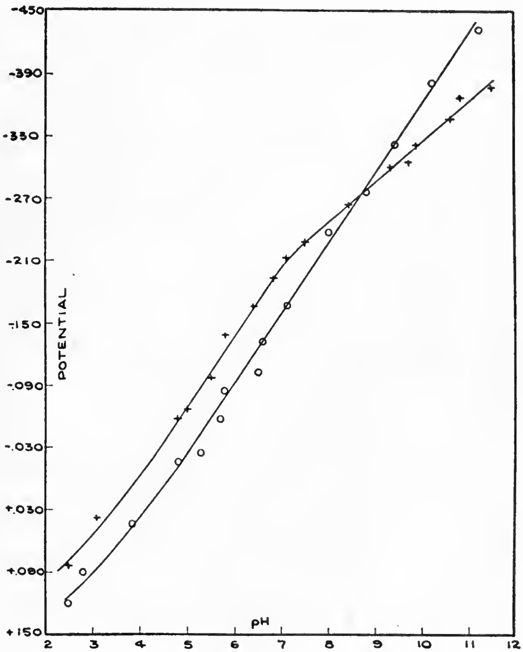


FIG. 3. Relation between measured potential and pH; + = elon, O = hydroquinone.

in potential of about 30 or 40 millivolts, and at about 20 or 30 grams there is no further effect.

The concentration of the developing agents also affects the potential, doubling the concentration increasing the potential by 12 to 20 millivolts.

These three constituents of a developer, sulfite concentration, developer concentration, and pH, are the only variables that appreciably affect the measured potential. In a given developer solution the developer and sulfite concentration do not vary enough to cause a measurable change in the potential. This leaves *p*H as the controlling factor and since, as was shown in Fig. 3, the potential varies almost linearly with *p*H over a rather wide range, it is possible to determine the potential changes in a given solution merely by measuring the *p*H changes. At the present time there is so much doubt concerning the exact nature of these measured potentials that the remainder of the paper will be discussed mainly in terms of *p*H.

Tests that will not be described here show that neither the measured potential nor the *p*H correlate usefully with the photographic properties of a developer solution. In the first place, bromide ion does not affect these variables at all, but it is well known that it has a very large effect upon the photographic action of a developer. Neutral salts such as sodium sulfate also affect development but do not affect *p*H or potential. The temperature of a developer has a large effect upon the photographic characteristics and while it does change *p*H and potential to a certain extent, this change does not correlate with the change in photographic effect.

When an *MQ* developer is aged, changes take place in its photographic activity that do not always correlate with *p*H changes. It has been shown by Lehmann and Tausch[3] that when an *MQ* developer is oxidized by air, about 10 times more hydroquinone than elon is used up and alkali is liberated, thus causing the *p*H of the solution to increase. In film the situation is reversed, ten times more elon than hydroquinone is used up and acid is liberated, the *p*H being decreased. Of course, bromide is also liberated during the latter process. When both these processes are going on simultaneously and at different rates, it is possible for several different conditions to result. The *p*H may increase while the photographic action may either increase, decrease, or remain the same; the *p*H may remain constant while the photographic action may remain constant or decrease; the *p*H may decrease, the photographic action decreasing to the same or different degree. It is now immediately evident that in these cases, measurements of *p*H changes may or may not correlate at all with the changes in photographic activity.

All this discussion emphasizes the fact that neither *p*H nor reduction potential can be used as a *single* variable for the complete specification of a photographic developer. The situation is entirely changed, however, if a complete chemical analysis of the developer solution is made. When a developer solution is used a short while its composition is no longer that of the original mix but is complicated by the presence of developer oxidation products, additional bromide, and reduced concentrations of developers. The photographic action of such a developer is different from that of the fresh solution and is usually checked by means of a photographic test-strip. But this test gives no ideas as to the concentration of the constituents of the solution. If measurements of *p*H and potential as well as a complete chemical analysis were made, the exact condition of the developer solution would be determined and the problem of controlling photographic developer solutions would be markedly simplified.

REFERENCES

[1] REINDERS, W.: "The Reduction Potential of Developers and Its Significance for the Development of the Latent Image," *J. Phys. Chem.*, **38** (June, 1934), No. 6, p. 783.

[2] EVANS, R. M., AND HANSON, W. T., JR.: "Reduction Potential and Photographic Developers, the Effect of Sulfite in Developer Solutions," *J. Phys. Chem.*, **41** (April, 1937), No. 4, p. 509.

[3] LEHMANN, E., AND TAUSCH, E.: "On the Chemistry of Elon-Hydroquinone Development," *Phot. Korr.*, **71** (Feb., 1935), No. 2, p. 17; **71** (March, 1935), No 3, p. 35.

INFRARED ABSORPTION BY WATER AS A FUNCTION OF TEMPERATURE OF RADIATOR*

A. H. TAYLOR**

Summary.—*Water transmits visible radiation but absorbs radiation in the infrared portion of the spectrum. The transmission of water to the total radiation from a source therefore depends upon the spectral distribution of the radiation. This transmission has been measured for tungsten lamps at various filament temperatures, and also for other well known sources of radiation.*

The efficacy of water-cells in absorbing infrared radiation in light-projection systems is well known. Coblentz[1] and Luckiesh[2] have published data showing the spectral transmission of different thicknesses of water and Luckiesh has also given curves showing the per cent of the total energy from a black body transmitted by various thicknesses of water. The spectral transmission curves show that one centimeter of water absorbs practically all infrared radiation longer than λ14,000.

By means of a thermopile we have recently measured the total transmission of radiation from tungsten lamps by different thicknesses of tap water at room temperature. The water, which comes from Lake Erie, was placed in a vertical tube having a thin glass bottom, the thermopile being placed below and the lamp above. Different wattages of tungsten lamps were used, the filament temperatures ranging from 2700° to 3490°K. The test results are shown in Fig. 1.

As was to be expected from spectral transmission curves for water, it was found that the transmission of a given thickness of water increases as the temperature of the radiator is raised. For example, a thickness of $^1/_2$ inch of water transmits 36.5 per cent of the radiation from a 40-watt lamp at 2700°K and 52.5 per cent of the radiation from a photoflood lamp at 3490°K. Also, to absorb 60 per cent of the radiation requires a water thickness of $^1/_3$ inch for the 40-watt lamp and 2 inches for the photoflood lamp.

Forsythe and Watson[3] have published data showing the temperature of various types of lamps. From their data and the data

* Received December 27, 1937.

** Lighting Research Laboratory, General Electric Company, Cleveland, Ohio.

in Fig. 1, an estimate as to the absorption of radiation from any tungsten lamp by water up to 7 inches thick may be made.

Some radiation absorption data for other sources may also be of interest. A water-cell with quartz faces and $^1/_2$ inch of water was found to transmit the following amounts of radiation from a quartz mercury arc: with new burner, 17 per cent; with old burner, probably used at least 2000 hours, 6.6 per cent. Some tests with a bunsen

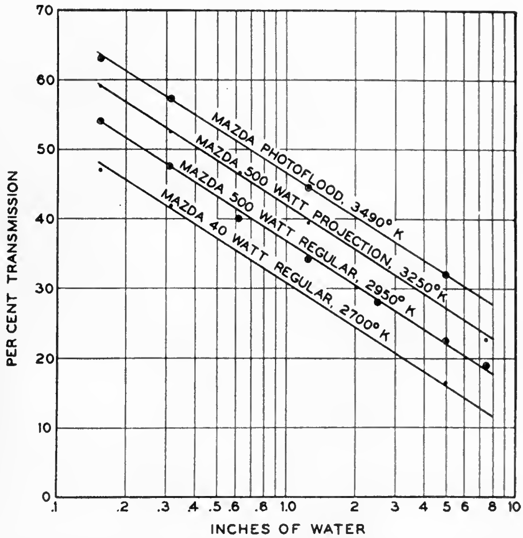


FIG. 1. Effect of thickness of water upon the total energy transmitted, using tungsten lamps at various temperatures.

burner and a calrod electric heating unit showed that $^1/_8$ inch of water transmits less than 1 per cent of the radiation from each.

The author acknowledges with thanks his appreciation for the assistance of Mr. G. P. Kerr in obtaining most of these data.

REFERENCES

[1] COBLENTZ, W. W.: "Radiometric Investigation of Water of Crystallization, Light-Filters, and Standard Absorption Bands," *Bulletin, Bureau of Standards*, **7** (1911), p. 619.

[2] LUCKIESH, M.: "Sources of Visible and Infrared Radiations for Deep Therapy," *J. Franklin Inst.*, **207** (Jan., 1929), No. 1., p. 79.

[3] FORSYTHE, W. E., AND WATSON, E. M.: "The Characteristics of Some Lamps Intended for Special Services," *Gen. Elect. Rev.*, **37** (May, 1934), No. 5, p. 251.

GOLDEN JUBILEE ANNIVERSARY OF THE MOTION PICTURE INDUSTRY

CHESTER MERRILL WITHINGTON*

It was just fifty years ago—1887, to be exact—that the groundwork was laid for the motion picture art, and with it the foundation of the Society of Motion Picture Engineers. The thought of putting motion into photography, which the late Thomas Alva Edison derived largely from the zoëtrope, a toy, and his immediate assignment of an associate to the task of developing a camera at his Newark Lamp Works laboratory, would, I believe, entitle that inventor to honorary recognition by this Society. And as chief of the experimental crew, the late W. K. L. Dickson undoubtedly should also be entitled to similar recognition.** The Ott brothers, John and Fred, Charley Kaiser, and Bill Heist rounded out the very first group of technicians and mechanics in the world engaged exclusively in developing the necessary apparatus for taking and exhibiting motion pictures.

Through an exhaustive paper published in the December, 1933, issue of the JOURNAL, members of the Society were given first-hand data of the Industry's early days by the late Mr. Dickson, as participated in by that writer. In the *Century Magazine* of June, 1894, Mr. Dickson and his wife collaborated on an article under the title: "Edison's Invention of the Kineto-Phonograph." And remember that this was just three months after the first commercial showing of motion pictures *via* Edison's kinetoscope or peep-show on Broadway.

My own observations on the pioneering days of motion pictures have been gleaned from personal interviews and some correspondence with men who were associated with Edison and played some part in the development of what today is the motion picture industry.

My chief object is to stress in this paper, to the industry itself, the fact that 1937 marked its fiftieth birthday. My basis for this state-

**Secretary*, Edison Pioneers, New York, N. Y.

** Both Edison and Dickson were elected Honorary members and are on the Honor Roll of the Society (*Ed.*).

ment is to be found on page 437 of the December, 1933, JOURNAL where, in a reproduction of an original memorandum in Edison's own handwriting, are to be found these words:

"In the year 1887, the idea occurred to me that it was possible to devise an instrument which should do for the eye what the phonograph does for the ear, and that by the combination of the two, all motion and sound could be recorded and reproduced simultaneously. This idea, the germ of which came from the little toy called the zoëtrope. . . has now been accomplished. . . . "

While the industry may be said to have had its inception at Newark, the major part of the experimental and developmental work on motion pictures was performed at Orange (N. J.) to which spot Edison moved to his new laboratory on Thanksgiving Day, 1887. Room *5* in that building actually was the birthplace of the art. A few weeks before his death, Oct. 23, 1936, I had the pleasure of a chat with Mr. Fred Ott in the Edison Laboratory building, during which he blushingly admitted the charge of being motion picture actor No. 1 for his famous "sneezing" act as an experimental stunt. But more important was his remark that in the experimental days of the motion picture camera, Mr. Edison, disappointed apparently at the slow progress being shown, said to John Ott: "John, I am not going further with this. It will never be anything but a toy." And if Mr. Edison had persisted in this frame of mind, it is possible that this Society never would have been formed!

Recently I had luncheon with the sole survivor of a trio who were the first to see a motion picture. Dickson is gone; so is Brown of Edison's mechanical staff. But Walter S. Mallory, also a former Edison associate, although not engaged in motion picture work, and now an executive of the Cement Institute, is hale and hearty in his mid-seventies.

"Even before Mr. Edison had a glimpse of an actual motion picture, we three saw the first bit of finished product," Mr. Mallory observed. "It was Fred Ott sneezing." And this group of three, in 1890, comprised the world's very first motion picture audience.

It is a well known fact that the premier commercial "peep show," forerunner of today's motion picture theater, occurred on April 14, 1894, at 1155 Broadway, New York City. I doubt that any details of that occasion are generally known in the motion picture industry. I had the good fortune a few months ago to hear the story from the lips of the man who actually managed the affair, a man who succeeded Samuel Insull as private secretary to Thomas A. Edison. Kinetoscopes, or peep-show machines, invented by Edison, made possible that historic event. A. O. Tate identified himself with the Edison interests in 1883 at 65 Fifth Avenue, New York, from which point was directed the setting up of Edison lighting systems throughout the world. Tate eventually was transferred to the new Edison laboratory in Orange, and upon Insull's promotion to greater duties, the former became the inventor's private secretary, in which position he was cognizant of the various interests of his employer. Among them was the motion picture development.

As the motion picture camera and means of exhibition reached the commercial state, the Chicago World's Fair of 1893 seemed an opportunity made to order for demonstration purposes. But through inability of the Edison Manufacturing Company to deliver 25 kinetoscopes or peep-show machines, which had been ordered, it remained for a syndicate, identical with that which had planned the Chicago demonstration, to secure in the following year, the space at 1155 Broadway for its opening. At a cost of $300 each, the equipment for the "peep-show" demonstration was to entail a $7500 investment. However, only ten machines could be made ready for the April, 1894, opening, and these were installed at the Broadway location where Mr. Tate was in charge.

But let Mr. Tate carry on:

"The syndicate includes Messrs. Raff and Gammon, who had been sales agents for Edison's phonograph, my brother Bertram, Thomas R. Lombard, and myself. We actually opened the show two days ahead of schedule because of a crowd which had collected outside as we were preparing the place. Deciding to take advantage of the situation we all got to work. I sold tickets; Tom Lombard, a large and imposing fellow, was the sidewalk representative; and my brother took the tickets. The take for that day was $153."

Incidentally, that $153, taken at 1155 Broadway on Saturday, April 14, 1894, comprised the very first receipts from an exhibition of motion pictures!

Motion picture history does not reveal the experimental cost of establishing a foundation upon which to erect this $4,000,000,000 industry, nor do the records at the Thomas A. Edison plant at Orange indicate the amount of expenditures which that pioneer made in carrying out his ideas of putting motion into photography. But in a letter to the writer, Frank L. Dyer, who was closely associated with Edison at a later date for a number of years, estimated that the experiments and tests that brought into being the motion picture camera, the first in the world, cost in the neighborhood of $15,000. From this base figure has arisen the $4,000,000,000 motion picture industry investment in the United States.

Strange as it may seem, not a bit of the early motion picture equipment that he created and developed was saved by Edison, nor can anything earlier than a 1912–13 model of the kinetophone be found today at the Edison library.* In setting up an Edison exhibit in 1936 at the Museum of Science and Industry, I contacted a man in New York who had what he claimed to be the mechanism of an Edison camera. He had purchased it with other cast-off material from the Bronx studio of the Edison Company; its original box, he added, had an Edison name-plate which seemingly was cast aside. At all events, this mechanism was noted at the exhibit as part of an original Edison camera, and at no time was objection ever entered to its authenticity.

There were nine models of Edison cameras, all of which were restricted exclusively to the Edison staff when that name was prominent in motion picture production. The principle of today's camera is traceable directly to the pioneer from the Orange laboratory, according to Mr. Dyer.

It is part of the record that the earliest bits of film ranged between 35 and 50 feet in length. The subject matter on such strips naturally was greatly restricted, and after a time the audience reaction was such as to urge the producers to improve their technic and programs. I have before me a letter recently received from a man abroad to whom belongs the distinction of having made the very first short-story films, one of them, the *Execution of Mary, Queen of Scots*, still being actively screened as a museum piece.

The man to whom I refer is Alfred Clark, Chairman of Electric & Musical Industries, Ltd., of London. Affiliating with the North American Phonograph Company, distributors of Edison phonographs, in 1889, Mr. Clark later joined Raff and Gammon, who had secured distribution rights for the Edison kinetoscope. In writing to me Mr. Clark stated that he . . . .

"was given the job of producing films. At that time the films available were few in number and composed generally of music hall scenes. I conceived the idea of some sort of historical scenes but was, of course, limited by the short length of film which gave a reproduction of something under three minutes.

---

* Since this article was written several earlier specimens have been acquired, among them a kinetoscope of the 1905 vintage.

"My first attempt was *The Execution of Mary, Queen of Scots,* and in this, when the Queen had placed her head upon the block, the photographic camera was stopped, a dummy figure was put in its place, and after the camera started again the dummy head was chopped off." (Conceivably this was the first professional use of stop-motion.)

"I think one can now say that these were the *first film productions ever made.* They were not just acrobatic scenes but were short stories with a sequence and were limited only by the shortness of the film."

Accompanying this information of interest and importance to the historical side of the motion picture industry, Mr. Clark also sent me a copy of a letter that he had written, under date of August 24, 1895, to F. Voegeler, 222 East Houston St., New York, N. Y., for costumes to be worn in his first production. They included costumes to be worn by the Queen who, Mr. Clark informed me, was impersonated by Mr. Robert L. Thomas. Other parts were taken by Edison laboratory employees. Explicit were the instructions for the guidance of the messenger who was to take the costumes to Orange, and these concluded with this admonition:

"As we also agreed, if Wednesday morning is a cloudy or stormy day you will let the costumes stay until the next *clear* morning, and do not send your man over if it is cloudy Wednesday, but wait until the next clear day, as we will have no use for him."

A month later, as production was pursued, Mr. Clark on September 26, 1895, wrote to W. E. Gilmore, of Edison Manufacturing Company, to the effect that Raff and Gammon wanted these subjects taken: *The Lynching; The Duel;* and *Indian Scalping Act.*

Mr. Clark had been in Orange on the preceding day and had discussed with Mr. Heist, one of the pioneer motion picture technicians and cameramen. He then wrote to Gilmore as follows:

"I suggested that the scenes would look much better if they could be taken where there were some trees and shrubbery—where the man in the lynching scene could be strung up from a real tree. Mr. Heist thought it would take too much time to move the kinetograph (camera), so we decided to take them in front of the high fence as heretofore. We will need *a pole* (strong enough to hang a man from) set in the ground and about *fifteen feet of rope* for the lynching scene. A *coach* to stand in the background in the duel scene and about twelve men to take part. These Mr. Heist said he would look after. I will attend to the costumes and everything else."

The next step in commercial exhibition came with the introduction of the *vitascope,* first successful projection machine establishing the principles that have governed projection developments from that day to this. The vitascope was the invention of Thomas Armat of Washington, D. C., who was inspired to his efforts by the display in that city of a battery of Edison peep-show kinetoscopes. Showmen customers of Raff and Gammon had for months been demanding a projection machine, a magic lantern application of the kinetoscope, so that a whole roomful of customers might be entertained at once.

Norman C. Raff's demands upon the Edison plant for such a machine were resisted. The peep-show machines were selling well and W. E. Gilmore, Edison's general manager, did not want that business disturbed. Also, at this juncture, problems of the phonograph business were proving sufficiently burdensome to occupy all the attention of West Orange. An Edison mechanic was assigned to take some machine parts and keep up a show of experimenting on projection at the Raff and Gammon offices in the Postal Telegraph Building. This diligent workman did not, however, satisfy the agents. Frank R. Gammon came upon the Armat projector and prevailed upon the inventor to bring it to New York for demonstration. It was also demonstrated, after many diplomatic exchanges, before Mr. Edison.

Because, as Mr. Raff argued, the amusement world was looking for an Edison projector, an agreement was set up for the making of the Armat machine, under the name vitascope, as ostensibly an Edison machine but carrying also the line "Armat Design." It also bore the Armat patent numbers. With the showing at Koster and Bial's Music Hall in Herald Square, New York, April 23, 1896, of Edison pictures on the vitascope, with Thomas Armat in the booth, the amusement career of the screen was born.

Some eighty-five vitascopes were delivered by the Edison plant under the agreement engineered by Raff and Gammon. The machines were put out on states-right franchise sales, and some went abroad. Presently the arrangement was discontinued and the Edison projecting kinetoscope appeared. The patents wars were beginning, and among them were the controversies between Thomas A. Edison and Thomas Armat. At the end of the patent litigations, resulting in the formation of the Motion Picture Patents Company, the Edison establishment was licensed by Armat, as evidenced by the patent plates on subsequent projectors.

Raff and Gammon's original literature on the vitascope stated:

". . . today it can almost be said that the impossible has been accomplished and a machine has been constructed which transforms dead pictures into living moving realities. . . . the vitascope can be placed from 50 to 75 feet distant from the canvas or screen and the most excellent results be assured."

The story of the venture of the late John P. Harris at 433-435 Smithfield Street, Pittsburgh, with the world's first all-motion picture theater is a well known part of motion picture history. This house, named the "Nickelodeon," had 96 seats, and there is authority for the statement that it maintained a daily average attendance of 7000 persons, from which attendance must have accrued daily receipts of $350. As a historic milestone in the motion picture industry, the Nickelodeon's daily "take" of $350 compares with the very first public showing of any motion picture in 1894, and its "take" of $153.

The question of cost always is of interest, especially when it is the first and never before made known. Ed Porter, who had served a hitch in the Navy, joined Edison's staff in 1893, and immediately was put to work upon the mechanism and use of the motion picture camera, in which he became expert, as those will admit who are familiar with his work of today. In reminiscing for my benefit, recently Mr. Porter recalled the very first "feature" film of all time, bearing the title *Life of an American Fireman.* With the full coöperation of the fire departments of Newark and Orange (N. J.), this "thriller" was made immortal in 100 feet of film back in 1898. It was Porter conceived, Porter directed, and Porter "shot," yet today credit for being the first "feature" film is given generally to another Porter picture, *The Great American Train Robbery*, another museum film of merit. Like its predecessor, this was done in New Jersey. The robbery took place mainly on property and in equipment of the Lackawanna Railroad, and its total cost, Mr. Porter recalled, approximated $300. This was made in 1902.

In this picture Mr. Porter made frequent use of "stop-motion" in his photography, and also developed other "tricks," notably double-exposure shots. Into making the fireman, Mr. Porter, to quote his words to me, "put all the elements and construction used in producing motion pictures today." In it was utilized the original "close-up" and the "switch back." The technic of "stop-motion" of forty years ago has made possible the motion picture cartoon of today.

Let me summarize briefly: From Edison's $15,000 expenditures for experimental and laboratory work on the first motion picture cameras over a period of two or three years starting in 1887; the first day's "take" of $153 from the premier kinetoscope show on Broadway in 1894; and the $300 cost of the best known first feature film in 1902, there has grown the motion picture industry and its $4,000,000,000 investment and 16,000 theaters of today!

NEW MOTION PICTURE APPARATUS

During the Conventions of the Society, symposiums on new motion picture apparatus and materials are held in which various manufacturers of equipment describe and demonstrate their new products and developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.

NEW IDEAS IN MOBILE SOUND RECORDING EQUIPMENT*

C. M. RALPH AND J. G. MATTHEWS**

STUDIO UNITS

The sound recording facilities of the average motion picture studio consist usually of fixed channels for stage and backlot production and several trucks for location use. For different locations and special work, some studios have supplemented this basic equipment with portable channels. Even greater flexibility than this standard equipment affords is required by a studio whose principal commodity is *sound* and whose business is largely that of furnishing sound equipment and service to a number of independent producers.

Since cost is a paramount consideration of the independents, a method of operation must be established that utilizes lower cost equipment wherever possible, keeps maintenance and overhead at a minimum, and puts every piece of equipment in almost constant use to permit a rental rate that this type of production can afford. Curtailed shooting schedules place an unusual demand upon equipment, which must provide flexibility sufficient for frequent moves; must be adequate as to power supply, to withstand long hours of uninterrupted service; and must be easily maintained.

Upon enlarging our activities in this field, several major decisions had to be made before embarking upon a rather extensive construction program. The Western Electric *Q* channel was chosen as the most suitable type of equipment for this service. It is small, light in weight, all a-c. operated, and neat and modern in appearance; and since it was designed primarily as a portable channel, its individual units are complete in themselves and easily interchangeable—an important consideration for maintenance. The compactness of the apparatus permits its installation in such manner that every key and switch is within reach of a seated operator. It was anticipated that the concentrated nature of this equipment would allow the use of standard body location units, described later.

---

* Presented at the Fall, 1937, Meeting at New York, N.Y.; received October 5, 1937.

** General Service Studios, Inc., Hollywood, Calif.

Since about 60 to 80 per cent of picture production takes place upon stages or within lot boundaries, it appeared that considerable saving in investment could be realized by designing a unit for this particular purpose, eliminating the expensive and bulky equipment necessary for independent operation away from power supply. The now commonly available house-trailer was suggested as ideal for this work, having additional advantages over trucks in lower first-cost and practically no mechanical maintenance.

This idea was adopted, and five units were purchased with two towing cars. The latter serve also as delivery and standby cars, one being equipped with complete portable testing apparatus for maintenance department routine and emergency use; consequently, these two self-mobile units fulfill the important requirement for maximum operating efficiency—constant use (Fig. 1).

The trailers selected were the best that could be obtained: well constructed, with steel chassis, hardwood frame, and all-steel body welded throughout; and

FIG. 1. Exterior view of sound trailer for studio use, showing monitor stand.

present a neat appearance in keeping with modern automobile design. Certain modifications from the manufacturer's usual model were specified: the chassis was reinforced for greater load capacities, heavier springs and tires were provided, some windows were blanked out, storage space and cable reel openings were cut in the rear deck, and more efficient heat and sound insulation (dry-zero) used. The trailers were received without the usual household interiors, all cabinet work being added on the General Service lot.

The sound recording equipment was arranged in a console, as shown in Fig. 2, at the front end of the trailer, care being taken to locate each piece of equipment for most convenient operation. The operator sits directly in front of the recorder and has all controls within easy reach at either side. The standard cable connections of the Q channel are retained, but are completely concealed behind the console. The equipment is installed so as to appear as a permanently mounted channel, but each individual unit is readily removable from the front for repair, replacement or servicing. The recordist has before him the main amplifier and noise-reduction unit on his right, and the recorder control panel and auxiliary panel on his left. The latter carries the motor-start switch, signals, clock, and monitor-amplifier controls. The monitor speaker is directly above and the two power units for *A* and *B* supply are on each side below the table.

A built-in bench on one side of the trailer contains drawers and cabinets providing ample storage space for spare parts and auxiliary operating equipment. At the rear on the opposite side is a darkroom for magazine loading, which is complete enough to allow breaking down "OK" takes, where that method of handling negative is used. The whole interior is done in a modern motif, lighting being provided by lumiline lamps behind frosted glass flush panels.

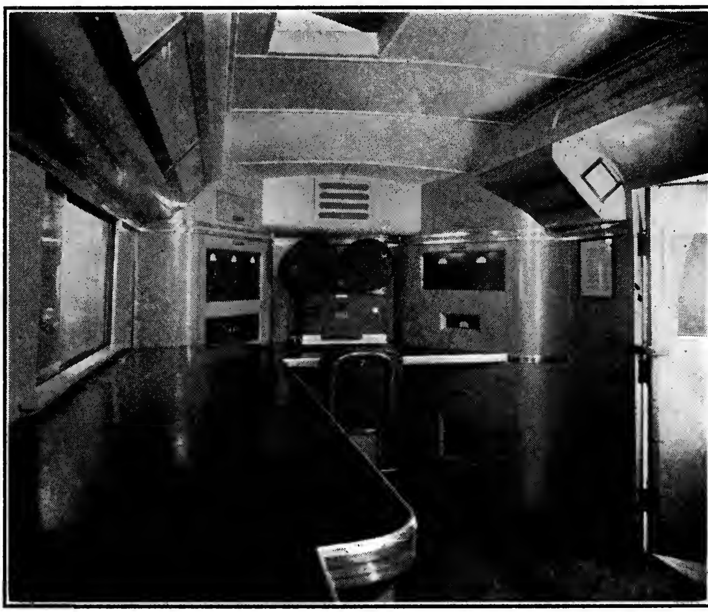


FIG. 2. Interior of truck showing sound recorder and controls.

The power-supply chosen as the most logical single source was 220-volt, three-phase a-c. 60-cycle, which is available on most lots and is required for most camera motors and provides the best regulation. The recorder motor is three-phase synchronous, and slow acceleration is accomplished by the line resistance method, the resistors being shunted by a compound relay when the motor is up to synchronous speed. Two 220–110-volt transformers are used: one 1-kva. for lighting, ventilating, convenience outlets, *etc.*, and one 2.5-kva. for supplying current to the power units. The power unit feeding the noise-reduction unit is operated through a Raytheon voltage regulator to prevent bias fluctuations. The transformers, voltage regulator, and fuse-box are mounted in a compartment at the rear of the trailer. A panel in this compartment mounts the entrance plugs and jacks, providing transmission and signal to the mixer, power supply, and remote-control motor line. The latter is used when it is desired to start the recorder from some other point (as in re-recording set-ups) or on 50-cycle lots, in which case a frequency converter is placed in the line. The power units will operate on either 50 or 60 cycles.

Cable reels are mounted inside the trailer at the rear, accessible through trap-doors in the rear deck, and cranked through holes in the side. One man can reel or unreel cable unaided. A mixer stand of unusual design to support the pick-up unit at a convenient height and a "fish-pole" type of microphone boom complete the equipment carried on the trailer, thus providing the producer with a complete high-quality sound recording channel right on his own lot for the duration of the picture.

The success in adapting the trailer to producing work led immediately to its consideration as a portable re-recording "room." It is of decided advantage for a producer to re-record on his own lot, where his cutting rooms are handy for last-minute changes, and where he can monitor the completed picture in a room to which he is accustomed. The plan now in process is to transform the customer's largest review room into a re-recording monitor room, by merely providing trunking facilities to a point where a re-recording and a recording trailer can be plugged in. Thus, duplication of expensive and relatively little-used equipment on each lot is avoided, and by having all producers so equipped, the mobile apparatus is kept in maximum use.

The re-recording trailer has four *RA-1010* ERPI re-recordng machines mounted in it with rewind and loop-running attachments, cutting facilities, blooping equipment, *etc.* This equipment is again all a-c. operated from three-phase, 220-volt supply, the exciter lamp supply being obtained from a three-phase rectifier with floating battery and *B* supply from a separate power unit. The trailer also carries special mixer and equalizer units. Six tracks may be handled, including two on the review room projectors. Review rooms for use with this equipment must therefore have double-film attachments, a distributor system for interlocking all motors (synchronously driven so as to correspond in speed to the recorder), and a mixer desk containing proper cables for terminating the mixer and equalizer units with a jack field for selecting tracks on various potentiometers in accordance with the equalizing treatment necessary. The special equalizer unit, built by Electrical Research Products, Inc., after our specifications, contains two high and low-frequency equalizers, a radio and telephone effect filter, and a variable high-pass filter, all of which may be placed in any of four tracks or in the output line. It is possible to insert these in the middle of a take without circuit disturbance, or an equalizer may be transferred from one track to another at any time.

LOCATION UNITS

The field or location unit requirements for this class of work include the usual facilities for complete sound channel and motor system operation at points remote from the studio and from available external sources of power supply. In addition, however, demands are frequently met that are not usually encountered elsewhere. Portability requirements range from completely portable "trunk" equipments to highly self-contained location truck channels. Operating requirements impose the need for the strictest economy of production time, under adverse conditions, together with twenty-four-hour-per-day service, at times, from any one of a number of different power sources.

This degree of portability and operational flexibility has been excellently met by the adaptation of a portable recording channel to a two-ton standard body truck. The Western Electric *Q* channel was found highly adaptable, and fulfilled the requirements for completely portable use. With adequate care in the physical and electrical arrangement it was found possible to have this combination result in a small, light and extremely mobile truck affording, as well, comfortable and convenient quarters for the operator. Figs. 3 and 4 show the exterior of the truck and the interior of the recording compartment.

FIG. 3. Exterior view of sound-truck for location work.

The provisions for power supply, to be mentioned in more detail later, make possible complete production operation under the following conditions:

(*1*) Where the production is remote from the conventional sources of power the basic power is derived from a bank of storage-batteries having a capacity for three-day operation.

(*2*) Where three-phase, 220-volt alternating current is available, the entire channel and motor system can be operated from this source. This condition allows for recharging of the storage-batteries.

(*3*) Where 110-volt single-phase alternating current alone is available, the entire channel can be operated from this source. The motor system power is then supplied basically from the storage battery.

(*4*) Where operation must be carried on even remote from the truck itself, the channel is operated on dry-cell batteries, and a different (d-c. interlock) motor system is used allowing small portable storage-batteries.

A general description of the channel naturally divides itself into the items of major interest. These are the storage-battery to alternating-current motor-generator, the power switching and distribution system, the motor system, the battery charger ventilation, the recording console, and the operating facilities. Fig. 5 illustrates in simplified form the general electrical arrangement.

For conversion of the storage-battery power into the required alternating current for operating the motor system and, at times, the channel, a two-bearing, 1800-rpm. motor-generator is used. This is driven on the motor end from a 36-volt storage-battery, and generates on the alternator end 220-volt three-phase

FIG. 4. Interior of location sound-truck.

alternating current. For the uninterrupted recording of film footages totaling twenty thousand feet while operating the sound recorder, two cameras, and occasionally a playback, it was found necessary to use a 2-hp. 2600-volt-ampere motor-generator and a 288-ampere-hour storage-battery. The machine is placed under the recordist's seat, shown in Figs. 4 and 6, and is supported directly upon the truck chassis through a series of rubber vibration absorbers. Due to this method of mounting and because of an efficient system of sound-proofing the inside of the generator compartment, vibration is entirely lacking and noise from the machine is inaudible at a distance of ten to fifteen feet. Continuous operation is possible due to forced-draft ventilation of the generator compartment. The design is such that the camera and recorder motors remain connected to the alternator through line switches, and are put into operation simultaneously with the motor-generator by means of its automatic starter and a push-button control station convenient to the operator.

A main switching panel occupies a convenient and unobtrusive position in the recorder's compartment. Reference to Fig. 4 shows the general appearance of this panel and its position on the left-hand wall of the compartment. This switch panel is, in effect, the control center of the channel. The switches are of the multiple jack-and-plug type, allowing manipulation of a large number of circuits by the simple operation of moving the plug from one position to another. This type of switch affords definite and high current-carrying capacity of the contacts and obviates the necessity for relays. From an operational standpoint

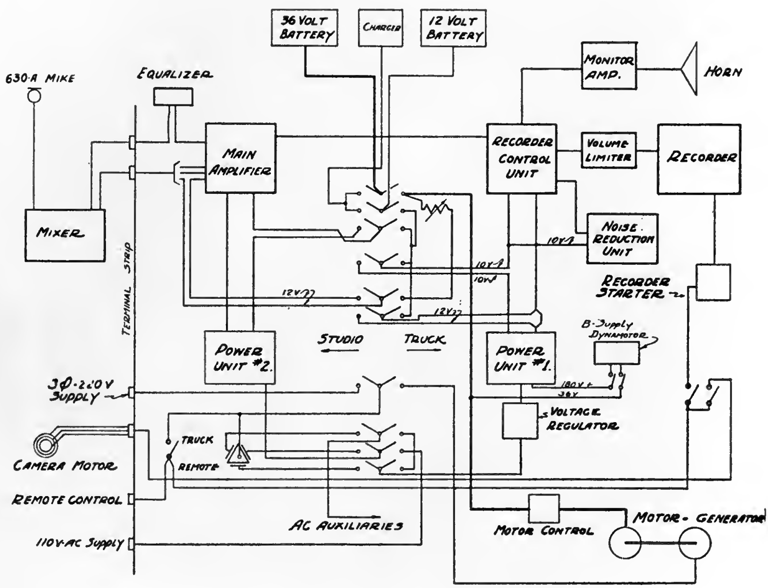


FIG. 5. "Q" circuit diagram, for truck.

this switching arrangement allows no opportunity for error in setting up the channel, as there is one position of the master switch plug for each condition of operation, as mentioned in the preceding paragraphs. As an example of the functions of this master switch, the following switching is accomplished when changing the channel from internal truck power operation to external three-phase power-line operation: transfer of the main-line three-phase from the alternator to the power inlet jack in the rear; transfer of the channel tube heaters from the storage-battery to power units; transfer of the plate circuit supply from auxiliary generator to the power units, connection of the power units to the power supply, transfer of the heater supply filter from the battery circuit to the power unit circuit, and other minor switching operations. This simplicity of operation has been found of value particularly when encountering uninitiated operators in rental service. In addition to switching, this panel is also the central location of all fuses for the truck to minimize delays from this source. Circuit testing and trouble shooting are also facilitated, as the junction box associated with the panel forms an electrical center from which all the circuits are distributed.

Recharging the storage-batteries is accomplished by means of a battery-charger installed on the truck. The charger was specially built for the purpose and incorporates the conventional tube rectifiers. The maximum charging rate is 30 amperes. Two batteries, one a 36-volt and one a 12-volt, constitute the complete battery equipment. No other batteries, either wet or dry, are used.* Insertion of the battery-charging plug at the top of the main switch panel selects for charge either the 12-volt, 36-volt, or both batteries. Simultaneous charging of the two batteries at different charging rates is also possible. Ventilation of the truck, for the removal of battery fumes, *etc.*, is accomplished by means of a motor-driven ceiling ventilator, which is automatically turned on whenever the charger is put into operation. At other times it is under the control of the operator.

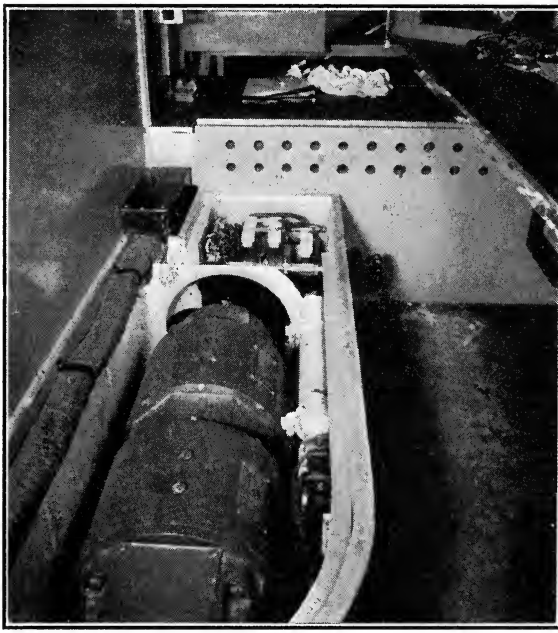


FIG. 6. Method of supporting motors.

The recording console is constructed similarly to the one described for the trailer. Removal of the equipment is thus possible for strictly portable work and

* Exception is order-wire dry-cells.

for interchangeability in maintenance. Standardization of the equipment in the light of appearance, layout, and operating routine was kept in mind throughout the design. By virtue of this it has been possible to establish standard operating routines for all the equipments.

The use of the truck channel in actual production has, thus far, shown it to be a very reliable and versatile unit. Cable extensions of the order of a thousand feet are common. Maximum freedom from trouble has been attempted by providing an alternate channel *A* and *B* voltage supply for use in the event of the failure of the conventional one. This is accomplished by switching to total a-c. power unit operation using the battery-driven alternator as a source of supply. However, continuous operation in this manner for extended periods is not practicable because of excessive demand on the 36-volt storage-battery and the driving motor of the generating plant.

The equipment has proved quite equal to the demands made upon it by the fast-moving location work that we encounter. In many instances the ratio of "moves" (or changes in production set-up and location) to scenes shot is of the order of one to two. This means high-speed manipulation to avoid delays. In such instances it is customary to operate with the extended mixer either on or within the truck. With this condition the sound equipment is continually ready to operate at any spot simply by extending a microphone and motor cable a few feet to the scene of the dialog. This on-the-set operation is made possible by the quietness of the truck power plant. Sound and vibration absorption were design objectives in the construction of the generator compartment and the installation of the sound recorder. Fig. 6 shows the interior of the compartment and illustrates the use of acoustic material, vibration-free mounting, and through ventilation.

Input and output connections to the truck for the purpose of connecting pick-up equipment, motor systems, signal systems, testing equipment, power lines, auxiliary equipment, *etc.*, are located at the rear of the body below the doors and are accessible at all times. This terminal box provides storage space for all equipment used external to the truck.

The synchronous-motor type of driving system was adopted for the camera and recorder. Its use was dictated by a number of considerations, namely, necessity for 1000-foot or longer motor-cable extensions, minimum of control equipment, economy of motor-cable conductors, and flexibility of speed control. The latter feature is accomplished by means of preadjusted armature and field resistors controlled by switches. Speed changes can be made from 24 frames to 22, 20, or 18 during a take, as is often required in "Westerns" to speed up the action.

Many companies operate intermittently on and off the studio lot in the course of a day or week, and in such cases the truck has proved itself very useful. While on the lot it can be used as a studio channel operating entirely on the lot's commercial power supply. This gives opportunity for replenishing the storage-batteries and allows quick moves to outside locations.

Transmission, power, and signal cable connections on the rear terminal strip of the truck allow its use to be interchangeable with that of the recording trailer as the recording unit of a mobile re-recording or scoring set-up. In this class of service the recorder can be remotely controlled from the projection booth and the operation interlocked by a system of signal lights.

Interchangeability, not only between individual pieces of apparatus but between whole units, truck or trailer, is one of the most valuable operational assets of this new equipment. When scheduling necessitates, a complete switch of equipment may be made without confusing the recordist with a new operating layout, or annoying the mixer with a different monitor, or irritating the producer by variation in quality of the product.

In closing, we wish to thank Mr. D. C. Hickson for valuable contributions to the physical appearance of the units and for the original suggestion of the use of trailers; our thanks also to J. R. Whitney and our colleagues, W. W. Lindsay, Jr., and R. S. Clayton for advice and collaboration in the design details.

A NEW MOTION PICTURE CAMERA CRANE*

E. H. HEYER AND E. L. FISCHER**

During the last fifteen years there has been considerable change in camera technic for motion picture production. The rather unnatural effect of cutting from long shots to close-ups has been avoided more and more by perambulating the camera from one position to another during the shot. In general, rolling tripods, camera dollies, and perambulating platforms are in use now for nearly all types of scenes. With more elaborate sets being designed every day, dialog and action becoming faster, more effective camera angles and pictorial effects being wanted, there was a need for more efficient perambulating apparatus to move camera and cameraman into the exact positions from which to take the most effective shots.

This problem is effectively solved by the so-called camera crane, of which several are in use in the major Hollywood studios. In common with previous designs, the new Universal camera crane shown in Fig. 1 provides the cameraman and his camera almost unlimited freedom of motion, up or down, left or right, backward, forward, or pivotal. This great freedom of motion facilitates following the actors up and down stairs, lifting away over props, arc lamps, and furniture, and most important, it affords the cameraman a new artistic means of increasing or diminishing the audience's field of view at any rate and from any direction desired.

Common also with its predecessors are the following general design features of the crane: A rigid structural boom supports upon its front end a camera carriage whose horizontal condition is maintained by a parallelogram mechanism joining it to two points of the central supporting post. The opposite end of the boom carries a balancing weight-box fitted with handles by which the operator swings the crane left and right or up and down. A catwalk supports the operator at a convenient height for reaching the handles, and may be extended, when desired, completely around the crane to accommodate large rotational movements. The

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received October 4, 1937.

** Universal Pictures Corp., Universal City, Calif.

whole structure is mounted upon a suitable chassis provided with pneumatic tires.

Although there is at least one much larger camera crane in existence, this new one may be classed as a large one in view of its maximum height of camera lens above the floor of 25 feet, as distinguished from small camera cranes having maximum lens heights of 17 feet or less. In this new crane a number of new fea-

FIG. 1. General view of camera crane.

tures have been incorporated which will be the subject of the remainder of this paper.

Beginning with data kindly furnished by other studios on the design and performance of previous camera cranes, a thorough investigation was made of all the problems involved. A questionnaire was circulated among our camera crews covering all important points of operation and features. From the replies, which were based upon experience with other camera cranes, we were able to eliminate unnecessary items and add new features for overcoming some of the difficulties previously experienced.

Although the material of the main boom is 17 *ST* duralumin the center portion is made rather wide and is stiffened by diagonal and cross braces, so that the total deflection with full operating load of 1200 lbs. is less than $^1/_2$ inch (see Figs. 1 and 2). In this respect the new crane is superior to most of its predecessors. A second structural feature of great importance is the method of supporting the camera carriage. In other camera cranes the point of support is at the rear of the

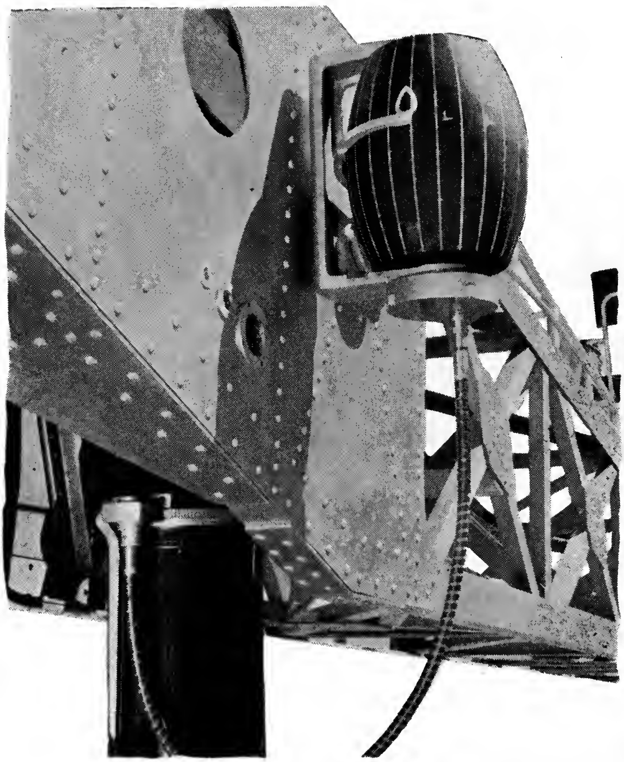


FIG. 2. Close-up showing structural details of boom and drum indicator.

carriage, so that the entire length of the carriage overhangs the end of the boom, and the combined weight of carriage, camera, and crew produces a tremendous strain in the boom and the leveling rod. In this design the last two feet of the front end of the boom are formed up approximately 30 degrees, to bring the carriage swivel into balancing position for the loaded carriage and yet not prevent complete rotation of the camera turntable. By doing so, nearly all strains are removed from the leveling rod, which now has only one function—to hold the carriage level at all points of elevation (see Figs. 1 and 3). All loads on the turntable are balanced as nearly as possible to prevent unnecessary tension and friction on parts and bearings and to allow smooth and easy operation.

In common with other camera cranes the turntable is operated by the cameraman through pedals and gears (Fig. 3), the present model permitting a 300-degree turn without resetting the pedals. A new feature provides almost automatic operation of the turntable for certain types of shots. For this purpose the pedals are disengaged and the turntable is clamped to a drive pulley inside the carriage. By means of an equalizing cable drive back to the center post and a set of bevel gears, the camera will point always in the same direction while the crane boom is swung around for long pull-back or "dolly" shots. This allows the cameraman to concentrate upon other details such as keeping the framing correct by means of

FIG. 3. End of boom, showing controls.

friction or gear heads, *etc.* The cable drive can be used also to operate the turntable from the rear end of the chassis by motor or hand power.

Another interesting feature is the new charting drum-indicator seen in Fig. 2. There are two moving parts to the indicator, a drum and a pointer, which indicate respectively the panning and tilting movements of the boom. To accomplish this the drum is geared to the stationary center-post, while the pointer is geared to the horizontal axis of the boom. After the line of travel is once marked upon the drum the operator can thereafter repeat the same crane movements precisely by moving the rear end of the crane so that the indicator arm follows the course charted upon the drum.

A duralumin catwalk, supported by outriggers (see Fig. 1), is provided from which the operator can easily lift or lower the boom while swinging it around a

320-degree circle. Non-slip rubber covering and easy handling of the light-weight duralumin sections are the main features of this catwalk.

Only one other perambulating camera crane (a much larger one, also owned by Universal) has a power-driven chassis. The crane chassis here described is driven by two variable-speed d-c. motors, each motor driving one rear wheel through a silent speed-reducer. The motors (Fig. 4) were specially built for noiseless operation and will provide, through a set of armature and field controls, a speed variation from $^1/_{10}$ to 12 miles per hours. The rear wheels can be disengaged from the drive, so that the chassis can be pushed, by man power, at speeds above the range mentioned. In spite of this power-drive feature, the front and rear wheels can be steered separately, as any other crane, because the rear axles are the outer

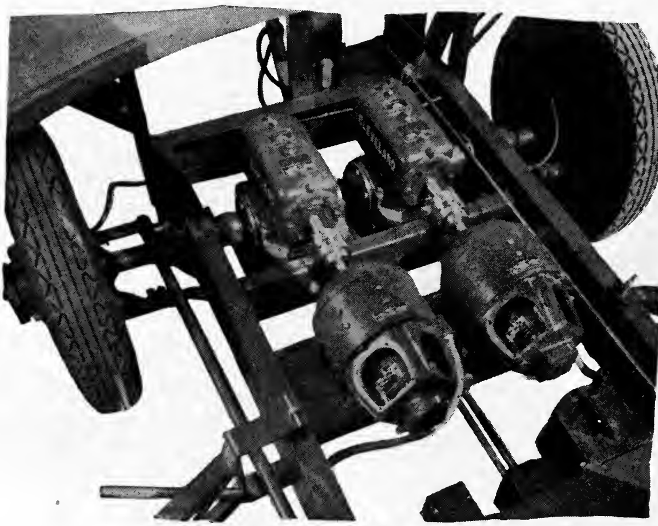


FIG. 4. Motor drive of rear wheels.

portion of a heavy-duty "front-wheel drive" truck axle. Hydraulic brakes are built in all four wheels. Dual type wheels can be attached to the rear-drive axle for operation on location.

Around the studio the crane will be used on a special wooden track. The joints of the track have an overlapping steel plate to which is welded a short shaft, which allows the joints to swivel and the track to be laid to any desired curvature.

The camera carriage and turntable are so designed that a very simple auxiliary turntable (not illustrated) can be plugged in underneath the regular turntable, permitting the camera lens to come within 16 inches of the floor, to be lowered between tables of a café set or into the trenches of a battle set, *etc.*

The main dimensions of the new crane are as follows:

Overall length of boom	23 ft. 6 in.
Center post to camera lens	20 ft.
Center post to rear end of weight bucket	8 ft. 4 in.
Maximum camera height over floor	25 ft.
Minimum camera height over floor	3 ft.
Minimum camera height with sub-turntable	16 in.
Floor to top of center-post	10 ft. 4 in.
Wheel base of carriage	11 ft. 7 in.
Width of carriage, hub to hub	7 ft. 5 in.
Speed of chassis	$^1/_{10}$ to 12 miles per hour.

A SOUND-FILM PHONOGRAPH*

D. CANADY AND V. A. WELMAN**

A sound-film recorder was described by the authors before the Society in 1936.[1] It is the purpose here to describe additional equipment, which has been designed and built to meet the requirements of the Phonetics Laboratory of the Department of Psychology of Oberlin College (Oberlin, Ohio) for research work conducted by that department under the direction of Dr. R. H. Stetson.

The equipment consists of a sound-film recorder essentially the same as described previously, and two sound-film reproducers or phonographs, as the College terms them, to meet particular requirements. The reproducers follow the design of the recorders except that a scanning drum is substituted for the recording drum and an exciter lamp and slit mechanism for the glow-lamp and slit, the modulated light-beam being directed by a prism through the door into a photocell assembly provided by the Psychology Department.

The two film-phonographs are coupled directly to one $^1/_6$-hp. synchronous motor through a differential device on each machine, by means of which either machine may be advanced or retarded with reference to the other, whether they are at rest or in motion. Thus it is possible to run two identical film records in step or to throw them out of step, in either direction, by any desired amount. For slow, careful examination of the film, either machine may be cranked forward or backward continuously without being disconnected from the other machine, which remains stationary (Fig. 1).

The Department's specifications called for bringing out a long loop in such a manner that it could be studied, observed, or marked while standing still or in motion without disturbing the threading of the machine, and for that purpose there was placed between the sound-head and the magazine a cast aluminum

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received October 6, 1937.

** Canady Sound Appliance Co., Cleveland, Ohio.

housing with three rollers to support the film and a friction-driven sprocket to provide the proper tension (Fig. 2). The housing is equipped also with two horizontal guide-rods carrying two low-voltage lamps with associated housings and cylindrical lenses, a suitable scale being fixed to the housing (Fig. 3). One of the lamps may be roughly adjusted by hand to any desired position, and the other finely adjusted by means of a crank-operated screw. This part of the equipment may be adapted to a great many uses by the inclusion of a variety of apparatus. The magazines are supplied with a carrier for supporting continuous loops of film, secured by four screws, and these carriers may be quickly removed for using standard reels.

The Department of Psychology of Oberlin is making an exhaustive study of speech, to which this equipment is incidental, and reports of which will no doubt

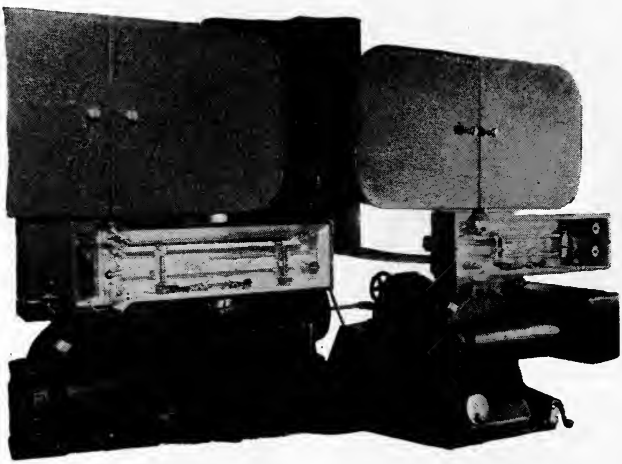


FIG. 1. Film phonographs coupled directly.

be published in due time. During these investigations it became desirable to record, reproduce, photograph, re-record and, reproduce certain sound-waves. Much more accurate equipment was found to be necessary than was available; in fact, ordinary commercial practice was not sufficiently accurate for their purposes: hence the development of this equipment. The same constancy of speed exhibited by the recorder under adverse power-supply conditions is found in the phonographs, and is essentially necessary in this case because both the frequency and voltage supplied by the local power company are subject to extreme variations, not occasionally but continuously, almost from minute to minute.

The photocells and associated equipment are housed in 3-inch steam pipe, the output being carried to the amplifiers in the center of the pipe on spacers. The amplifier circuits and their construction are the development of the technical assistants of the Department, J. M. Snodgrass and P. F. Brown, and will probably be described at some future time. In the recorder either the glow-lamp or a

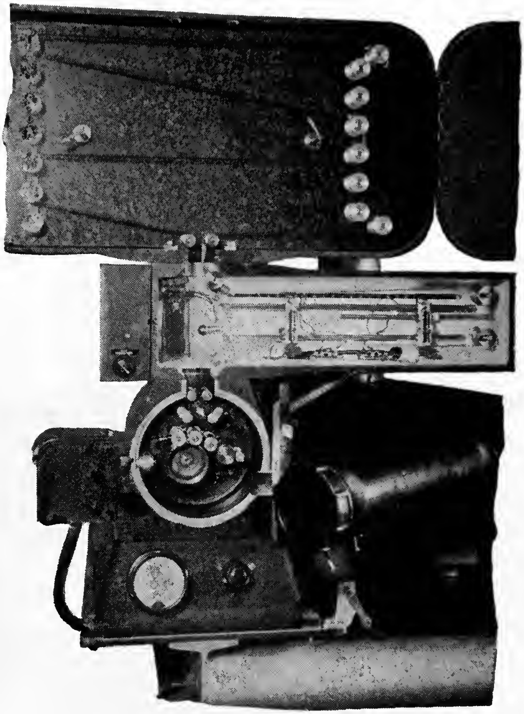


FIG. 2. Compartment for bringing out loop for observation and study.

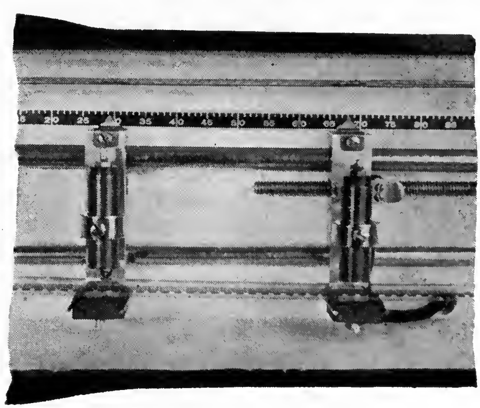


FIG. 3. Guide rods and scale.

galvanometer may be used, but for the purpose of their work the Department finds the glow-lamp more suitable.

Summing up the chief points of interest, attention is called to the construction of both the recorder and reproducers to attain remarkable constancy of speed under adverse conditions of line supply; the differential gearing arrangement by which the phase of each machine may be varied relative to the other while at rest or in motion; and the added housing and its equipment for experimental purposes.

REFERENCE

[1] CANADY, D.: "New Recording Equipment," *J. Soc. Mot. Pict. Eng.*, **XXVIII** (March, 1937), No. 3, p. 309.

PRECISION ALL-METAL REFLECTORS FOR USE WITH PROJECTION ARCS*

C. E. SHULTZ**

All reflecting surfaces used for present-day projection purposes are metal. In the well known glass type of reflector, the silver layer acting as the reflecting surface is supported by a base of glass, which acts also as a protecting medium against the damaging effects of an open arc and its associated heat. In the all-metal type of reflector, both the supporting base and the reflecting surface are, as may be expected, composed of metal.

The limitations of the glass type of reflector in projection practice are best exemplified by the following two quotations from the report of the Projection Practice Committee published in the January, 1935, issue of the JOURNAL.

"(*1*) Examination of reflector mirrors in theaters in which 'Suprex' carbons have been used for some time shows that there is *continual pitting* resulting in noticeable decrease in screen light. In order to maintain the screen illumination at its best, the mirrors should be replaced when noticeably pitted.

"(*2*) Elliptical reflectors are not ground and polished. In other words, they vary in focal length as well as in working distance, or both ...."

An all-metal reflector is now being presented which is designed to overcome these shortcomings of the glass type of reflector.

Such an all-metal reflector must, by its very nature, be a front-surface reflector.

The reflecting surface, being directly exposed to an open arc, must be able to withstand the heat, gases, and molten particles of copper and incandescent carbon thrown upon it. Consequently, a reflecting material resistant to these damaging

---

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received September 10, 1937.

** Heyer-Shultz, Inc., Montclair, N. J.

agents is employed. The all-metal reflector is surfaced with rhodium, a metal having a melting point of about 3600°F, or almost 1000 degrees above the melting point of steel. Rhodium, in solid form, is insoluble in all acids, including aqua regia. These properties make the material well suited for use as a reflecting surface. However, rhodium has a reflectivity of 75 per cent as compared to silver on glass, which is 85 per cent.

Greater precision of curvature is highly desirable in the all-metal reflector in order to direct to the conjugate focus all the rays possible that are incident upon its surface. Even though the difference between the efficiency factors of the reflective metals used in the two types is 10 per cent, this difference is substantially reduced when tests are made through projection systems and compared upon the screen. This reduction is in relation to the comparative accuracies of

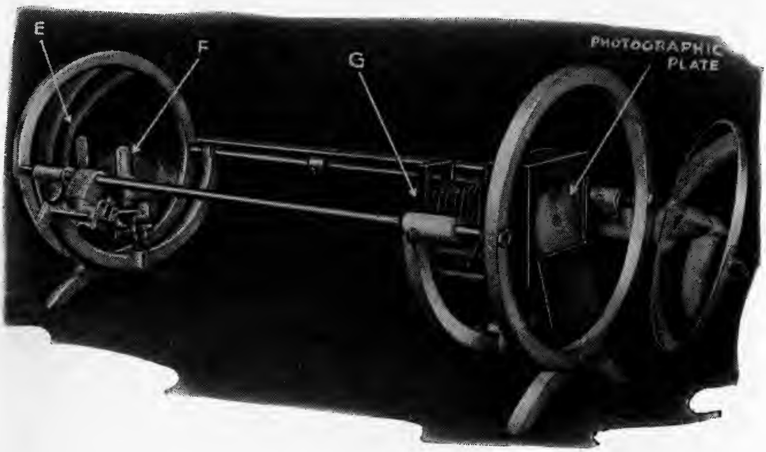


FIG. 1. Apparatus for testing ellipsoidal reflectors.

different glass-type reflectors against which tests were made. The greater accuracy of the all-metal reflector also makes possible greater range of focus of the light-source and more uniform screen illumination due to better imaging of the crater of the positive carbon.

Because of these improved features, less attention is required on the part of the projectionist to maintain best screen results. The reflector is unbreakable, and under normal projection conditions is indestructible. The reflecting surface of rhodium, being insoluble in all acids, can not tarnish. Due to the inertness of the rhodium against chemical reagents, and its high melting point, incandescent carbon particles and molten globules of copper thrown out from the arc do not imbed themselves into this surface as they do in glass.

Consequently, the precision all-metal reflector is capable of standard performance under severe conditions over long periods of time, and is guaranteed by the manufacturer against every normal projection hazard for a period of one year. The two types of reflector may be simply compared as follows:

	Glass Type	*Metal Type*
(*1*)	Higher initial reflectivity.	Lower initial reflectivity.
(*2*)	Less accurate contour.	More accurate contour.
(*3*)	Breakable.	Not breakable.
(*4*)	Subject to rapid deterioration of reflecting surface through sulfiding of the silver layer and pitting of the front glass surface.	Resistant to pitting and tarnishing.
(*5*)	A spare is necessary.	No spare is necessary.

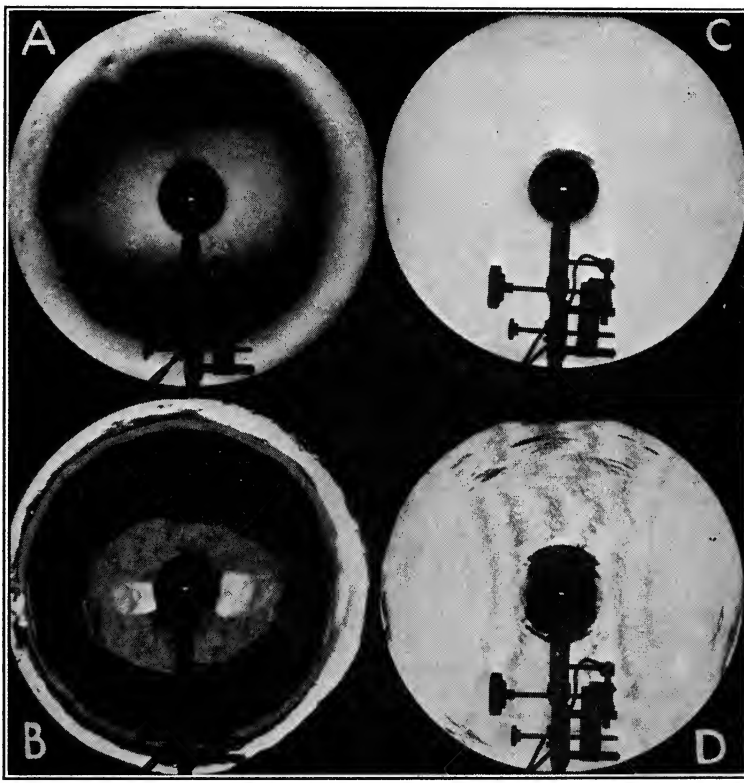


FIG. 2. Surface pictures of reflectors taken with the apparatus shown in Fig. 1.

Apparatus upon which the surface pictures of ellipsoidal reflectors are made is shown in Fig. 1. *E* is the reflector held in position in a holder; *F* is a light-source of size proportional to the aperture *G* at a distance from *F* representative of the focal-length of the reflector, while the distance *EG* is representative of the working distance of that same reflector.

As *F* is to *G* as a normal arc crater is to a standard aperture in the projection optical train, the image thrown upon the ground-glass of the camera (or the photographic plate) is an image of all the reflected pencils of light incident upon the reflecting surface and correctly focused at the conjugate focus which occurs at the aperture *G*. All shadow areas appearing on this image are distortion areas or uncorrected parts of the true ellipsoidal curve and should not appear under these conditions.

By reducing the size of the aperture *G*, and leaving all other conditions fixed, we are able to magnify these areas immensely as the proportions change very rapidly in relation to one another. When we reduce the aperture *G* to nearly a pin-hole, only a well corrected ellipsoidal curve will bring to conjugate focus through this opening all the pencils of light incident upon it from a light-source equivalent in size to the crater of an average projection arc.

This method is an extremely accurate, yet fast, way of checking ellipsoidal curvatures in terms of per cent of shadow area visible in the focused image.

By means of this system it is possible to photograph the light-rays incident upon the reflecting surface of an ellipsoidal reflector, and thereby to find errors in the form of shadows. The negative stock used for these pictures was commercial Ortho.

Photographs *A* and *C* (Fig. 2) were exposed through a 19-mm. iris opening. The ratio of this stop to the 5 mm. long filament of the light-source is in proportion to the ratio of the aperture and carbon set-up used in average projection practice.

A and *C*, which are surface pictures of a glass reflector and an all-metal reflector, provide a striking comparison between the accuracies of the two types. *B* and *D* represent extreme test conditions only, as no projection reflector would ever be called upon to work under such critical set-ups. In this case the converging rays of light pass through a 1-mm. opening, thereby showing inaccuracies of curvature more readily.

A DEVICE FOR CLEANING SOUND-TRACK DURING PROJECTION*

R. J. FISHER**

Film will collect dirt, dust, and lint in a number of ways. Excess oiling of mechanisms makes the film oily and causes dirt, dust, and lint to adhere more easily. Dirt, dust, and lint flying in the air in the projection room from fans, sweepings, *etc.*, get on the film during rewinding and projection. Static electricity generated by friction during the process of rewinding and projection causes dust and lint to adhere to the sound-track. Dirt, dust, and lint collect in the valves of both

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received September 9, 1937.

** Flower City Specialty Co., Rochester, N. Y.

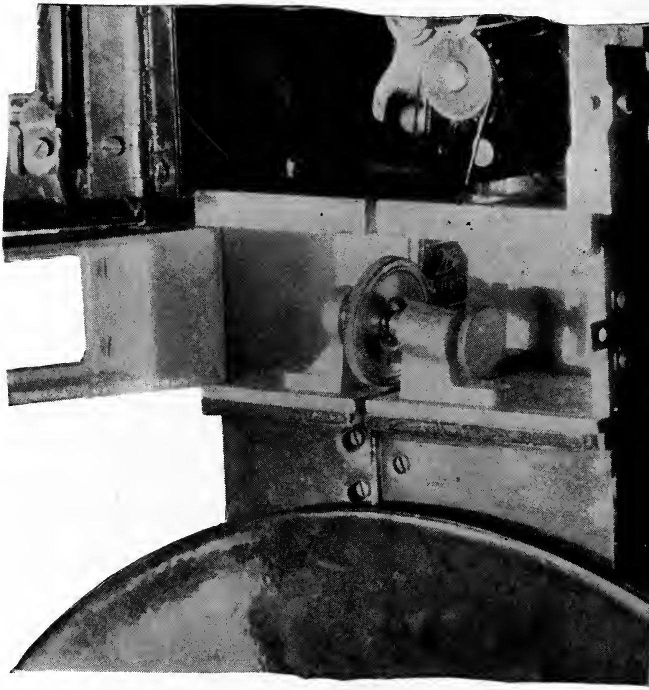


FIG. 1. Sound-track cleaner on projector, open for threading film.

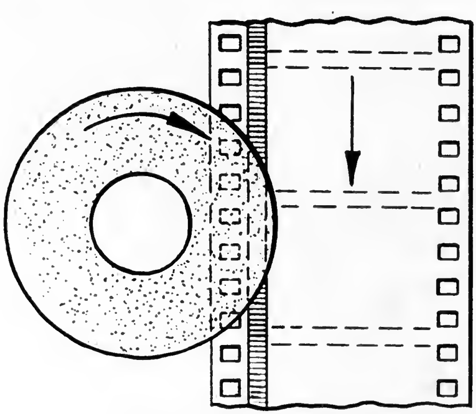


FIG. 2. Showing position of cleaning disk on sound-track.

upper and lower magazines and in turn is deposited upon the film. The shaking of film reels during transportation in shipping cases lined with cardboard or other soft material causes the lining material to chip off and grind up and lodge upon the film.

Many projectionists have a habit of allowing the end of a reel of film to drag upon the floor of the projection room and to collect dust and dirt, which is deposited in the projector during the showing and is spread over the full length of the next film to be shown.

Distortion in sound reproduction due to dirt on the film is not new, and has been a problem since the advent of sound motion pictures. Even when sound was recorded on records, the disks had to be brushed each time they were run. With the great advances now being made in high-fidelity and wide-range recording and reproduction, the dirt problem has become aggravated because of the more critical scanning. The sounds due to the finer grains of dirt, dust, and lint are more easily amplified along with the recorded sound.

To achieve true and faithful reproduction of recorded sound it is of the highest importance, therefore, that the sound-track be clean, so that the light-beam transmitted through it to operate the sound reproducing apparatus shall be subject only to the intended conditions produced when the sound was recorded, and not the unintended and varying conditions due to dirt. Although cleanliness of the sound-track is of the greatest importance in faithfully reproducing recorded sound this is a field that has been grossly neglected.

The sound-track cleaner described here is not the result of an overnight idea. It was started several years ago, since which time continuous experimentation has been carried on until we were successful in producing the present cleaner. An earlier model that we produced was located just below the take-up sprocket. We thought this was the last word, until tests conducted at Electrical Research Products, Inc., showed that although the device cleaned the sound-track properly a slight flutter was introduced that was not noticeable to the ear but did show up in the flutter meter. Following suggestions by some of the engineers the cleaner was redesigned, adhering to the original principle but changing the location and simplifying its operation.

The cleaner is now located in the upper part of the projector, just below the upper magazine valve, and cleans the sound-track just before it passes around the upper feed sprocket. It is very easily installed, because no changes are necessary on the projector with the exception of removing the upper magazine valve. The cleaner is placed on top of the mechanism where the film-valve is located. Then the valve is placed on top of the cleaner and screwed down with the same screws that hold the film-valve on the projector. The magazine is put back into place as before and the installation is complete (Fig. 1). In all this takes about ten minutes.

The cleaning disks are held in two metal holders. In the center of each holder is a bearing point running in two oilless bearings. The bearing nearest the projector lamp is held in a tension spring barrel which provides even pressure of the cleaning disks against the sound-track of the film. The tension is very slight, just enough to cause a wiping action. The inside of each disk-holder has a small well in which the dirt and lint is deposited while the cleaning disks revolve with the motion of the film during the process of projection (Fig. 2).

The disks have two cleaning surfaces, so that both sides of each disk can be used. When one side becomes dirty the disk is reversed in the holder. One pair of disks will clean about 4000 feet of sound-track, or two large reels. The disks are used dry, which avoids all danger of softening the emulsion or leaving any kind of coating upon the sound-track. They are made of a special composition which is softer than the film or the emulsion, so that they will not scratch or otherwise injure the film.

The principal ingredients of the composition are small particles of cork and jute fiber, held together in a practically homogeneous mass by a binding and softening material including glycerine and a special glue. This material has been found by test to be very efficient in picking up and retaining oil and dirt, such as is found on the sound-track. It is recommended that a clean pair of cleaning disk surfaces be used on each reel during projection.

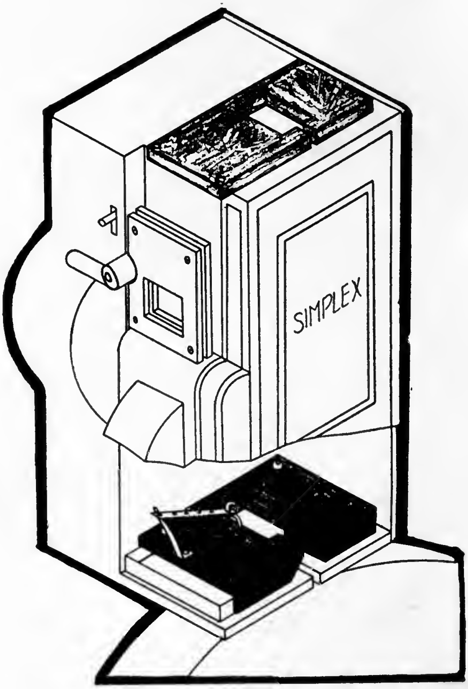


FIG. 1. Diagram showing upper and lower fire-valves.
(See article on opposite page entitled "Flash Fire Valve," by R. J. Fisher.)

FLASH FIRE-VALVE*

R. J. FISHER**

Flash fire-valves are designed to eliminate all danger of serious film fires in projectors during projection caused by broken or torn sprocket-holes, bad patches, worn out mechanism, *etc.* The operation of the valves makes it impossible for fire in the projector during the process of projection to get into either film magazine, and limits the length of film that can burn in the projector to about 18 inches, or just what is threaded through the mechanism.

The valves are so constructed that they operate very rapidly and in all tests that have been made they did not fail to work. The mechanism is inclosed in a metal case, and consists of a track or slot in which a shutter operates to close the film opening below the upper magazine and above the lower magazine. The shutters do not cut the film, which would allow the end of the film that might still be smouldering to pass through the film-valve rollers into either magazine, but they hold the end of the film in the fire-valve. The shutters are held open by a fusible link made of uncoated film, which burns more quickly than coated film. They are closed by the action of a strong flat spring inclosed in the track on the valve mechanism in which the shutter rides. It is impossible for a piece of burning film to pass the fusible link without touching off the fuse.

Since these fire-valves operate entirely by fire, there is no electrical apparatus to get out of order. It has been proved by repeated tests that the operation of flash fire-valves installed on any existing projector will eliminate danger of serious film fires that start in the projector. The valves can be designed to fit any projector now in use in any theater.

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received May 30, 1937.

** Fisher Manufacturing Co., Rochester, N. Y.

A PORTABLE LOOSE-SHEET MICROPHOTOGRAPHIC CAMERA*

R. H. DRAEGER**

The work on the design of the microphotographic camera described in this article was started in Washington, D. C., approximately two years ago and was made possible through the coöperation of various governmental and non-governmental agencies. The Navy Department, Bureau of The Census, the Works Progress Administration, and the Department of Agriculture were the principal governmental departments coöperating. Funds for carrying out the experimental and developmental work were provided by the Chemical Foundation, and were administered through the Documentation Division of Science Service, Washington, D. C.

* Received October 27, 1937.

** Medical Corps, U. S. Navy, Washington, D. C.

The camera was built for the Bureau of The Census and is to be used experimentally for microfilming birth and death certificates in the field. The present method of gathering vital statistical data involves having hand-copied transcripts of the pertinent facts of these records prepared by the individual States and sent to the Bureau of The Census. Microfilming the original birth and death certificates in the individual States, if feasible, will have several advantages over the present methods in point of time, expense, accuracy, and completeness of record.

With these objects in view a compact, portable, self-contained unit has been designed and built. The unit, shown in Fig. 1, consists essentially of a cast

FIG. 1. Front view of camera, showing platen raised.

aluminum head fitted into a rectangular aluminum case having a hinged platen in front and a camera and operating mechanism movably mounted upon a plate at an angle in the rear.

The camera and operating mechanism for timing the exposure and advancing the film are identical to that used on the large universal microphotographic camera[1] exhibited and operated at the Paris International Exposition, 1937.*

This mechanism is of sturdy and reliable construction, following the general practice of motion picture camera design. Experience with improvised copying apparatus has not proved satisfactory for handling a large volume of work because the ordinary driving and shutter mechanism is not constructed to operate

* An exhibition of microphotographic apparatus sponsored by the American Library Association and demonstrated by the University of Chicago.

continuously for millions of exposures. The shutter used in this camera is electrically operated, and has a sufficiently wide time range to permit the use of ordinary positive motion picture film. The advantages of positive film are low cost and fineness of grain.

A plate-glass window is provided upon which the sheet to be copied is placed face downward. The hinged platen is then closed holding the sheet in place while the photographic exposure is being made. A mirror is movably mounted within the case upon an arm at an angle directly below the plate-glass window for directing the light-rays from the window to the camera lens. The use of a mirror in this manner greatly reduces the overall dimensions of the apparatus

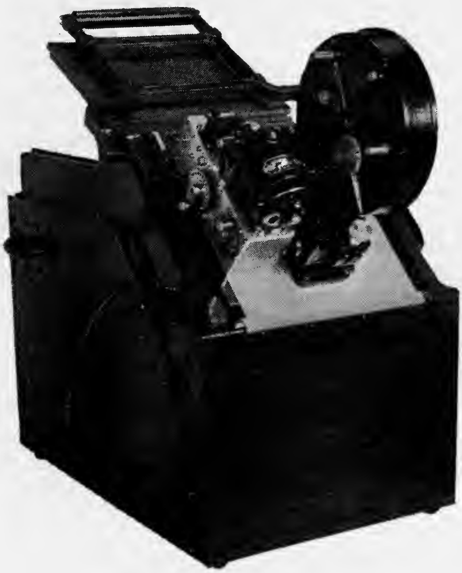


FIG. 2. Rear view of camera, showing operating mechanism.

and also allows the camera and operating mechanism to be placed in a convenient position at the rear of the head.

The reduction ratio can be changed within a small range to accommodate sheets of different sizes. This is accomplished by the simultaneous movement of the interconnected camera and mirror which brings about the effect of moving the camera toward or away from the copy. This movement of camera and mirror has been so coördinated that the rear edge of the photographic field remains fixed, assuring accurate centering of the sheet being copied without the need of a movable stop.

To provide uniform lighting of the photographic field, which is so necessary in this type of camera, a rectangular placement of 6-volt lamps in series has been used. The lamps are placed beneath the glass window in the case in such a position that neither direct nor reflected rays from the plate can enter the camera lens.

The lights are turned on by the camera-operating mechanism only during the exposure interval, thus reducing the effect of heating from the lights. During continuous operation the temperature rise within the camera case directly under the glass window amounts to only 8°C.

The film-gate is fitted with removable interchangeable gate pieces to accommodate both 35- and 16-mm. film, although for the purpose intended it is expected that all copying will be done on 35-mm. motion picture film. The film-gate is also adjustable in length and interconnected with the film-advancing mechanism. A single lever provides the necessary adjustment of film-gate length and advancing mechanism to utilize the entire area of the film.

The operating mechanism provides the cycle of events necessary for the function of the camera. It advances the film, operates the shutter and lights, times the exposure, and releases the hinged platen, allowing the latter to rise when the exposure is finished. All the electric circuits have been so designed that a careless or inexperienced operator can do no damage to the apparatus by faulty manipulation.

The film magazine, which may be seen attached to the camera in Fig. 2, will accommodate 200 feet of film. The film roll is placed in the magazine as it comes from the manufacturer, without rewinding, and is removed in the same way. The magazine is provided with a light-trap requiring no interlock with the camera.

Operating the camera is quite similar to feeding a small printing press. The operator places the first sheet upon the glass plate, face downward, and closes the platen. This initiates the cycle previously described, terminating in the rising of the hinged platen. The operator then removes the platen as before. The cycle of operation, other than the closing of the platen, is entirely automatic. The speed of operation naturally depends partially upon the speed of the operator, and may be conservatively estimated at 500 sheets an hour.

REFERENCE

[1] DRAEGER, R. H.: "A New Design for the Microphotographic Camera," Communications to the World Congress of Universal Documentation, 1937, p. 93.

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 copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C.

Cinematographie Française

20 (Jan. 28, 1938), No. 1004

L'Objectif Apochromat (Apochromat Lens) Technique and Material (p. 1)

Communications

18 (Feb., 1938), No. 2

Amplifier Expansion Circuits (p. 11) — A. Nadell

Modulation Suppression of a Weak Signal by a Stronger One (p. 14) — H. Roder

Electronics

11 (Feb., 1938), No. 2

Thyratrons and Their Uses (p. 9) — E. F. W. Alexanderson

Cathode-Ray Wave-Form Distortion at Ultra-High Frequencies (p. 13) — R. M. Bowie

Time Delay in Resistance-Capacity Circuits (p. 26) — E. W. Kellogg and W. D. Phelps

Television Film Scanner (p. 50)

Filmtechnik

14 (Jan., 1938), No. 1

Tonfilm und Kopieranstalt (Sound-Films and Printing Establishments) (p. 6) — W. Hartmuth

International Photographer

10 (Feb., 1938), No. 1

News of New Products (p. 5)

Shooting Mob Scene Stills (p. 12)

Toning Battery (Four New Toning Machines Nearing Completion at M-G-M) (p. 28)

Duplex Automatic (New Tinting and Toning Machine) (p. 29)

International Projectionist

13 (Feb., 1938), No. 2

New Standards for Old (p. 11)	T. C. BARROWS
Notes on Capacity and Condensers (p. 12)	L. P. WORK
New Simplex *E-7* Projector a Great Advance in the Art (p. 17)	
The Place of Television among the Visual Arts (p. 20)	A. N. GOLDSMITH
Outdoor Theatres Utilize New Projection Set-Up Technic (p. 22)	G. L. MCGOVERN
Analyses of Modern Theatre Sound Reproducing Units (p. 24)	A. NADELL

Kinematograph Weekly

252 (Feb. 24, 1938), No. 1610

Film Pictures on Metal Support (p. 35)

Large Screen Television in Colour (p. 35)

New B & H 16-Mm. Projector—The Filmoarc with Arc as Illuminant (p. 40)

Kinotechnik

20 (Jan., 1938), No. 1

Erfahrungen mit Sicherheitsfilm beim Normalfilm (Experiments with 35-Mm. Safety Film) (p. 1)	L. METZ
Geometrisch-Optisches vom Kinolampenspiegel (Geometrical Optics of Reflectors) (p. 10)	H. NAUMANN AND H. SCHREYER

20 (Feb., 1938), No. 2

Die Kinotechnik auf der Fruhjahrsmesse, 1938 (Motion Picture Equipment, 1938) (p. 29)	
Stand der Filmbearbeitungstechnik (Film Processing Technic) (p. 34)	W. GEYER
Verbesserungen an Tonkopiergeraten (Improvements in Sound-Printing Apparatus) (p. 39)	H. FREESE
Schlupffreies Tonkopieren (Non-Slip Sound Prints) (p. 43)	H. LEHMBERG

Motion Picture Herald (Better Theatres Section)

130 (Mar. 5, 1938), No. 10

Acoustic Treatment as a Function of Auditorium Design and Decoration (p. 33)	C. C. POTWIN
From a Candle-Flame to the High-Intensity Arcs of Today (p. 35)	

Photographische Industrie

36 (Feb. 2, 1938), No. 5

Das Problem der Farbenfilm-Kopie (The Problem of Printing Color-Films) (p. 104)

36 (Feb. 9, 1938), No. 6

Moderne Schwarz-weiss- und Farben-Tonfilm-Projektion (Modern Black-and-White and Color Sound-Film Projection) (p. 141)

36 (Feb. 16, 1938), No. 7

Fortschritte in der Bild- und Tontechnik der Kinovorfuhrung (Progress in Motion Picture Projection) (p. 191)

Proceedings of the Institute of Radio Engineers

26 (Feb., 1938), No. 2

Beam Power Tubes (p. 137) — O. H. SCHADE

Single-Side-Band Telephony Applied to the Radio Link between the Netherlands and the East Indies (p. 182) — N. KOOMANS

Frequency Discrimination by Inverse Feedback (p. 207) — G. H. FRITZINGER

A New Type of Selective Circuit and Some Applications (p. 226) — H. H. SCOTT

Television

11 (Jan., 1938), No. 120

A New Optical Method of Television Reception (pp. 69–70) — OKOLICSANYI

A New System of Large-Screen Projection (pp. 96–99, 126–127) — E. P. RUDKIN

A Push-pull Transmitter for 5 and 10 Meters (pp. 116–118, 128)

Transactions of the Illuminating Engineering Society

33 (Feb., 1938), No. 2

Brightness of the Mercury Arc (p. 147) — J. W. MARDEN, N. C. BEESE AND G. MEISTER

Comments on Proper Use of Illumination Terms (p. 193) — G. H. STICKNEY AND E. C. CRITTENDEN

BOOK REVIEWS

Film Making from Script to Screen: Andrew Buchanan, *Faber and Faber, Ltd.* (London), 1937, 196 pp.

This little book was written by a well known British director of motion pictures and is intended to be of interest both to the professional and the amateur. It is pointed out that the amateur, because of his greater freedom of action, often creates greater originality in a film than the studio director, who is often handicapped by definite rules. The context is divided into two parts, of which the first deals with the structural details of film story production, and the latter with specific film problems. There are 16 illustrations.

G. E. Matthews

Servicing Sound Equipment: James R. Cameron, *Cameron Publishing Co.* (Woodmont, Conn.), 1937, 367 pp.

This book represents a useful reference on the equipment used by the projectionist. It contains explanations of the fundamentals of component parts used in the reproduction of sound, such as the use of meters, transformers, and the functioning of vacuum-tubes in amplifiers.

Several chapters are devoted to the servicing of equipment giving likelihood of potential and possible points of trouble, to enable the most experienced as well as the beginner to locate trouble by suggestion throughout the book.

Circuit diagrams of both the Western Electric and the RCA Photophone systems are located at the back of the book, in compact form for quick reference.

T. G. Veal
O. Sandvik

Film and School: H. Rand and R. Lewis, *D. Appleton-Century Co.* (New York), 1937, 182 pp.

Courses in photoplay appreciation have been introduced into several American colleges during the past decade. This book has been written, under the sponsorship of the National Council of Teachers of English, as a reference work for such courses. In the preface, it is stated: "We have movie-made children; we are movie-made people; and the movies are already a part of our education. Our task now is to correlate them with other activities offered in the school program."

The book attempts to set up standards whereby the pupil may become better equipped to evaluate the motion picture. Teachers and pupils throughout the country contributed the data from which the book was written. The sections are divided into the following general headings: (*1*) Moving Pictures, a Social and Educational Force; (*2*) How Moving Pictures Interpret Life; (*3*) The People Who Make Moving Pictures; (*4*) Rating Scales, Reviews, and Criticisms; (*5*) Moving Picture Clubs; (*6*) More to Be Done.

There is a comprehensive section on source materials. The book is illustrated with fifty-seven photographs and diagrams relating to moving pictures in production.

G. E. MATTHEWS

International Dictionary of Cinematography: E. Cauda. (English, German, Italian, French; containing 18,000 words and expressions concerning motion picture science, technic, industry, trade, and art, with 400 illustrations.) The appendix contains alphabetical lists of the key words for all the languages, with reference to the main body of the work. In many instances the English is faulty, but in spite of errors and careless proofreading the book will doubtless be extremely useful. Published in Italy: *Stab. Tip. "Leonardo da Vinci,"* Cittá di Castello. 1936.

SOCIETY SUPPLIES

The following are available from the General Office of the Society, at the prices noted. Orders should be accompanied by remittances.

Aims and Accomplishments.—An index of the *Transactions* from October, 1916, to December, 1929, containing summaries of all articles, and author and classified indexes. One dollar each.

Journal Index.—An index of the JOURNAL from January, 1930, to December, 1935. containing author and classified indexes. One dollar each.

SMPE Standards.—The revised edition of the *SMPE Standards and Recommended Practice* was published in the March, 1938, issue of the JOURNAL, copies of which may be obtained for one dollar each.

Membership Certificates.—Engrossed, for framing, containing member's name, grade of membership, and date of admission. One dollar each.

Lapel Buttons.—The insignia of the Society, gold filled, with safety screw back. One dollar each.

Journal Binders.—Black fabrikoid binders, lettered in gold, holding a year's issue of the JOURNAL. Two dollars each. Member's name and the volume number lettered in gold upon the backbone at an additional charge of fifty cents each.

Test-Films.—See advertisement in this issue of the JOURNAL.

OFFICERS AND GOVERNORS OF THE SOCIETY
1938

L. A. JONES
Engineering Vice-President

K. F. MORGAN
Executive Vice-President

J. I. CRABTREE
Editorial Vice-President

S. K. WOLF
President

E. A. WILLIFORD
Financial Vice-President

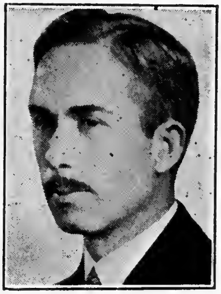
H. G. TASKER
Past-President

W. C. KUNZMANN
Convention Vice-President

J. FRANK, JR.
Secretary

L. W. DAVEE
Treasurer

A. N. GOLDSMITH
Governor



M. C. BATSEL
Governor

A. C. HARDY
Governor

H. GRIFFIN
Governor

R. E. FARNHAM
Governor

G. FRIEDL, JR.
Chairman, Atlantic Coast Section

S. A. LUKES
Chairman, Mid-West Section

J. O. AALBERG
Chairman, Pacific Coast Section

SECTIONS OF THE SOCIETY

(*Atlantic Coast*)

*G. FRIEDL, JR., *Chairman*

L. W. DAVEE, *Past-Chairman*
*D. E. HYNDMAN, *Sec.-Treas.*
*H. GRIFFIN, *Manager*
**P. J. LARSEN, *Manager*

(*Mid-West*)

*S. A. LUKES, *Chairman*

C. H. STONE, *Past-Chairman*
*A. SHAPIRO, *Sec.-Treas.*
*B. E. STECHBART, *Manager*
**G. W. BAKER, *Manager*

(*Pacific Coast*)

*J. O. AALBERG, *Chairman*

K. F. MORGAN, *Past-Chairman*
*G. A. CHAMBERS, *Sec.-Treas.*
*H. W. MOYSE, *Manager*
**C. W. HANDLEY, *Manager*

* Term expires December 31, 1938.
** Term expires December 31, 1939.

COMMITTEES OF THE SOCIETY

(Correct to March 20th; additional appointments or changes may be made at any time during the year, as necessity or expediency may require.)

ADMISSIONS

L. W. Davee, *Chairman*

G. Friedl, Jr.	S. Harris	P. J. Larsen
H. Griffin	D. E. Hyndman	M. W. Palmer

BOARD OF EDITORS

J. I. Crabtree, *Chairman*

A. N. Goldsmith	L. A. Jones	H. G. Knox
A. C. Hardy	E. W. Kellogg	G. E. Matthews

CONVENTION

W. C. Kunzmann, *Chairman*

J. I. Crabtree	O. F. Neu
H. Griffin	S. Harris

EUROPEAN ADVISORY COMMITTEE

J. Van Breukelen, *Chairman*

H. Warncke	F. H. Hotchkiss	I. D. Wratten

EXCHANGE PRACTICE

A. W. Schwalberg, *Chairman*

O. C. Binder	H. C. Kaufman	N. F. Oakley
A. S. Dickinson	J. S. MacLeod	H. Rubin
G. K. Haddow	H. A. Mersay	J. H. Spray

HISTORICAL

E. Theisen, *Chairman*

J. E. Abbott	G. A. Chambers	G. E. Matthews
T. Armat	W. Clark	T. Ramsaye

MUSEUM

(Western)

E. Theisen, *Chairman*

O. B. Depue	J. A. Dubray	A. Reeves

LABORATORY PRACTICE

D. E. Hyndman, *Chairman*

J. O. Baker	E. Huse	J. M. Nickolaus
L. A. Bonn	P. J. Larsen	H. W. Remerschied
R. M. Evans	C. L. Lootens	W. A. Schmidt
G. H. Gibson	R. F. Mitchell	J. H. Spray
T. M. Ingman	H. W. Moyse	M. Townsley

NON-THEATRICAL EQUIPMENT

R. C. HOLSLAG, *Chairman*

D. P. BEAN
F. E. CARLSON
W. B. COOK
H. A. DEVRY
E. C. FRITTS
H. GRIFFIN
J. A. HAMMOND
L. B. HOFFMAN
J. H. KURLANDER
J. A. MAURER
R. F. MITCHELL
A. SHAPIRO
B. YAGER

PAPERS

G. E. MATTHEWS, *Chairman*

P. ARNOLD
L. N. BUSCH
A. A. COOK
L. J. J. DIDIEE
C. FLANNAGAN
E. W. KELLOGG
R. F. MITCHELL
F. H. RICHARDSON
P. R. VON SCHROTT
C. K. WILSON
I. D. WRATTEN

(*West Coast*)

L. A. AICHOLTZ, *Chairman*

C. N. BATSEL
O. O. CECCARINI
L. D. GRIGNON
W. A. MUELLER
H. C. SILENT
H. G. TASKER

PRESERVATION OF FILM

J. G. BRADLEY, *Chairman*

J. E. ABBOTT
J. I. CRABTREE
A. S. DICKINSON
R. EVANS
M. E. GILLETTE
C. L. GREGORY
T. RAMSAYE
W. A. SCHMIDT
V. B. SEASE

PROGRESS

J. G. FRAYNE, *Chairman*

W. H. BAHLER
L. N. BUSCH
G. A. CHAMBERS
R. E. FARNHAM
F. L. HOPPER
H. G. HUMPHREY
W. LEAHY
G. E. MATTHEWS
V. E. MILLER
G. H. WORRALL

PROGRESS AWARD

A. N. GOLDSMITH, *Chairman*

J. I. CRABTREE
A. C. HARDY
W. B. RAYTON
S. K. WOLF

PROJECTION PRACTICE

H. RUBIN, *Chairman*

T. C. BARROWS
F. E. CAHILL
J. R. CAMERON
A. A. COOK
C. C. DASH
J. K. ELDERKIN
J. J. FINN
R. R. FRENCH
E. R. GEIB
A. N. GOLDSMITH
A. GOODMAN
H. GRIFFIN
S. HARRIS
J. J. HOPKINS
C. F. HORSTMAN
D. E. HYNDMAN
J. J. KOHLER
P. A. MCGUIRE
E. R. MORIN
M. D. O'BRIEN
G. F. RACKETT
F. H. RICHARDSON
B. SCHLANGER
C. M. TUTTLE
J. S. WARD
V. A. WELMAN
A. T. WILLIAMS

MEMBERSHIP AND SUBSCRIPTION

E. R. GEIB, *Chairman*

Alabama
P. A. KING

California
J. O. AALBERG
C. W. HANDLEY
E. HUSE
R. H. McCULLOUGH
G. A. MITCHELL
P. MOLE
K. F. MORGAN
W. A. MUELLER
H. G. TASKER

Georgia
N. WEIL

Illinois
H. A. DEVRY
B. J. KLEERUP
S. A. LUKES
C. G. OLLINGER
J. M. SCHAEFER
J. H. TOLER

Massachusetts
J. S. CIFRE
S. SUMNER
A. B. WEST

Australia
H. C. PARRISH

Austria
P. R. VON SCHROTT

Canada
F. C. BADGLEY
G. H. BATTLE
C. A. DENTELBECK
B. E. NORRISH

China
R. E. O'BOLGER

Michigan
J. F. STRICKLER

Minnesota
C. L. GREENE
R. H. RAY

Missouri
J. S. COPLEY

New York
A. BECKER
F. E. CAHILL
A. A. COOK
A. S. DICKINSON
J. J. FINN
J. FRANK, JR.
S. HARRIS
D. E. HYNDMAN
W. H. INGRAM
O. E. MILLER
F. H. RICHARDSON
P. D. RIES
C. J. STAUD
L. M. TOWNSEND
J. S. WARD

England
W. F. GARLING
R. G. LINDERMAN
E. McMASTER
R. TERRANEAU

France
L. J. J. DIDIEE
L. G. EGROT
F. H. HOTCHKISS

Germany
W. F. BIELICKE

Ohio
C. C. DASH
R. H. GILES
V. C. WELMAN

Pennsylvania
H. BLOOMBERG
A. GOODMAN
I. SAMUELS

Texas
H. H. FRASCH

District of Columbia
H. T. COWLING
R. EVANS
N. D. GOLDEN
F. J. STORTY

Travelling
E. AUGER
C. BRENKERT
F. HOHMEISTER
W. C. KUNZMANN
D. McRAE
O. F. NEU
H. H. STRONG

Hawaii
L. LA CHAPELLE

Holland
J. VAN BREUKELEN

India
G. D. LAL
H. S. MEHTA

Japan
T. NAGASE
Y. OWAWA

New Zealand
C. BANKS

PUBLICITY

W. WHITMORE, *Chairman*

J. J. FINN
J. R. CAMERON
W. GREENE
S. HARRIS
P. A. MCGUIRE
G. E. MATTHEWS
F. H. RICHARDSON

STANDARDS

E. K. CARVER, *Chairman*

P. H. ARNOLD
F. C. BADGLEY
M. C. BATSEL
L. N. BUSCH
A. COTTET
L. W. DAVEE
A. C. DOWNES
J. A. DUBRAY
P. H. EVANS
R. E. FARNHAM
C. L. FARRAND
G. FRIEDL, JR.
H. N. GRIFFIN
A. C. HARDY
L. B. HOFFMAN
R. C. HUBBARD
E. HUSE
C. L. LOOTENS
K. F. MORGAN
T. NAGASE
N. F. OAKLEY
G. F. RACKETT
W. B. RAYTON
C. N. REIFSTECK
H. RUBIN
O. SANDVIK
J. L. SPENCE
J. VAN BREUKELEN
I. D. WRATTEN

STUDIO LIGHTING

C. W. HANDLEY, *Chairman*

R. E. FARNHAM
W. C. KUNZMANN
J. H. KURLANDER
V. E. MILLER
M.W. PALMER
G. F. RACKETT
E. C. RICHARDSON
F. WALLER

TELEVISION

A. N. GOLDSMITH, *Chairman*

M. C. BATSEL
R. R. BEAL
A. S. DICKINSON
C. DREHER
P. T. FARNSWORTH
J. FRANK, JR.
N. D. GOLDEN
P. C. GOLDMARK
H. GRIFFIN
O. B. HANSON
H. R. LUBCKE
L. A. MCNABB
R. F. MITCHELL
A. MURPHY
A. F. MURRAY
V. B. SEASE
J. L. SPENCE
O. SANDVIK
G. H. WORRALL

SECTIONS OF THE SOCIETY

(*Atlantic Coast*)

*G. FRIEDL, JR., *Chairman*

L. W. DAVEE, *Past-Chairman*
*D. E. HYNDMAN, *Sec.-Treas.*
*H. GRIFFIN, *Manager*
**P. J. LARSEN, *Manager*

(*Mid-West*)

*S. A. LUKES, *Chairman*

C. H. STONE, *Past-Chairman*
*A. SHAPIRO, *Sec.-Treas.*
*B. E. STECHBART, *Manager*
**G. W. BAKER, *Manager*

(*Pacific Coast*)

*J. O. AALBERG, *Chairman*

K. F. MORGAN, *Past-Chairman*
*G. A. CHAMBERS, *Sec.-Treas.*
*H. W. MOYSE, *Manager*
**C. W. HANDLEY, *Manager*

---

* Term expires December 31, 1938.
** Term expires December 31, 1939.

SECTIONAL COMMITTEE ON MOTION PICTURES

(*American Standards Association*)

A. N. GOLDSMITH, *Chairman*

P. H. ARNOLD
M. C. BATSEL
F. G. BEACH
E. K. CARVER
W. CLARK
A. S. DICKINSON
J. A. DUBRAY
E. W. ELY
R. E. FARNHAM
C. FLANNAGAN
J. G. T. GILMOUR
H. GRIFFIN
A. C. HARDY
F. L. HERRON
F. I. HUNT
L. A. JONES
D. B. JOY
G. A. MITCHELL
G. S. MITCHELL
O. F. NEU
J. M. NICHOLAUS
N. F. OAKLEY
D. PALFREYMAN
J. E. ROBIN
A. R. SMALL
J. L. SPENCE
J. H. SPRAY
H. G. TASKER
G. H. WORRAL

SOCIETY ANNOUNCEMENTS

WASHINGTON CONVENTION

As the Convention will barely have ended by the time this issue of the JOURNAL is distributed, it will not be possible to include any of the details of the Convention. However, the next issue will contain a description of the highlights of the Convention and the final program as followed at the sessions.

The tentative program and abstracts of nearly all the papers scheduled were published in the April issue. A few additional abstracts are published in the following pages.

ADMISSIONS COMMITTEE

At a recent meeting of the Admissions Committee, at the General Office of the Society, the following applicants for membership were admitted to the Associate grade:

BLACKFORD, B.
845 Arnett Blvd.,
Rochester, N. Y.

CONNER, W.
219 N. Broad St.,
Philadelphia, Penna.

CUTHBERT, G.
104 Bond St.,
Toronto, Ontario, Canada.

DEGRUMMOND, L. M.
4738 Tobias Ave.,
Van Nuys, Calif.

DUPUY, F.
2 Avenue Victor Hugo,
St. Mande (Seine), France.

FRANCISCI, B.
A. Cerasi,
19, Rome, Italy.

GOPAL, K.
10 Cantonment Rd.,
Lucknow, India.

HALL, R. D.
35 W. 96th St.,
New York, N. Y.

HOPFENBERG, J. A.
729 Seventh Ave.,
New York, N. Y.

HURLEY, F.
"Stoneherge,"
Bay View Hill Rd.,
Rose Bay, Sydney, Australia.

LAWRENCE, J.
278 Alexander St.,
Rochester, N. Y.

LYCETT, E. A.
3851 Edenhurst Ave.,
Los Angeles, Calif.

MARSTEN, F. R.
2131 "O" St., N. W.,
Washington, D. C.

McGHAN, E. W.
721 E. 17th South St.,
Salt Lake City, Utah.

NAFASH, W. G.
624—47th St.,
Brooklyn, N. Y.

POPE, L. E.
3706 Broadway,
Kansas City, Mo.

SCHAEFFER, E. J.
3632 N. Ashland Ave.,
Chicago, Ill.

SEFING, J. J.
National Theatre Supply Co.,
1560 Broadway,
New York, N. Y.

STEINBERG, J.
1497 Carroll St.,
Brooklyn, N. Y.

STEVENSON, M. H.
Radio ZUE, Sydney Pty. Ltd.,
29 Bligh St.,
Sydney, Australia.

TURNBULL, W. J.
18037 Pelkey St.,
Detroit, Mich.

VANVOLLENHOVEN, L.
34 Hillside Ave.,
New York, N. Y.

WAXLER, B.
1643 Clay Ave.,
Bronx, N. Y.

WEISS, J.
1746 Andrews Ave.,
Bronx, N. Y.

WICKINS, L. W.
8 Earl St., Randwick,
N. S. W., Australia.

WILSCHKE, E. O.
929 E. Dorset St.,
Philadelphia, Penna.

In addition, the following applicants have been admitted by vote of the Board of Governors to the Active grade:

AICHOLTZ, L. A.
Universal Studios,
Universal City, Calif.

GRIGNON, L. D.
5451 Marithon St.,
Hollywood, Calif.

SCHAEFER, C. L.
22 Vincent St.,
Binghamton, N. Y.

ABSTRACTS OF PAPERS FOR THE WASHINGTON MEETING

The following abstracts were received too late for inclusion in the April Journal and are published here for reference purposes:

"The Fundamentals of Color Measurement"; D. L. MacAdam, *Kodak Research Laboratories*, Rochester, N. Y.

The modern science of color measurement had its origin in the researches of Helmholtz, Maxwell, and Grassmann in the years from 1852 to 1855. This science found no important practical application until the opening of the twentieth century when the (F.E.) Ives colorimeter was applied to the measurement and specification of the colors of practical illuminants. In 1922 the Optical Society of America, through its Committee on Colorimetry, recommended data and technics for color measurement which were immediately adopted throughout the world, replacing numerous unrelated, and often inconsistent, technics that had been developed to meet the insistent demands of various industries for color specifications. A set of data based upon the most recent researches was recommended by the International Commission on Illumination in 1931, and these more satisfactory data have in turn replaced the data and extended the unification of methods which originated with the O.S.A. Report of 1922.

Standard I.C.I. color specifications can be computed from spectrophotometric data. The fundamental relations that are used to define the quantities in terms of which colors are specified are most concisely expressed in mathematical formulas, which will be simply explained. As a matter of fact, short cuts based upon the standard I.C.I. 1931 data have been developed in the past few years so that no acquaintance with any mathematics other than ordinary arithmetic is now necessary for the performance of any of the essential operations encountered in standard color measurement. A typical example will be exhibited, and the interpretation of the results in terms of the dominant wavelength, purity, and brightness will be made clear by use of the chromaticity diagram. The conditions required in order that the colors of two samples shall match under some definite illuminant are that the three quantities in terms of which the colors are specified must be the same for the two samples.

"New Background Projector for Process Cinematography"; G. H. Worrall, *Mitchell Camera Corp.*, Hollywood, Calif.

A new type of background projection apparatus has been developed for use in process work. This apparatus has been developed around the Mitchell sound movement or film-advancing mechanism used in the Mitchell sound type camera; so that the same type of mechanism that exposed the picture may now be used for projection in process work. The projector was developed with two things in mind, namely, freedom from maintenance due to heat spilled around the aperture, and reducing the noise as much as possible so as to eliminate booths.

"A Consideration of the Screen-Brightness Problem"; O. Reeb, *Osram, G.m.b.H.*, Berlin, Germany.

The great interest that the problem of optimal screen brightness holds in motion picture engineering is proved by the numerous researches on the subject in recent years. Besides the very interesting American papers published in this JOURNAL, some recent German works are worthy of consideration.

In 1936, K. F. Zimmermann published a paper entitled, "Technical Investigation of Picture Projection." He determined the dependence of the visual effect upon the screen brightness and found that a maximum value is attained at about 14 foot-lamberts. He investigated also the influence of light distribution, and the influence of a temporary brightness change. Finally he pointed out that the time that the eye needs to see all recognizable contrasts varies, according to the brightness level, between $^1/_3$ and $^1/_{10}$ second.

In 1936, J. Rieck published a paper that verified, under conditions similar to those in cinema theaters, the character of the contrast-sensibility relation that Brodhun and König had found in their classical research.

Very recently H. Frieser and W. Münch reported results obtained by projecting a detail test-object. They determined the contrast threshold function under conditions very similar to those of actual projection. They did not find a material increase in the number of distinguishable contrast steps for picture brightnesses exceeding 10 foot-lamberts.

It is to be hoped that the consideration of the results of all these investigations will form a basis for early temporary screen-brightness standardization.

"Wide-Screen Projection at the 1937 Paris International Exposition"; H. Griffin, *International Projector Corp.*, New York, N. Y.

The development of the "Hypergonar" lens in 1927 by Chretien, of the University and Optical Institute of Paris, introduced a device whereby the field of an objective may be doubled in one direction only. This lens was incorporated in the projection equipment used at the Palace of Light of the 1937 Paris International Exposition. The panoramic screen had an area of 600 square meters, and was 60 meters long and 10 meters high. It was built up with a mixture of lime and sand as a base, then covered with an insulating varnish, six layers of zinc white, and, finally, with an adhesive varnish upon which small spherical glass beads were sprayed with an air-gun. The screen was curved slightly and faced an outdoor auditorium, seating 4000 persons.

Two Simplex projectors fitted with special lenses and the Chretien device and each showing one-half of the picture were operated synchronously by a third projector placed between them. The third projector also carried a sound-film record. Each projector was equipped with a 250-amp. arc (70 volts) and a fixed-focus (120 mm.) $f/2$ objective. A special 110-volt 800-amp. generator was used.

The films were made with two cameras, each equipped with the special Chretien optical device and operated by a synchronous motor. One-half of the scene was photographed with each camera.

"Photographic Effects in the Feature Production 'Topper' "; R. W. Seawright and W. V. Draper, *Hal Roach Studios, Inc.*, Culver City, Calif.

An account is given of the various types of photography used in the feature production *Topper*. Among the shots discussed are a split screen against a projected background, demonstrating the feasibility of such treatment. Other effects are: Multiple exposures, animated split screen, animated travelling matts, straight animation, intricate matching of action, and a new process of subtractive matting.

A statement is included on the precautions taken to eliminate weave between the production shots taken with Mitchell cameras and the duping, which was done on Bell & Howell machines. The paper is illustrated with various selections from the picture, made by the processes described.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXX **JUNE, 1938** **Number 6**

CONTENTS

JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

Subscription to non-members, $8.00 per annum; to members, $5.00 per annum, included in their annual membership dues; single copies, $1.00. A discount on subscriptions or single copies of 15 per cent is allowed to accredited agencies. Order from the Society of Motion Picture Engineers, Inc., 20th and Northampton Sts., Easton, Pa., or Hotel Pennsylvania, New York, N. Y.

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

Publication Office, 20th & Northampton Sts., Easton, Pa.

General and Editorial Office, Hotel Pennsylvania, New York, N. Y.

West-Coast Office, Suite 226, Equitable Bldg., Hollywood, Calif.

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

PROCEEDINGS OF THE SOCIETY LUNCHEON AT THE SPRING CONVENTION

WARDMAN PARK HOTEL, WASHINGTON, D. C.
APRIL 25, 1938

Summary.—*A description of the proceedings of the informal luncheon held on the opening day (April 25, 1938) of the Spring Convention at Washington, D. C.; including remarks by Col. Daniel I. Sultan, Engineer Commissioner for the District of Columbia; Honorable Clarence F. Lea, Member of Congress from California; and Honorable Daniel C. Roper, Secretary of Commerce.*

Approximately two hundred members, guests, and friends of the Society gathered together at the informal luncheon held on the opening day of the Spring, 1938, Convention at Washington, D. C., on April 25th, held at the Wardman Park Hotel.

Seated at the Speakers' table, in addition to President Wolf and other officers of the Society, were the Honorable Daniel C. Roper, U. S. Secretary of Commerce; the Honorable Clarence F. Lea, Congressman from California; and Colonel Daniel I. Sultan, Engineer Commissioner for the District of Columbia. Opening the proceedings, President Wolf spoke as follows:

President Wolf: Ladies and gentlemen, members of the Society and guests:

On behalf of the Board of Governors and the Committees that made this Convention possible, I wish to welcome you here. I shall first introduce several of our present and past officers who are seated here at the Speakers' table, with the exception of those whom I shall introduce later and who will speak to you.

President Wolf introduced to the members Mr. J. I. Crabtree, *Editorial Vice-President;* Dr. J. G. Frayne; Mr. E. C. Richardson; Mr. E. A. Williford, *Financial Vice-President;* Mr. J. Frank, Jr., *Secretary;* Mr. A. S. Dickinson, past member of the Board; Dr. Alfred N. Goldsmith, a present member of the Board; and Mr. G. Friedl, Jr., Chairman of the Atlantic Coast Section and a member of the Board of Governors. President Wolf continued as follows:

PRESIDENT WOLF: It is very fitting that we should come to Washington occasionally. We met here in October, 1935. Since that time the interest in and the need for motion pictures has grown tremendously in the City of Washington, particularly in the government agencies. All the old-line agencies have departments either producing or exhibiting motion pictures. In fact, if I were armed with the proper figures I might even go so far as to say that there is more film here than there is in Hollywood.

Another very interesting thing about this meeting is that we have, by one hundred per cent, a larger contingent of ladies than ever before. There are more than seventy-five ladies here, which might indicate that the White House has much greater drawing power than Hollywood.

Ladies and gentlemen, we have three guests who have come here to speak to us today. The first on the program will welcome us to Washington. He is the man who is responsible for the maintenance of this beautiful city, which perhaps some of you have already had a chance to see. He is Colonel Daniel I. Sultan, Commissioner of Engineering for the District of Columbia. Colonel Sultan!

COLONEL SULTAN: Mr. Chairman, Mr. Secretary, Ladies and Gentlemen:

You make one mistake when your Chairman says you occasionally come to Washington. We do not have New York, which is New York after all, and there is only one such place in the world. We do not have Hollywood. But as one of the administrative heads of the City of Washington I will admit to no one that there is any city in the world that can compare to our national capital as a place to visit. I shall not mention the Bureau of Standards and all the technical things we have to offer you, but certainly when it comes to a beautiful city, Washington will bow to no one!

I hope that you will find time away from the technical discussions that fill your program to visit some of these places—some of our shrines, which are sources of inspiration to anyone who will come and find the opportunity to see them; the home of Washington; the Tomb of the Unknown Soldier, and many others that every citizen of the United States should visit at least once a year.

We hope that you will come back, and that your present stay will be a happy, a pleasant one. If there is anything the District Government can do to make your Convention more successful I hope you will let us know. We are delighted to have you with us!

PRESIDENT WOLF: Thank you, Colonel Sultan! Our next speaker is a native son. We are very fortunate in having the senior representative from the State of California to address us. He mentioned to me this morning something I have rarely heard a Californian admit, that the weather here in Washington was today, at least, as good as he gets in California.

Representative Lea is Chairman of the Interstate Commerce Committee, and for that reason it is most appropriate that he should speak to us. It is my great pleasure to present to you the Honorable Clarence F. Lea, member of Congress, from California!

CONGRESSMAN LEA: Mr. Chairman, Ladies and Gentlemen: I regret that Senator McAdoo, who was originally invited to take the place that I occupy on your program, is not here today. The Senator asked that I express his regrets at being unable to be with you. So to a degree I am a pinch-hitter for Senator McAdoo.

I am reminded of an incident that occurred some years ago. A very celebrated man in a high federal position resigned, and another distinguished man, who, however, lacked the great standing of the former man, was finally appointed by the President to occupy the position. Will Rogers commented that the President had decided not to fill the place resigned by the former official, but merely to appoint another man to sit in the chair: that is what I am doing here at this time for Senator McAdoo.

I know little about your industry, and especially the technical phases of it: if I were a student of the industry I would have to be assigned to the primary class. Yet I have the interest in your industry that is common to all Americans. I have great admiration for the engineers who are so largely responsible for the marvelous accomplishments of the picture industry of the United States, which leads the world. If I could give credit where it was due, I should teach America to appreciate and perhaps acclaim some of the members of your Society with that degree that is accorded to some of the most popular stars upon the screen.

You engineers have implemented the industry. You have provided the transmission of the voice and the picture that has made the industry grow and become marvelous in America. Without your work it would have been a vain effort. I recognize that it is not the publicity end that you serve. You are more like the necessary stoker who fueled the battleship down at Cuba many years ago when it went to its successful victory for America. You do the job, a hard, exacting job, yet of fundamental importance.

Even though you may not gain the place in popular acclaim that the screen star does, I hope that your reputation, based upon your good works, is sufficient to carry over to the man who has charge of the purse that rewards you.

We in public life learn, as the years go by, something of the proper appraisement of public acclaim. There is one great example that American people might always well remember: After Washington's great triumph, when he was elected President of the United States, he went to New York to be inaugurated. Every sign of the affection and confidence of the American people, all they were able to indicate at the time, was bestowed upon him. The harbor was full of ships; every noise-maker was made use of; and every banner and everything the people could do to bestow their praise was manifested.

Someone spoke to Washington and mentioned how happy and proud he should be of the great display of affection of the people. Washington, with a solemn face, turned to the man who spoke to him and said, "Even at this moment I realize the time may come, and perhaps shortly, when the performance of my duty will turn their hurrahs into condemnation." Every man in public life learns to know that that is true.

So in your profession, as in that of us who are in public life, the true hope that we can have, the satisfaction that we may attain, is not going to be in the acclaim but rather in the consciousness of having done a useful service to our country. If we can accomplish that, the effort is a success.

There is a rather remarkable fact of your industry, and that is that it has two great centers of activity: one out on the West Coast and another three thousand miles away at New York; and, as your President reminded us here today, a new activity in the Government. But forgetting the last, we can remember the east and the west centers of this industry; out there, until recently, primarily production; and here in the East, primarily invention and development, particularly of the mechanical phases of the industry. It was said a long time ago that the three wise men came from the East. It has been said that they went west because they were wise. But we in the West must admit that the three men, so far as they were concerned, became wise before they went west.

It is a marvelous activity that your industry is engaged in. Its possible influence upon the future of this country is great. I often try to contemplate what will be the ultimate result of it, its educational effects, the development of an appreciation of better art in all lines, in the elimination of class prejudices and provincial ideas through the nation, in the unification of the nation that will finally contribute to its strength and solidarity. All those things are within the direct influence of your industry.

I remember *The Covered Wagon*, a good many years ago. It made a great impression upon me. My father was one of those pioneers who in 1851 crossed the plains on a covered-wagon trip of six months. And I had known of that, of course, all my life, but I never had a true appreciation of what my father had done until I saw *The Covered Wagon* upon the screen. That story, presented to the people of America, created impressions beyond what the most able author in all the world would be able to create. A comparatively unknown or forgotten phase of American history was brought out of its obscurity, and the covered-wagon story, portraying those heroic features of American frontier life, has become a common tradition and a common inspiration, and a matter for all time.

I am happy to be here today. I hope your Convention will be a most successful one, and I take pleasure in commending your activity and your tremendous contribution to the happiness, the entertainment, and the education of the American people.

PRESIDENT WOLF: Thank you, Mr. Lea. We are particularly fortunate in having also upon our program today a man who has a most profound appreciation of the problems that confront our industry, a man who has jurisdiction over the phases of the Government with which all engineers sooner or later come into contact. He has also been of inestimable value to our President in the administration of governmental affairs during recent years. It is a great pleasure for me to present to you the Honorable Daniel C. Roper, Secretary of the U. S. Department of Commerce.

SECRETARY ROPER: Mr. President, Ladies and Gentlemen: I should like to emphasize what Congressman Lea has said with regard to the opportunities and services that your organization is contributing toward the solidarity of our national thinking, for greater consciousness of the need of solidarity for our country and for the world.

I grew up in South Carolina at a time when sectionalism was very much in evidence. I used to think in my boyhood days that sectionalism meant differences between the North and the South. But later, I discovered that there was a good deal of sectionalism between North and South Carolina.

We were greatly disturbed at that time over whether Andrew Jackson was born in North or South Carolina. There was appointed by the two States an engineering group to run the line between the States. In that zigzag section of the State line known as the Waxhaw settlement, the engineers were shifting their instrument from one direction to another when an old woman came out from a cabin and said, "Why are you pointing that gun at my house?"

They assured her that they were not using a gun but a surveying instrument, to find out whether she lived in North or in South Carolina. She asked, "Do you suppose I would live in South Carolina?"

"Well," they said, "you may know where you live, but all persons do not know, and we are going to find out."

Unfortunately, when the line was established it put the old lady's house immediately over in my State of South Carolina. She went into hysterics, and this is the way they tried to console her:

"My dear woman, we are not going to move your house; we are not going to change your neighbors. You will have the same home, the same neighbors, the same water to drink, the same air to breathe. The only difference is that hereafter, when people ask you where you live, you will have to say that you live in South Carolina."

"And that's what I dread," said the old lady, "for I have always heard that South Carolina was a monstrous unhealthy state."

Your organization is one of those great groups of civilizing agencies that are bringing us into a common conception of a solid country, of a solid nation, impressing the fact that no section of the country can suffer without other sections suffering, and if you would have a great and prosperous nation you must see to it, so far as possible, that all sections of the nation prosper. Your motion picture industry is therefore one of our greatest educational agencies, and it is with regard to that that I wish to speak.

I have just come from a conference at my desk with a very interesting gentleman who wishes to develop trade relations between his nation and this nation. I said to him, "Do you know that the greatest thing that you can do for your nation and for this nation is to make sure that as much space is given in your newspapers to the constructive things in the United States as you now give to crime and to destructive things? If you will endeavor to find the assets of the United States and other countries, both material and human, you will be amazed at how rapidly we understand each other, how much we have in common, how necessary it is to find out, not how we can take advantage of each other, but how we can coöperate in helping each other to live."

That is a great service opportunity in the picture industry. Congratulations on the method of coöperative approach, therefore; to the treatment of problems affecting your industry directly, as well as the opportunity of promoting the welfare of your industry through constantly improving public service.

In these times of rapid communication, when barriers of distance have been practically eliminated, there is a general awakening to the need of adjustment to changed conditions. No nation can now safely isolate itself from our closely interwoven world, however much it may be inclined to live within and unto itself. A corollary of this interdependence is the responsibility on the part of such leaders as you have to make this relationship an opportunity not only for the highest possible technological development, but for the cultivation of better understanding and thus to effect a coöperative attitude, one toward the other.

A gentleman of a foreign nation came to see me a few days ago and said to me, "What would you suggest that my nation bring to the World's Fairs at New York and San Francisco?"

I knew he was thinking in terms of items of trade, and knew I did not have to impress that upon his mind. Therefore, I said, "Bring the spirit of your nation. See to it that that is represented, and you will have contributed to an understanding far beyond some articles of trade, because it will be found that there is a golden thread running through all the communities of civilization that we can well appreciate and understand."

The motion picture industry occupies a peculiarly strategic position for making major educational contributions, therefore, at a time when truthful knowledge of conditions, purposes, and plans is vital to the civility in all our international relations. The motion picture reaches more people than any other educational agency, transcends international boundaries, and through the technic of photography speaks a universal language. It has creditably met the test of public expectations in the past, but must initiate an even more fundamental service in the future if it would successfully coördinate the facilities with others in the mutual objective of reinforcing the foundations of civilized society.

Nations are justified in cultivating their own respective ideals and ideologies; yet all have a common rallying point, a common golden thread in the endeavor to promote safe and peaceful progress for themselves and for the world. This international ideal finds its best expression in the philosophy of good neighborliness which implies respect for the rights of others and coöperation through a high appreciation that comes only through an understanding of each other.

We have spent too much time in high-powered salesmanship. We need to reverse the process and to study other nations, what they need to develop their civilization, and to work out plans to help them develop their programs of life rather than all the time trying to sell them our civilization. In the interest of trade alone we should not try to make all civilizations the same.

It is an interesting and significant corollary that the growth and influence of the Society of Motion Picture Engineers has been comparable with that of the motion picture industry itself. The two phases represented by art and science have advanced coöperatively and concurrently. Certainly the patient research of such world-renowned scientists as Edison, Eastman, and others, living and dead, has been the underlying factor in the development of facilities for motion picture entertainment; but for the marvelous inventions that have been made and are constantly being improved the modern theater would not have been possible.

Inventive genius has likewise made universal distribution possible, so that a film on exhibition in Washington today is available virtually simultaneously to the people of all lands and climes. What difference, ladies and gentlemen, does it make whether Hollywood is in Washington or Washington in Hollywood? I listened last night to a program that I thought was coming from Washington, but which later discovered was coming from Hollywood. We are all one community through these processes of education, the radio and the moving picture.

Not only has the inventor provided the foundation upon which a great motion picture industry rests, but he is constantly re-searching for refinements to keep that structure up to date. The Department of Commerce is interested in promoting the success of the industry, and recognizes that progress is dependent in a large way upon technical and scientific achievement. That means that the industry can not be static. Under the impacts of research and in response to the demands of the public for improvements, the changes that we may anticipate for the future are certain to eclipse the marvelous developments of the past.

The problem, as I see it as Secretary of Commerce, in trying to work with and for you, as your trustee here, is to determine how far the Federal Government can go in helping, without injuring, your initiative. Keep that in mind. What we want to do is to help industry to help itself, and not take away from industry any of its initiative and any of the work that it can best do for itself.

The advent of sound pictures less than twelve years ago was considered revolutionary at the time; yet it is the accepted and universally approved type today, with the result that there is little demand for the silent film. It is interesting to note that the plans for the future of the industry do not primarily involve new and different methods of sales and merchandising so much as new uses, color, television, and other developments that lie in the field of science.

However, that does not mean that major emphasis should be placed upon technology. For example, it is recognized that as an instrumentality for publicizing the mutual ideas, ideals, and customs the motion picture is playing a most important role. The reflection through film of the standard of living and the ideals of the people of the United States, their manner of life and their environment, inevitably creates impressions that have potentialities for good as well as for evil. If we can not maintain high standards, certainly industry and society will suffer beyond any description that I could give you. Much depends upon the moral uplift and the moral standards of tomorrow.

It has been said that trade follows the films, and it is also true that no other major industry in the United States depends upon foreign markets to a greater degree than the film industry. With a large percentage of your gross revenue coming from abroad, producers are not only enhancing their own economic welfare through the growing popularity of American pictures in foreign countries, but an important derivative influence, in the form of the silent salesman, is the creation of demands for other typically American commodities that the pictures themselves portray in the way of stage settings. So, in enlarging its own markets the film industry is a factor in promoting the foreign trade in general through the incidental focusing of attention upon the American standard of living. Thus we can provide and promote the standard of living of other countries, upon which to a very great extent our own standard in the future must rest.

The Department of Commerce, through its Motion Picture Division, headed by Mr. N. D. Golden, is trying to coöperate effectively with the industry toward extending the use of the American motion picture film. Constant studies are being made of film conditions abroad, and this information is made available to the industry and to all who are interested through personal contacts and through publications. Likewise, important domestic data are compiled by the Bureau of the Census of the Department of Commerce, and you are already acquainted, of course, with the National Bureau of Standards, as well as our United States Patent Office. These service units not only encourage inventors and protect their discoveries, but they pursue research that is helpful in pointing the way to improvement in scientific standards.

However, research within the industry must be continued. The government should never go so far as to deaden your initiative in that direction. The greatest asset in American life today is the American initiative in thought and action. The motion picture must meet an increasing number of types of competition for the consumer dollar, and the consumer is himself becoming quite discriminate. He expects the best that science and art can produce, and thus in large measure is the final decider, the arbiter, of what that standard must be. Therefore you have the double function of raising the conceptions and the standards of life to higher planes, and at the same time, of course, of financing your own operations. We recognize that as one of the great engineering problems of the immediate future.

The profit motive needs to be subordinated, therefore, to public service if, indeed, we would preserve the profit motive. This approach will prove to be the more satisfactory to all concerned because without it your profit motive will be embarrassed. Ours and other nations have a right to expect that the best and not the worst will be emphasized in the picture. The motion picture needs to be a forceful purveyor of truth. I think that is the lesson. It needs to be a forceful and effective purveyor of truth!

If I had my way I would make sure that no program, whether it be radio or motion picture, should be given to the world that speaks evil of any nation. Endeavors must be made to convey the truth and to uphold ideals when those ideals are of common consent, and in that way create the good will of all. The picture needs to be a faithful ambassador, therefore, of good will. It needs to be a physician, to heal ills through correct diagnosis of domestic and international human relations. It is the eye, the ear, the mouthpiece for all peoples, and my faith is that producers in your line sense their great responsibilities to society in that respect, and that their position of leadership in this great and growing American industry will be maintained and enlarged, not only in the interest of the industry itself but in the interest of bringing all sections of our country to understand that no sectionalism will be permitted and that the whole world will be brought to a better understanding and greater coöperation, to safeguard against war and unrest.

I thank you!

PRESIDENT WOLF: Thank you, Mr. Secretary, for your generous and thorough appraisal of our industry and our own efforts. We will be inspired by your very excellent words.

REPORT OF THE PROJECTION PRACTICE COMMITTEE*

Summary.—*For some months the Projection Practice Committee has been conducting a survey of motion picture theaters for the purpose of determining the existing conditions under which motion pictures are presented. The following report summarizes the data obtained from the survey and presents them in the form of charts showing the ratios of viewing distance to screen width, seating length to seating width, and seating width to screen width. Other charts show the distance from the floor to the bottom of the screen, the angle of projection, screen width, and arc current.*

The survey covers approximately 600 theaters, and is shown to be fairly representative of the entire industry by reason of the fact that index figures calculated from the survey for only 400 theaters did not change when the number of theaters increased to 600.

The data presented are to form the basis of an analysis leading to the determination of criteria for proper motion picture theater design.

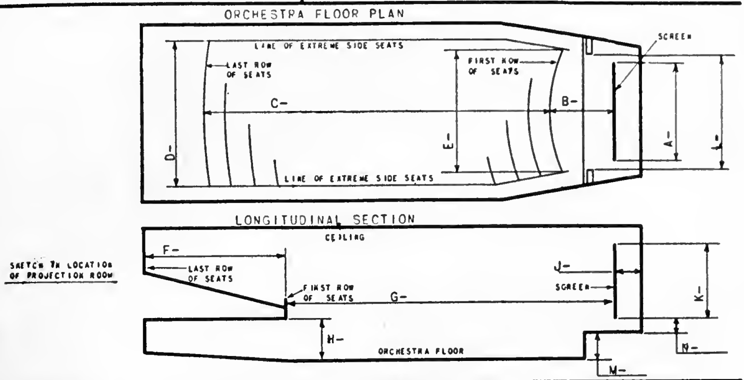
For convenience in conducting the studies on the many projects engaging the attention of the Projection Practice Committee, several sub-committees have been formed which have been working very vigorously on their respective problems throughout the year. However, in view of the pressing need for reliable information on theater structures, that part of the work was pressed forward with all speed so as to be able to report on it at this time.

Another important job that the Committee is doing resulted from a request by the National Fire Protection Association to study the "Regulations for Nitrocellulose Motion Picture Film," with the view of presenting to the NFPA any recommendations for changes that the Committee might deem advisable. Accordingly, the Sub-Committee on Fire Hazards has completely revised all the NFPA regulations referring to projection rooms, and has the material in shape for presentation to the NFPA Committee on Hazardous Chemicals and Explosives at the meeting to be held at Atlantic City the latter part of May. The latter Committee will probably take several months to consider the recommendations, after which time it is expected that the proposed regulations may be presented to the Society, probably as a joint report of the SMPE Projection Practice Committee and the NFPA Committee on Hazardous Chemicals and

* Presented at the Spring, 1938, Meeting at Washington, D. C.; received April 8, 1938.

SOCIETY OF MOTION PICTURE ENGINEERS
Hotel Pennsylvania New York City

S U R V E Y OF MOTION PICTURE THEATRE STRUCTURES	Please fill in all questions listed below and return this sheet to representative of the society or enclose same in postage paid addressed envelope provided.



Question No. 1.
Mark on above diagrams, dimensions A,B,C,D,E,F G,H,J,K,L,M,N.
Dimension A should be White Picture WIDTH.
Dimension K should be White Picture HEIGHT.
Dimension L should be Width of Proscenium Opening.

Question No. 2.
State seating capacity - A-Orchestra ______
B-Balcony ______
Total ______
Stadium seating is considered an extension of or part of orchestra level seating.

Question No. 3.
Check type of screen in use -
A- Beaded or metallic ______
B- Diffusive-mat white ______
C- Other-Describe ______

Question No. 4.
Check type of projection light source in use.
A- Low Intensity ______ Amps.
B- High Intensity "
1) High-Low (Reflector) ______ "
2) Condenser Type ______ "
3) Suprex ______ "
C- A.C. Arc ______ "

Question No. 5.
State type of current and voltage in projection room.
AC Volts ______
DC Volts ______

Question No. 6.
State focal length of projection lens ______

Question No. 7.
State angle of projection in degrees ______

Question No. 8.
State year of erection or basic alteration of theatre.

Question No. 9.
Name of theatre ______
Location ______

Form A-- ______
B- ______

PROJECTION PRACTICE COMMITTEE

FIG. 1. Survey Chart.

Explosives, and eventually published in the JOURNAL. We hope to present the final report at the next Convention.

REPORT ON THEATER SURVEY

Motion picture theater structures should be designed according to standards that will insure satisfactory reception, by the audience, of the screen performance. The need for such standards has been emphasized by the survey made by this Committee of approximately 600 theaters. Charts similar to that shown in Fig. 1 were distributed by the Committee among a number of large companies of the industry whose engineers assisted in obtaining the dimensions requested on the chart. Accompanying the charts were letters describing the purpose of the survey. Instead of mailing the charts directly to the managers of theaters, it was felt that the results would be more uniformly determined if the measurements were made and the charts filled out by men experienced in such work. Accordingly, the field men and the management of RCA Manufacturing Co., International Projector Corp., Electrical Research Products, Inc., National Carbon Co., Inc., Forest Electrical Co., Bausch & Lomb Optical Co., and National Theater Supply Co. are all to be thanked for their co-operation. In addition, a number of charts were distributed to the delegates to the Convention of the MPTOA at Miami last March.

Although the survey includes only about 4 per cent of the total number of theaters in operation in the United States, care was taken so that these 600 theaters would represent a fair cross-section of all the theaters of the country. Theaters in every State and theaters of capacities varying from 200 to 4000 seats are included in the survey. Averages computed from the survey at a point when 400 theaters were covered showed the same index values as when the number of theaters surveyed reached 600, indicating that the facts obtained are fairly representative of general theater conditions.

The information obtained from the survey reveals the fact that the basic theater forms, relative screen sizes, and viewing conditions vary to a very wide extent. Variations in design, as shown in the graphs, spread over an extent of at least three times what might be regarded as tolerable. Only 16 per cent of all the theaters surveyed proved to have satisfactory conditions for all the basic considerations of proper motion picture presentation. Considering only the theaters erected after 1930, the percentage was 27.

A set of standard requirements for theater construction could easily have limited these variations and thereby have benefited motion picture presentation greatly. As it is, however, there appears to have been considerable neglect, disregard, or ignorance of motion picture viewing principles in the design of motion picture theaters. This is evidenced by the fact that the smooth broken curves, drawn through the jagged graphs for the purpose of roughly representing average tendencies, are amazingly similar in general shape to the well known probability curve. The inference follows, therefore, that the fulfillment of satisfactory viewing conditions in theaters, up to the present, has been primarily a matter of chance and not of intention. Perhaps this disregard of proper motion picture design principles may be attributed to the fact that motion picture theater design has evolved from the stage-theater form, which is unfortunate since the basic form required for the stage theater is quite different from that required for the motion picture theater.

Since the motion picture has become the sole, or, at least, the most important means of entertainment in almost all theaters where motion pictures are exhibited, it is important that recommended practices for motion picture theater design be formulated. Such recommended practices could be followed as guides not only in designing new theaters but in remodeling and reëquipping existing theaters. They would indicate the ideal conditions desirable in new structures and the variations from the ideal that would be tolerable, if necessary, in correcting undesirable conditions in existing structures. To be of practical use these standards should take cognizance of such physical conditions as

(*a*) regular and emergency audience "traffic";
(*b*) practical structural possibilities;
(*c*) shapes of ground plots; and
(*d*) limitations of motion picture film and equipment.

Special attention should be given to all such matters in order that the proposed practices may be applied in a sufficient number of instances to assure raising the general quality of motion picture presentation. The survey made by the Committee clearly indicates that the practical limitations are not the only causes of the existing undesirable conditions, but that there has been almost a complete lack of scientific planning of the motion picture structure. Proper relative importance can, of course, be given to practical considera-

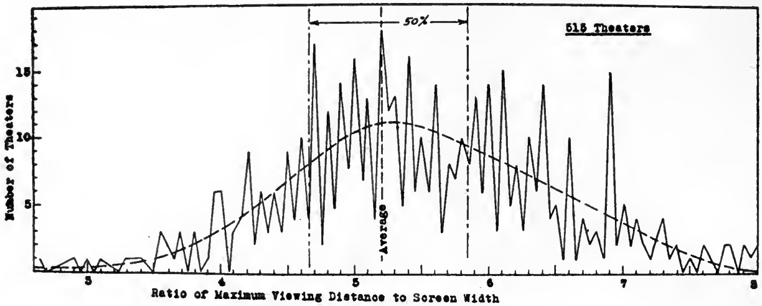


FIG. 2. Viewing distance in terms of screen width (*see c, Fig. 9*).

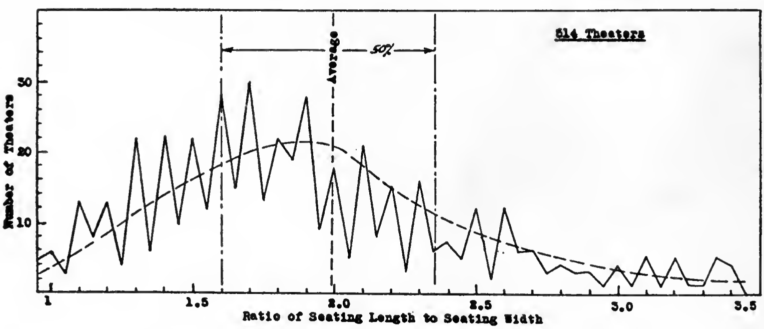


FIG. 3. Seating area characteristics (*see a, Fig. 9*).

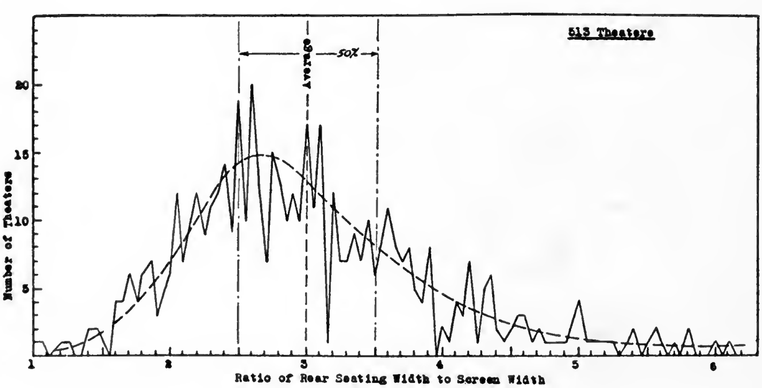


FIG. 4. Relation of seating width to screen width (*see d, Fig. 9*).

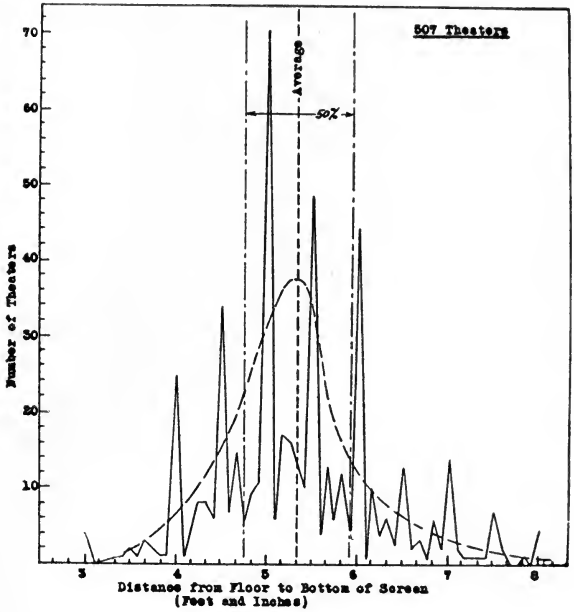


FIG. 5. Location of screen above floor of auditorium (*see b, Fig. 9*).

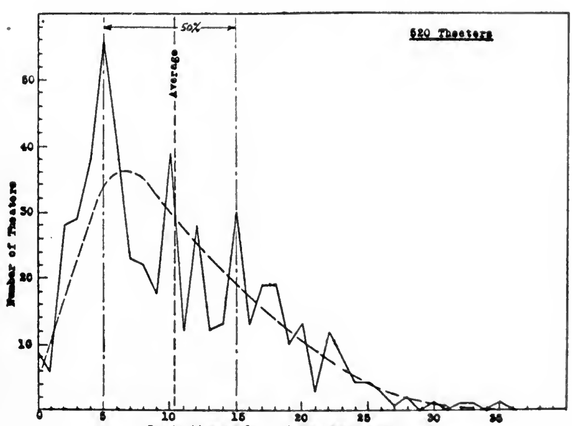


FIG. 6. Projection angle (*see e, Fig. 9*).

tions; but, at the same time, all possible importance must be assigned to design principles based upon scientific planning.

The ideal motion picture theater would be one that contained the maximum number of desirable seating positions per cubic foot of structure. In many instances where the shape of the ground plot, or the laws governing exit facilities, *etc.*, have been such as would assist in building satisfactory theaters, there have been no design principles or recommended practices available to guide the designers. In other instances where the conditions, to begin with, were not so fortunate, the poor proportions of the ground plots or the restrictions of building laws led to the erection of motion picture theaters most unfortunate in design. Therefore, any recommendations of this Committee should include recommendations indicating the best possible use of poorly proportioned as well as more correctly proportioned plots. This is necessary because street plans and excessive land costs produce many variations in ground plot shapes.

Laws governing theater construction in many instances require that aisles, passageways, and exit doors be so located as to cause a loss of valuable seating area. These laws have been made with little regard for their effect upon the proper functioning of the theater from the standpoint of motion picture presentation. Proposed practices for theater construction must therefore indicate the placement of traffic areas where they will diminish the effective seating area least. They should also indicate to the governing authorities wherein their existing safety laws may interfere with the better design of theaters without prejudicing to any extent the safety considerations upon which the laws originally may have been based.

With the modern fireproof and fumeproof construction employed for projection rooms, with the elimination of stage scenery and excess draperies, and with the generally fireproof nature of the entire theater building, a new approach may be made to the question of emergency exit requirements. This Committee now includes a theater architect and a state official on theater construction inspection. In addition, other architects and governing authorities are being invited to supply such information to the Committee as will make it possible to submit the final findings as a guide to be used by all the states and municipalities in writing laws relating to motion picture theaters. It is the opinion of the Committee that all motion picture theater construction should be under the guidance of competent theater architects.

In addition to improving the general quality of motion picture theater design, structural standards will assist a great deal in clarifying many of the motion picture equipment problems. For example, light-producing sources, motion picture screen characteristics, and sound systems might be classified according to their ability to fulfill the requirements of definite types of theater structure.

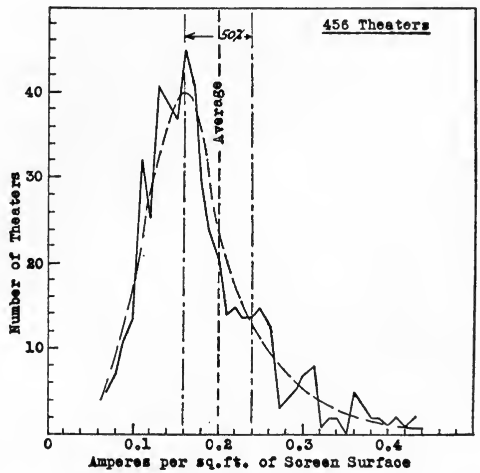


FIG. 7. Projector arc current.

The basic design of the motion picture theater depends more than anything else upon the necessity of satisfactorily viewing the picture. The factors involved are:

- (*1*) Picture detail.
  - (*a*) Screen size in relation to viewing distance.
  - (*b*) Screen brightness.
- (*2*) Obstruction of view.
- (*3*) Distortion of picture.
  - (*a*) In projection.
  - (*b*) In viewing.

Figs. 2–9 and Table I have been computed from the data provided by the returned survey charts. Figs. 2 and 7 will be especially helpful in studying the picture detail problem. Fig. 5 is intended for use in determining the area of the screen obstructed by the heads of spectators. Figs. 3 and 4 indicate the conditions controlling picture-image distortion due to viewing angles. Fig. 6 shows the projection angle, another factor affecting picture-image distortion.

The survey indicates that seating capacities have steadily become smaller. Whereas 26 per cent of the theaters surveyed, erected before 1930, have capacities of 1500 seats or over, only 10 per cent of the theaters erected after 1930 have capacities so great. Theaters of 2000-seat capacity and over, erected after 1930, amount to only 5 per cent of the total.

TABLE I

Theater Survey, Characteristics of Theaters

	Lower Extreme	50% of the Theaters Min.	Av.	Max.	Upper Extreme
Ratio max. viewing dist. to screen width	2.60	4.65	5.20	5.85	8.00
Ratio seating length to seating width	0.90	1.52	1.98	2.35	3.50
Ratio rear seating width to screen width	1.00	2.50	3.00	3.50	6.20
Screen width	10′	16′	18′–6″	21	34′
Distance from floor to bottom of screen	3′–0″	4′–9″	5′–4″	5′–9″	8′–2″
Projection angle	0°	5°	10°.5	15°	35°
Amperes (arc) per sq. ft. of screen surface	0.06	0.16	0.20	0.24	0.44

Future recommendations should show the disadvantages encountered when capacities of over 1500 seats are contemplated. A point to be noted in the survey is that the characteristics of the theaters having capacities greater than 2000 seats do not fall within the 50-per cent group, indicating that an important percentage of the seats in these large theaters are more or less subject to undesirable viewing conditions, and that best results in establishing standards of design will be attained if the seating capacities are assumed to be, say, 1500 or less. This maximum applies to the usual rectangular ground plan. Somewhat greater capacities may be possible in a trapezium-shaped ground plan.

Although the screen-image size is related to the maximum viewing distance, screen-image sizes in the theaters covered indicate a tendency toward sizes too small for the given viewing distances. This may be due to a general desire to avoid sufficient magnification to reveal film graininess and thereby assist in rendering seats closest to the screen undesirable. Fig. 8 shows that the average screen-image is 18.5 feet wide, 50 per cent of the theaters surveyed having screen-images ranging from 16 to 21 feet wide.

Using the average screen width of 18.5 feet (Fig. 8) and assuming this width represents maximum desirable magnification of the 35-mm. film, approximately 800 seats can be arranged in a single tier. Should the maximum permissible magnification be assumed capable of producing an acceptable 25-foot screen image, a capacity of 1100 seats would be accomplished in a single tier. These capacities are arrived at by assuming, temporarily, the averages indicated in Figs.

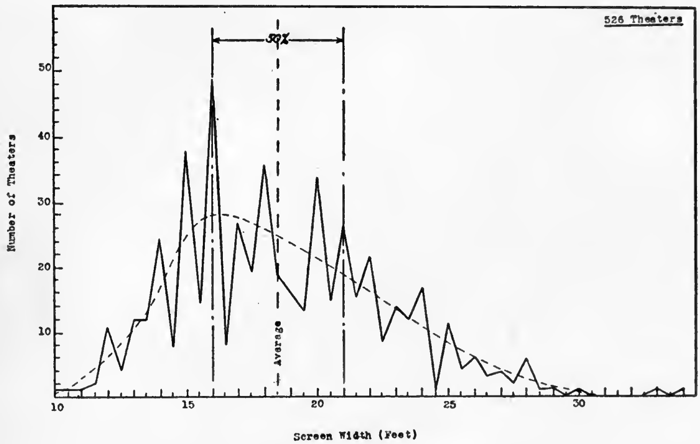


FIG. 8. Chart of screen widths.

3 and 4. If a second or upper tier of seats be employed in both the 800- and 1100-seat instances, these capacities would be increased respectively to approximately 1200 and 1700 seats. These figures indicate the reason for assuming that 1500 seats may be the advisable maximum capacity.

While the data shown in the graphs do not determine, without further study, ideal theater proportions and dimensions, they do, however, reveal conditions that may be regarded as at least tolerable. For example, the conditions in theaters the proportions and dimensions of which fall within the 50-per cent group marked on the charts may, for immediate practical purposes, be regarded as tolerable. Fig. 9 depicts these characteristics graphically. The figures shown should not be interpreted as representing any attempt on the part of the Committee, as yet, to fix maximum or minimum conditions: further analysis is required.

Considered from the standpoint of visual aspects only, the ground plan of a motion picture theater is controlled, first, by the ability of the audience to see the details of the picture. This ability is determined by:

(*a*) the illumination of the screen;
(*b*) the brightness contrast of the projected image;
(*c*) how much image detail is to be discernible to the spectator (the art of cinematography is here the guiding factor);
(*d*) the width of the film, which controls the maximum screen-image size.

Second, the ground plan is controlled by the area within which the viewing angles afford an acceptably undistorted appearance of the two-dimensional screen-image.[1] Still another consideration in determining the ground plan is that of choosing between a single tier of seats and a multilevel seating plan. The desire to obtain a maximum number of seats on valuable ground area has usually been the important reason for adopting upper-level seating schemes. Yet the most plausible reason for multilevel seating is that excessive viewing distances can be avoided and minimum screen-image sizes can be used. The multilevel seating scheme would tend toward a more squarely proportioned and smaller ground plan; whereas the single-level seating plan tends toward the elongated rectangular plan, and, naturally, larger ground area.

The ideal motion picture theater form, considered from a purely technical and artistic standpoint, may develop into a form that may not in some instances fulfill all the rigid requirements set forth for the commercial motion picture theater; yet it is the obligation of the Society to indicate what would be the most desirable form of theater, and all those who are concerned with the design of theaters may adhere as closely to these recommendations as may be practically possible, in any case being sure to stay within the limits set forth as tolerable.

The following principles determine the characteristics of ideal motion picture presentation:

(*1*) Minimum seating capacity, permitting minimum screen-image sizes.
(*2*) Control of screen-image size, to avoid over-magnifying film graininess.
(*3*) Minimum viewing distances, to enable greater cinematographic use of the screen-image.
(*4*) Maximum seating capacity possible while still adhering to the requirements of (*2*) and (*3*) above.

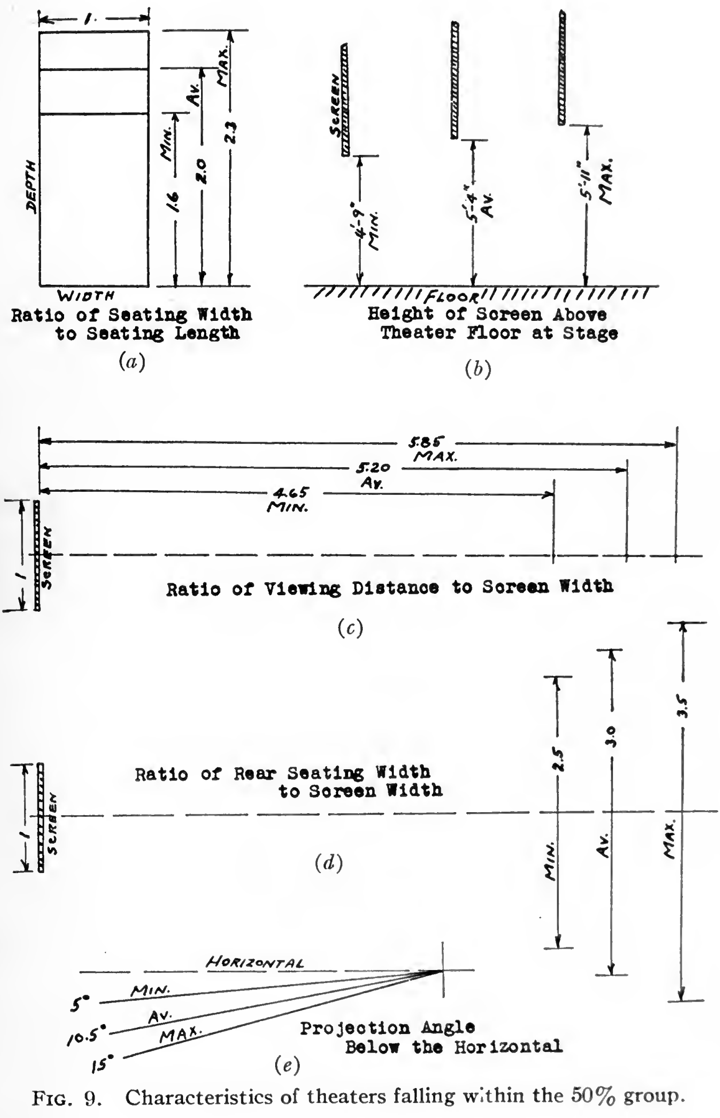


FIG. 9. Characteristics of theaters falling within the 50% group.

(5) Maximum number of seats within an area from which the screen-image will not appear objectionably distorted.
(6) Floors or steps properly graded, to afford unobstructed view of the screen-image from every seat.
(7) Maximum screen brightness, using a minimum of electric power.

It is the intention of the Committee to give further detailed study to the problems of picture detail, screen brightness, cinematography, magnification ratio, image distortion, and obstruction of the screen-image. By considering the factors revealed by the survey and other studies it will be possible to formulate definite recommendations for standards for motion picture theater design.

B. SCHLANGER, *Chairman*
SUB-COMMITTEE ON THEATER SURVEY

REPORT OF SUB-COMMITTEE ON PROJECTOR AND SCREEN ILLUMINATION

For a long time the Projection Practice Committee, through its sub-committees, has been working on the problem of discovering meters that could be used in the theaters for measuring the light from the projector incident upon and reflected from the screen. Such meters should be simple to operate and relatively low in cost, in order to be within the means of all theaters. Meters have been available in the past by means of which such measurements may be made, but in all cases the meters were very high-priced and required for their operation men specifically trained in the art of handling meters.

Some progress has been made, however, in that a meter is now available by means of which the incident light may be measured, but no report can be given at this time as further studies are being conducted with the meter with regard to its use in connection with screens of various types and under various circumstances. Very little progress can be reported, however, with regard to measuring the reflected light, so that for the present no means are available for determining the reflection coefficient of the screen other than by using specially measured and graded samples of paper such as accompanied the report of the Projection Practice Committee in the June, 1933, issue of the JOURNAL.

The Committee plans to continue its work on screen illumination during the coming months, and hopes to render a more definite report at a later time.

R. R. FRENCH, *Chairman*
SUB-COMMITTEE ON SCREEN ILLUMINATION

PROJECTION PRACTICE COMMITTEE

H. RUBIN, *Chairman*

T. C. BARROWS
F. E. CAHILL
J. R. CAMERON
A. A. COOK
C. C. DASH
J. K. ELDERKIN
J. J. FINN
R. R. FRENCH
E. R. GEIB
A. N. GOLDSMITH
A. GOODMAN
H. GRIFFIN
S. HARRIS
J. J. HOPKINS
C. F. HORSTMAN
D. E. HYNDMAN
J. J. KOHLER
P. A. MCGUIRE
E. R. MORIN
M. D. O'BRIEN
G. F. RACKETT
F. H. RICHARDSON
B. SCHLANGER
C. TUTTLE
J. S. WARD
V. A. WELMAN
A. T. WILLIAMS

REFERENCE

[1] TUTTLE, C.: "Distortion in the Projection and Viewing of Motion Pictures," *J. Soc. Mot. Pict. Eng.*, **XXI** (Sept., 1933), No. 3, p. 198.

DISCUSSION

MR. JONES: The Projection Practice Committee is one of our most active committees, and, under the direction of Mr. Rubin, has held monthly meetings for quite a number of years. The Committee is to be congratulated and thanked by the Society for this most excellent work. This is one of the first really adequate surveys of theater conditions, and the Society should consider its value as very great indeed.

MR. GOLDSMITH: The Projection Practice Committee has not proposed herein any standards. This is no attempt to crystallize theater practice at this stage. The report is merely based upon the safe assumption that the median characteristics of the 50 per cent group centering around the average, represent tolerable practice at present, because many millions of persons enjoy and pay for the performances that result within those conditions, and the audience probably enjoys them most around the average conditions. On that basis the report, without being stereotyped or frozen, does give a great deal of help to the architect, to the exhibitor, and to the designers of equipment. It is believed to be the most valuable theater survey that has so far been produced.

MR. RICHARDSON: In the past the motion picture has been very badly affected by distortion of the screen-image, and any recommended practice that the Committee may set up to correct this condition will be very welcome. I hope also that the Committee will consider the effect of the theater characteristics upon the quality of the sound.

MR. SCHLANGER: The Committee intends to collaborate in this work with the Sound Committee.

MR. FRANK: In the past few months I have witnessed a number of discussions between architects, exhibitors, projectionists, and supply salesmen, with regard primarily to screen size, position, and so forth. At the same time other phases of theater construction entered. The arguments always center about personal prejudices not based at all upon scientific reasoning. Up to the present it has been impossible for anyone to settle such discussions or arguments authoritatively, and the decision generally is the wish of the exhibitor. Sometimes one or the other can prove that the results on the screen are better under one condition than another. Now, for the first time, the entire industry is in a position to refer to something that is authoritative, something that tells us at least what the existing conditions are.

The Committee, of course, emphasizes that those conditions may by no means be ideal, and we hope in the not too distant future that the ideal conditions will be set forth. But everybody should recognize that now, when we have an argument about how high a screen should be in a theater, we can at last turn to a document and say to our clients or anyone else with whom we may be discussing the matter, that here is a survey that indicates that the average height of the screen from the theater floor, throughout the country, is five feet four inches, and merely because an architect wants to put it ten feet high is no reason why he should do so.

We should spread this message as far and wide as we can, to make the greatest amount of use of this very interesting survey.

MR. GOLDSMITH: The Committee and the Society should be very proud of one thing, namely, that in this case the industry and particularly the companies that were mentioned, have rallied nobly behind the Society and the Committee. This is one of the finest examples of motion picture industry coöperation with the Society that we have yet had. We are very pleased with this, and think it is an omen of better days.

REPORT OF THE COMMITTEE ON EXCHANGE PRACTICE*

Summary.—*A brief account of the activities of the Committee during the past six months. Among the subjects discussed are the following: reel bands, splicing, processing and waxing, condition of reels in theaters and exchanges, cleaning films, instructional material to accompany films, and film cases.*

Meetings of the Committee have been held regularly each month, and although at this time the Committee does not have a considerable number of concrete facts to report, nevertheless these meetings have proved of considerable value in enabling the exchange heads of various companies to discuss their problems with each other, to arrive at workable and satisfactory solutions of these problems, and to pave the way for solving other existing difficulties in exchange operations.

While the question of administration does not properly fall within the purview of the Society's functions and interests, nevertheless these regular meetings provided the further advantage of enabling the representatives to discuss their administrative problems with one another, and so contributed somewhat to improving the efficiency, uniformity, and operation of the exchange service. These subjects are not matters of record in the minutes of the meetings, but it should be emphasized that they represent an important contribution to the welfare of the industry.

Among the subjects discussed at the various meetings were the following:

Reel Bands.—A collection of reel bands used by the various companies was made, which showed that no important differences existed among them, although it was the opinion of the Committee that uniformity in the nature of the instructions placed upon the reel bands would be desirable.

Splicing.—Considerable study was given to the problem of getting the operators in the exchanges to splice film properly, even when they are supplied with proper splicing equipment.

A study of splicing machines and methods is in progress, and will

* Presented at the Spring, 1938, Meeting at Washington, D. C.; received March, 9, 1938.

be reported upon later. The question of whether it is advisable or not to use bicarbonate of soda or other solvent to make the splices or merely a simple scraping operation to remove grease and dirt completely and thus allow a homogeneous weld to be made, was given considerable attention. The question also arose as to the proper direction in which to make splices, and it was agreed that the trailing film (with respect to rotation of the sprocket) should be spliced on top of the leading film. Less trouble seems to occur when the patches are made in this manner rather than in the opposite manner, and accordingly this procedure has been adopted in all the exchanges represented on the Committee.

Processing and Waxing.—Although for a long time consideration has been given to the subject of processing and waxing film, the Committee is not prepared at the present time to report upon the subject. Some companies use one system and some another, and apparently each system has its advantages and disadvantages depending upon the point of view and the application. The Committee hopes to report further on the subject at a later date.

Condition of Reels in Theaters and Exchanges.—Objections have come to the Exchange Practice Committee from the Projection Practice Committee and others to the effect that the condition of reels received in theaters from exchanges is often very bad. In some instances the flanges are bent badly, and in other instances the reel has been so roughly handled as to rip the center hub out of place, thus making it impossible to run the reel in the projection machine. Samples of mutilated reels were exhibited at one of the meetings and considerable attention was given to questions that had been raised regarding the thickness of the metal and the ribbing and beading, which determine the stiffness; to burs, which arise in stamping, and which are likely to cut the operator's hands; the size of the finger holes which it has been claimed are sometimes too small to permit removing the reels easily from the projector magazines; and other less serious questions which are receiving the attention of the Committee.

The manner in which film reels and cases are handled in exchanges and by carriers is extremely important, and the Committee is endeavoring to change the point of view of the industry that the rough handling that is now regarded as ordinary "wear and tear" should not be regarded as ordinary.

Cleaning Films.—The questions before the Commitee with regard to film cleaning are as follows:

(*1*) Does current film require cleaning?
(*2*) If so, by whom and where?
(*3*) By what type of machine?

With regard to *1*, the question was mainly an economic one, as to whether the expense and labor would be justified by improvements in condition of the film and its length of life. The commercial life of film varies; it is generally shorter than it used to be, and seldom is longer than a year, which makes the need of lengthening its life further somewhat doubtful. On the other hand, the Projection Practice Committee has indicated that even in the case of new film, in use by highly trained personnel, oil and dirt will get upon the film and within a week will be seen in the image upon the screen. In the interest of better screen-images, it would appear that cleaning is necessary, aside from the question of the life of the film.

Instructional Material.—Investigations are being made to determine what degree of uniformity exists with regard to labels, instructional material, *etc.*, sent to theaters with the reels from the exchanges. As this work has not been completed, it will be reported upon at a future date.

Film Cases.—Many criticisms have come to the Committee concerning the manner in which film cases are handled in exchanges and theaters and by carriers, and an attempt is being made to induce the carriers in particular to exercise greater care in handling the containers. Various suggestions have been made also for facilitating the handling of heavy film cases in exchange vaults, the suggestion being that the upper racks be reserved for single-reel pictures so that the heavier loads willl not have to be lifted very high. The distribution of the cases in the vaults could be so graded as always to place the heavier loads at the bottom.

A. W. SCHWALBERG, *Chairman*

O. C. BINDER
A. S. DICKINSON
H. C. KAUFMAN
J. S. MACLEOD
H. A. MERSAY
N. F. OAKLEY
H. RUBIN
J. H. SPRAY

SMPE 16-MM. TEST-FILMS*

Summary.—*A brief description of the SMPE 16-mm. sound and visual test-films. The visual test-film is an optical reduction of the 35-mm. visuol test-film; and the 16-mm. sound test-film is an optical reduction of a special 35-mm. recording, pre-corrected so that the selected frequencies (50 to 6000 cycles) will be reproduced at constant level by an ideal reproducer.*

Several years ago the Society made available to the industry, as a development of the Projection Practice Committee, a visual and a sound test-film on 35-mm. film. In view of the rapid expansion of the 16-mm. industry, a need was felt for similar films in the 16-mm. industry, a need was felt for similar films in the 16-mm. size. Accordingly, arrangements were made by the Society to supply optical reduction prints of the 35-mm. visual test-film.

As described in the August, 1933, and March, 1934, issues of the JOURNAL,** the visual test-film consists of the following test-targets, each preceded by a title stating the purpose for which it is intended, arranged in the following order:

(*a*) Small diamonds and vertical bars arranged alternately in rows for checking travel-ghost.

(*b*) Small squares arranged diagonally across the frame, for checking picture jump and picture weave.

(*c*) Fine vertical lines closely spaced, for checking marginal and radial aberration of objective (projection) lens.

(*d*) Fine horizontal lines closely spaced, for checking marginal and radial aberration of objective (projection) lens.

(*e*) Small squares for checking best focal position of objective lens.

Complete instructions for making these tests are contained in the reprint mentioned above, which apply equally to the 35-mm. and 16-mm. size. The 16-mm. visual test-film is printed on acetate stock and is about 400 feet long.

At the same time there arose in the 16-mm. industry a need for a sound test-film similar to the one already prepared for the 35-mm. industry. Accordingly, when the time came to prepare a new 35-mm.

* Demonstrated at the Spring, 1937, at Hollywood, Calif.

** Reprints of the latter article are available upon request from the office of the Society.

negative, provisions were made to record at the same time a 16-mm. version identical to the 35-mm., except with respect to the range of frequency recorded. It was not thought advisable to record in the 16-mm. film frequencies higher than 6000 cycles, whereas frequencies up to 10,000 were included in the 35-mm. version. Also, the buzz-track frequencies for the 16-mm. film are 3000 and 5000 cps., whereas for the 35-mm. film they are 6000 and 9000. In other respects, the contents of the two films are identical. The contents of the 16-mm. film are as follows:

(*a*) Buzz-track for checking the position of the scanning beam relative to the sound-track.

(*b*) 3000-cycle and 5000-cycle notes for checking the focus and rotational adjustment of the sound optical system.

(*c*) Selected frequencies, including 50, 100, 200, 300, 500, 1000, 2000, 3000, 4000, 5000, 6000 cycles for ascertaining the overall output characteristics of sound-heads and amplifiers. This track was recorded at constant level in order to avoid voltage calibration when a volume indicator is used. In listening, the 1000-cycle note will sound louder than the others, because the normal ear is more responsive to notes of that frequency than to higher or lower notes. This track may be used to check the range of frequency covered by the equipment.

(*d*) Speech recordings for checking intelligibility of speech and theater reverberation.

(*e*) Piano recording for checking flutter and "wows."

(*f*) Orchestral recording for checking naturalness of reproduction.

The 16-mm. sound test-film is printed by optical reduction from a special 35-mm. negative pre-corrected so that in the section of selected frequencies (50–6000 cycles) the levels at the various frequencies will always be the same, except at 6000 cycles, which is −2 db. This makes voltage calibration unnecessary when a volume indicator is used in making measurements on equipment. If the frequencies are reproduced by an ideal reproducer the output readings will then be constant except, as noted, at 6000 cycles. The negative track is of the variable-width type, recorded with ultraviolet light.

In view of the fact that there is only one row of sprocket-holes in the 16-mm. film, there is one continuous sound-track, making the film approximately 400 feet long; whereas in the 35-mm. size the sound-track is divided into two parts, one part next to each row of sprocket-holes. The 35-mm. film must then be run through the reproducer twice, in opposite directions, to play it completely.

RESEARCH COUNCIL NOMENCLATURE FOR RELEASE PRINT SOUND-TRACKS*

JOHN K. HILLIARD**

Summary.—*A general description of the types of movietone sound-track currently being released or to be released in the immediate future, according to plans: (1) single variable-density; (2) single variable-density squeeze; (3) single variable-density double-squeeze; (4) push-pull variable density; (5) push-pull variable-density squeeze; (6) bilateral variable width; (7) duplex variable-width; (8) unilateral variable-width; (9) push-pull variable-width.*

During the past year all these tracks have been used to some extent in released movietone pictures. Samples of the tracks are shown and described. A description is also included of the general technic involved in recording and reproducing the so-called "Hi-Range" and "Lo-Range" prints. During the past two years this particular type has been used successfully in extending the volume range of variable-density releases to approximately 50 db. This release is intended to be shown only in theaters having equipment adequate to reproduce music 6 to 10 db. higher than average dialog.

A description of the mechanics and technic for re-recording with the squeeze-track is outlined. This procedure increases noise-reduction from 3 to 6 db., depending upon the amount of squeeze.

Recent use of push-pull and squeeze-tracks in variable-density recording, as well as the modifications of the aperture used in variable-width recordings, have led to the appearance, on release prints, of several new and different types of sound-tracks. For this reason these tracks will be illustrated and the type of equipment necessary for their projection will be designated, in order to lessen confusion in their use and help in standardizing their nomenclature.

All types of variable-width tracks can be distinguished from variable-density tracks by the fundamental difference between the two, namely, that the variable-width tracks consist of opaque and transparent portions extending along the length of the film, with the two

* Received October 7, 1937; presented at the Fall, 1937, Meeting at New York, N. Y.

** Metro-Goldwyn-Mayer Studios, Culver City, Calif. *Chairman*, Committee on Standardization of Theater Sound Projection Equipment Characteristics, Research Council, Academy of Motion Picture Arts & Sciences, Hollywood, Calif.

portions separated by a dividing line that constitutes an oscillogram of the signal; whereas variable-density records consist of alternating dark and light portions extending across the track and merging gradually into one another. Although there will be differences within any one type, this primary distinction between the two types is easily discernible.

Within each general type of recording, each particular form of track is considered from the standpoint of the type of reproducing equipment necessary for its reproduction, and then from the nature of the track itself and the manner in which noise-reduction has been applied. The various tracks will be illustrated and their nomenclature given, and then the manner of choosing the respective names explained.

VARIABLE-DENSITY SOUND-TRACKS

A variable-density record to be reproduced on a standard reproduction system of sufficient power for the auditorium under consideration is illustrated in Fig. 1. This track is a single low-frequency note, but all signals, no matter how complicated, will consist of alternate dark and light striations, the complexity of the signal merely resulting in a non-uniformity from point to point along the length of the track.

Such a record, called *Single Variable-Density*, covers the whole width of the track, and, although noise-reduction may have been applied during recording, it is not easily discernible and is unimportant for nomenclature purposes.

Fig. 2 is a sample of *Single Variable-Density Squeeze-Track*, and may be reproduced on any standard reproducing equipment of sufficient volume range, as explained in another paper.[1]

The upper portion of Fig. 2 is a *Single Variable-Density Track* of the usual 100-mil width to which noise-reduction in the form of squeeze has not been applied. The center section shows the manner in which the *V*-shaped mask affects the recording beam and reduces the track width. The lower portion of Fig. 2 illustrates a track reduction of 75 per cent, or 12 db. The usual reductions in track width used are reductions to 25 and 50 per cent of the original track width—reductions of 12 and 6 db., respectively.

The track shown in Fig. 2, is termed *Single Squeeze-Track* to differentiate it from the track shown in Fig. 3, which is double-squeeze. This track, called *Single Variable-Density Double Squeeze-Track*, may be reproduced on any standard system having adequate volume range.

FIG. 1. Single variable-density.

FIG. 2. Single variable-density squeeze, showing transition from full-width track to squeeze-track.

FIG. 3. Single variable-density double squeeze, showing transition from full-width track to double squeeze-track.

FIG. 4. Push-pull variable density.

FIG. 5. Push-pull variable-density squeeze, showing full-width track, double squeeze of 6 db. and double squeeze of 12 db. (*Upper*) no squeeze; (*Middle*) 6 db. squeeze; (*Lower*) 12 db. squeeze.

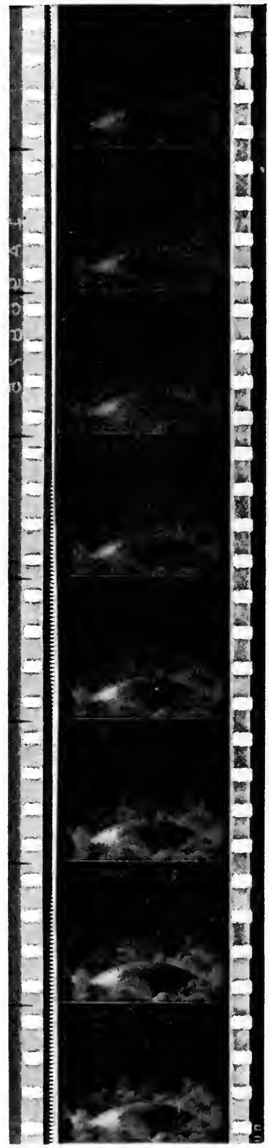


FIG. 6. Unilateral variable-width.

FIG. 7. Bilateral variable-width.

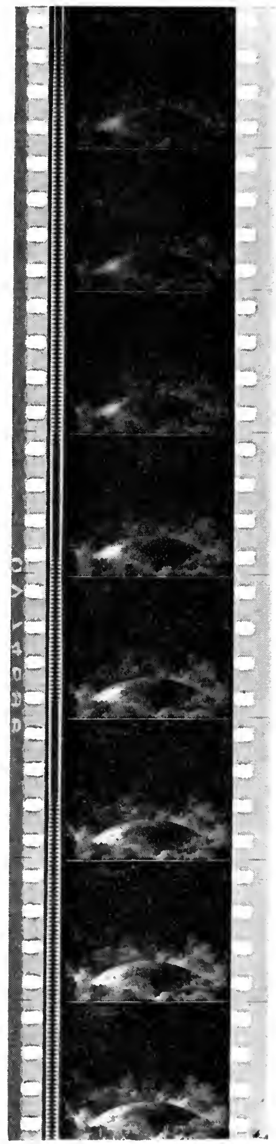


FIG. 8. Duplex variable-width.

This form of track is obtained by using a mask in the form of a *W* inserted in the recording beam in the same manner as is the *V* mask for a single squeeze-track. As the mask takes effect, the track is reduced in the center as well as at the sides, as shown, and a bilateral, or double, track results.

Although this track, during the period of operation of the *W* matte, is a bilateral track, it is termed *Single Variable-Density Double Squeeze*, as the work "single" refers to the fact that it is recorded by a two-ribbon valve and is fundamentally a normal variable-density track made bilateral by the addition of the matte in the recorder.

In studio work where a 200-mil track is often used, one-half of such a push-pull track (termed *Wide Push-Pull*) has the same appearance as a single variable-density track; while one-half of a wide push-pull double squeeze-track will have the same appearance as a single variable-density squeeze-track. To avoid any such confusion when using this nomenclature the term *Single* has been applied to the tracks recorded with a two-ribbon valve and the term *Push-Pull* to tracks recorded by a four-ribbon valve.

Fig. 4 is a sample of a *Push-Pull Variable-Density Sound-Track*, and Fig. 5 illustrates a *Push-Pull Variable-Density Squeeze-Track*, either of which can be reproduced on any system of sufficient volume range for a squeeze-track, provided the system includes a push-pull photocell.

Push-pull records consist of two tracks divided by a septum or center line, with the two tracks 180 degrees out of phase. When double squeeze is applied to a push-pull record the septum is broadened and the outer edge of the track carried toward this septum.

Push-pull tracks may be distinguished from standard tracks, regardless of whether or not squeeze has been applied to either or both these tracks, by the fact that in the former the two tracks are 180 degrees out of phase; that is, considering a lateral cross-section of the two push-pull half-tracks, a dark portion on one half-track will be opposite a light portion on the other half-track (Figs. 4 and 5). On a single track, which is bilateral as a result of double squeeze, light portions are opposite light portions, just as the dark portions are opposite one another (Fig. 3).

The term "push-pull," applied to either variable-width or variable-density, refers only to Class *A* push-pull records, for the reason that, in the present stage of the reproducing art, Class *B* push-pull tracks are impracticable from a commercial reproduction standpoint, and, as a consequence, are not used. If at any future date it is necessary to include Class *B*, the terms Class *A* and Class *B* will then be included in the nomenclature.

VARIABLE-WIDTH SOUND-TRACKS

This type of track, as previously explained, may easily be recognized by the fact that the opaque and transparent portions of the track extend along the length of the film; in contrast to the variable-density record, in which the light and dark portions extend laterally across the film.

Fig. 6 illustrates a single-envelope variable-width track in which noise-reduction (reduction in width of the transparent portion of the track) has been accomplished by the application of the shutter method. Consequently this track is termed *Unilateral Variable-Width.*

Fig. 7 illustrates a *Bilateral Variable-Width* track, so-called because it is a double-envelope track on which noise-reduction has been accomplished by means of bias current on the galvanometer. Fig. 8 illustrates a *Duplex Variable-Width* track, which is also a double-envelope track in which noise-reduction has been accomplished by means of a double shutter, each shutter acting from one edge of the sound-track and both shutters actuated by part of the signal current.

The tracks illustrated in Figs. 6, 7, and 8 may be reproduced on any reproduction equipment with sufficient power for the auditorium under consideration.

Fig. 9 illustrates a *Push-Pull Variable-Width* track, which may be reproduced on any equipment of sufficient power, provided the equipment has a double or push-pull photocell.

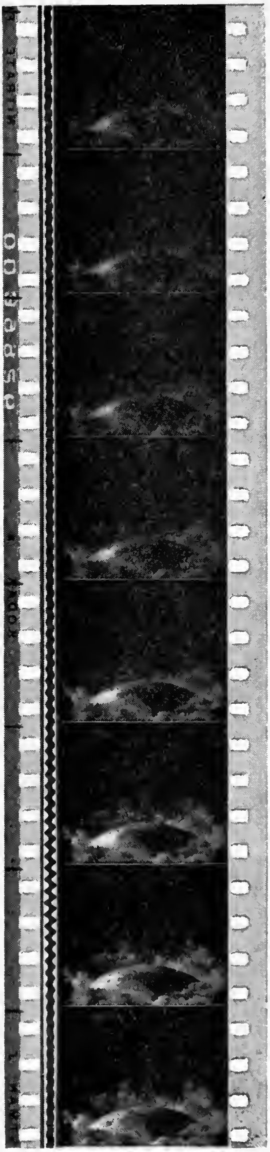


FIG. 9. Push-pull variable-width.

Push-pull variable-width tracks may be distinguished from other variable-width forms of recording in the same manner as the variable-density recordings are distinguished; that is, by the fact that the two half-tracks of the push-pull track are 180 degrees out of phase.

REFERENCE

[1] HILLIARD, J. K.: "Notes on the Procedure for Handling High-Volume Release Prints," *J. Soc. Mot. Pict. Eng.*, **XXX** (Jan., 1938), No. 1, p.

Editorial Note: Subsequently to the presentation of this paper before the Society of Motion Picture Engineers last October, formal approval was given to the proposed nomenclature by the Research Council of the Academy of Motion Picture Arts & Sciences and published in their Technical Bulletin on Nov. 24, 1937. This nomenclature is being submitted to the Sectional Committee on Motion Pictures of the American Standards Association, for Approval as an American Standard.

A digest of these nomenclature specifications is printed below to bring them to the attention of readers of the Journal. The figure numbers correspond to the illustrations mentioned in Mr. Hilliard's paper, printed above.

ACADEMY RESEARCH COUNCIL STANDARD NOMENCLATURE FOR RELEASE-PRINT SOUND-TRACKS

PLAYS IN "STD." POSITION OF SOUND-HEAD SWITCH

Single variable-density . . . . Fig. 1
Single variable-density squeeze . . . . Fig. 2
Single variable-density double squeeze . . . . Fig. 3
Unilateral variable-width . . . . Fig. 6
Bilateral variable-width . . . . Fig. 7
Duplex variable-width . . . . Fig. 8

PLAYS IN "P.P." POSITION OF SOUND-HEAD SWITCH

Push-pull variable-density . . . . Fig. 4
Push-pull variable-density squeeze . . . . Fig. 5
Push-pull variable-width . . . . Fig. 9

CLASSIFICATION AS TO TYPE OF RECORDING

Figs. 1, 2, 3, 4, and 5 illustrate the different types of variable-density sound-tracks, while Figs. 6, 7, 8, and 9 illustrate the various variable-width tracks.

CLASSIFICATION ACCORDING TO POWER REQUIREMENTS NECESSARY FOR UNDISTORTED REPRODUCTION

Those tracks illustrated in Figs. 1, 4, 6, 7, 8, and 9 may be reproduced on those systems having a volume range that was considered adequate up to the present time and prior to the installation of the modern improved equipment with its relatively greater amplifier power.

CLASSIFICATION BY TYPE OF EQUIPMENT NECESSARY FOR REPRODUCTION

"Push-pull" tracks as illustrated in Figs. 4, 5, and 9 can be reproduced only on systems having a double or "push-pull" photocell, together with the necessary associated circuits.

Fig. 5 illustrates the different amount of "squeeze," or track reduction, now being applied to variable-density recordings. The upper portion of this figure shows a "push-pull" track before the application of any "squeeze," the center portion a reduction in track width of one-half, and the lower section a reduction of three-fourths, these being reductions of 6 and 12 db., respectively.

PICK-UP FOR SOUND MOTION PICTURES (INCLUDING STEREOPHONIC)*

J. P. MAXFIELD,** A. W. COLLEDGE,** AND R. T. FRIEBUS†

Summary.—*Although the basic principles underlying sound pick-up for motion pictures have been understood for some time, the ability to carry them out completely in the presence of the requirements of artistry, photography, lighting, etc., has constituted a difficult problem. The paper discusses some of these problems, particularly with respect to the acoustics of production sets and scoring stages. The problems of stereophonic reproduction are also discussed in some detail.*

The severity of the requirements of sound pick-up for motion pictures has increased considerably during the past eight years. While the basic principles underlying pick-up have been understood for some time, the ability to carry them out completely in the presence of the requirements for artistic acting, photography, lighting, *etc.*, has constituted a difficult problem to solve. The successful recordings coming out of Hollywood today testify to the success that has attended the efforts of the technicians constantly to improve their work.

The two most important factors of sound pick-up are, first, the acoustics of the space surrounding the source, and second, the technic of microphone placement. The requirements of lighting, photography, *etc.*, frequently interfere with the full realization of either or both these factors. As would be expected, therefore, most of the pick-up technic is an intelligent compromise, and many ingenious schemes have been tried to effect these compromises successfully.

ACOUSTICS

While the sole purpose of the control of the acoustics is to obtain a sound record that will correlate with the picture, the realization of this result leads to two very different types of acoustic control.

* Presented at the Fall, 1937, Meeting at New York, N. Y.; received April 14, 1938.

** Electrical Research Products, Inc., New York, N. Y.

† C. C. Langevin Co., New York, N. Y.,

The conditions encountered on the production set obviously differ markedly from the conditions existing on a scoring stage. A production set may consist of one, two, or three walls. It may be placed inside a sound stage or out in the open on location, and in any case is surrounded by lights, cameras, and other necessary equipment. The scoring stage, on the other hand, is usually a completely enclosed room where acoustic characteristics can be controlled in the standard manner developed for theaters, auditoriums, studios, *etc.*, keeping always in mind the special requirements of the motion picture industry.

Production Sets.—The problem of acoustic control confronting the engineer on production sets is that of obtaining a sound record that, when coördinated with its picture, will sound as if the action had really taken place in the scene shown in the picture.[1] The necessary control to achieve this illusion is easiest to accomplish if the set has at least three walls. Where the illusion is of importance to the dramatic effect of a scene taken in a two-wall set, it is possible to erect a third wall outside the lighting or picture area to fulfill the acoustic requirements.[2] This expedient is probably not warranted in many of the routine production takes. In any event, the production set should be built in a stage whose walls have high sound absorption so that the space surrounding the set is as nearly as possible an imitation of open outdoors. It is, of course, obvious that a set built out-of-doors fulfills the necessary conditions of surrounding space.

Scoring Stages.—There are two problems that face the production engineer in connection with scoring. The first is the production of background music for titles or dialog sequences in which the music is merely an accompaniment to the action on the screen. The second is the production of sound, usually music, to be later synchronized with the picture of the apparent sound-source. While the music is made in the scoring stage, the picture is usually made on a production set in synchronism with a playback from the original record made in the scoring stage. Fortunately, the acoustic conditions required for these two purposes are essentially the same. Any differences desired in the recorded acoustic properties can usually be cared for by microphone placement.

An ideal scoring stage should have a volume between 140,000 and 240,000 cu. ft., the smaller size being suitable for the vast majority of recordings. In this connection it should be remembered

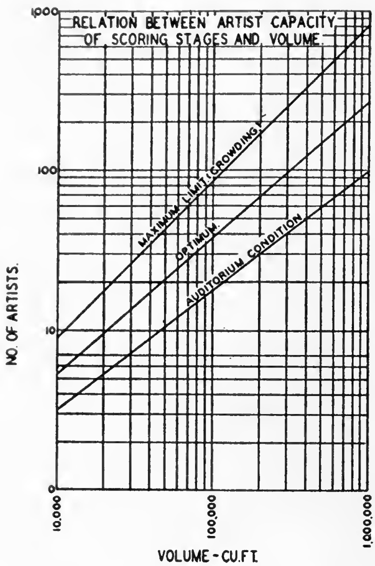


Fig. 1. Number of musicians in relation to size of stage

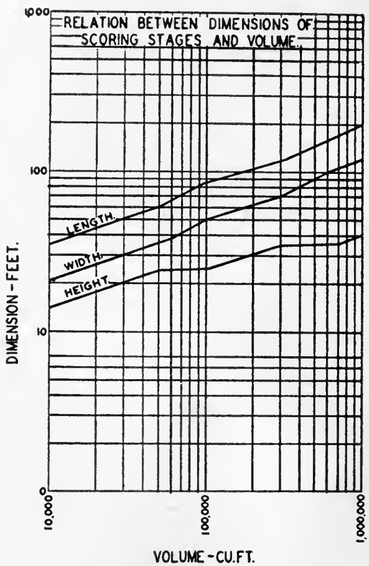


Fig. 2. Relation between volume and linear dimensions of stage.

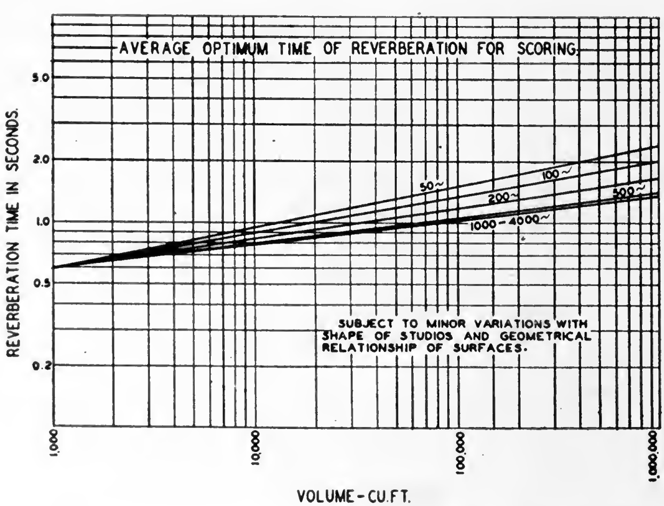


Fig. 3. Reverberation time as a function of size of room or stage.

that it is practically impossible to imitate the acoustics of a large room in a room that is actually small. On the other hand, the acoustics of a small space can be imitated easily in a large room by the judicious use of flats or other reflecting surfaces.

Fig. 1 shows three curves relating the number of musicians usable in a stage with the size of the stage. The lower curve represents the average condition found in auditoriums used for symphonic music.[3] The middle curve represents the practical optimum in which the factors of maximum quality, best illusion, and minimum cost of waste space have all been included.[4] The upper curve, marked "maximum limit," represents the largest number of musicians that can be crowded into the space and still do reasonably satisfactory recording.

It is quite true that in the past scoring stages and studios have been crowded beyond this limit, but it has been the experience of the authors that under these circumstances a large part of the dramatic value of the music has been lost, and that in all cases music recorded under these conditions fails to produce the expected dramatic effect.

Fig. 2 shows the ideal relation between the size of the stage and its length, width, and height, respectively.[5] It is, of course, understood that reasonable variations of these curves produce no detectable damage on the resulting acoustic characteristics. In addition to the general shape factors shown in Fig. 2, it is desirable to make the walls slightly irregular in shape. These irregularities may present flat surfaces whose horizontal dimensions are as great as 12 or 15 feet, and it is usually undesirable to make the angle between the irregular portion and the line that the straight wall would have taken greater than 1 in 12.

Having considered the size of the room and its shape, the next problem is the internal acoustic treatment. Fig. 3 shows a family of curves giving reverberation time as a function of room or stage size.[4] Each of the curves shows the proper value at the frequency associated with it. A little study of these curves will show that the larger the auditorium the greater is the desirable rise in reverberation time for the lower frequencies. From these curves and a knowledge of the size of the room, standard methods may be applied to determine the quantity and the frequency characteristic of the absorbent material necessary to obtain the characteristics represented in Fig. 3.

For the best possible recording it is not sufficient only that the reverberation time be correct. The sound distribution pattern within the stage is also of vital importance. This sound pattern consists of short-time reflections from the walls near the musicians and of the longer-period reflections that travel completely around the stage. While the resulting record would sound unnatural if all the short "slaps" were removed, musically the most pleasing part of the reverberation consists of the reflections that travel long distances between reflections, namely, the so-called "around-the-room" reverberations. It is, therefore, necessary to consider with great care the distribution of the live and dead areas within the stage. It will be seen, therefore, that it is highly undesirable to damp any complete wall of the stage since such a sound absorbing surface will rapidly damp all the "around-the-room" reverberation.

There is one additional factor to be considered, namely, the relative liveness of the surfaces in the orchestral and in the microphone end of the stage. If all the walls of a studio were treated uniformly a situation would result during recording in which the orchestra would be placed in the dead end and the microphone in the live end of the stage, since the added damping brought about by the presence of the musicians would cause the orchestral end to be the "deader." It is therefore desirable to place a larger percentage of the damping material necessary to obtain the correct reverberation time in the end of the studio where the microphone will be placed.[6]

ACOUSTIC PERSPECTIVE

When a person is viewing a scene in real life, he is viewing it with two lenses—the eyes—and with two pick-up devices—the ears—which are in fixed relation one to the other. The present sound picture has neither a stereoscopic picture nor stereophonic sound. It is the equivalent of a one-eared, one-eyed man viewing a real-life scene. It is fortunate that nature endowed our eyes, whether one or both, with an accurate sense of direction, since a one-eared person has practically no means of detecting direction acoustically. On the other hand, the loss of one eye greatly diminishes the ability of the observer to determine distance, whereas the loss of one ear, particularly under indoor conditions, acoustically enhances the sense of distance. We therefore find that the picture helps to draw the apparent position of the sound from one side to the other of the picture screen, while the acoustic perspective of the sound aids the eye in interpreting the picture perspective which is partially destroyed by monocular projection.

Production Sets.—The method of achieving acoustic perspective was discussed some years ago[1] and a relation was worked out between the microphone position and the focal length of the camera lens taking the accompanying picture. The data regarding this relation were presented in a family of three curves, each curve representing the requirements for a different type of set condition. Unfortunately, no means was given for the recording operator to know under which of the three conditions he might be operating. It was therefore somewhat difficult to apply the technic in a practical manner.

Further practical experience with the method has led to the use of a single curve of the type shown in Fig. 4. On the first close-up

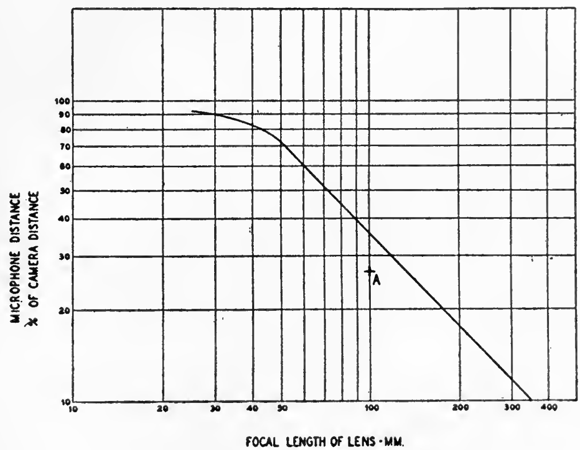


FIG. 4. Relation between focal length of camera and microphone position, for achieving acoustic perspective.

made in a given set the microphone distance for properly coördinating the sound and the picture can be determined by ear. This is the present standard practice for all the takes made. As an illustration of the use of this curve let us assume that the camera is equipped with a 100-mm. lens and that the microphone position, for the first take, falls at the point *A*. A line sketched through *A* parallel to the curve of Fig. 4 then shows the correct relation for all further takes made in this set. It is believed that this procedure, which takes but very little time, has merit in spite of the fact that many skilled operators can make a reasonably satisfactory ear adjustment for any given take. On the other hand, where some time has elapsed between the first use of a set and its subsequent use, changes of judgment may occur so that the two groups of takes do not inter-cut as satisfactorily as they should. The use of the suggested technic avoids such mismatches.

It has been the authors' experience, and that of some of the microphone men with whom they have discussed this problem, that unless some such guide is used there is a tendency to set the close-up takes correctly and to make the microphone positions for the long-shot and semi-long-shot takes decidedly too close. The use of the curve, of course, helps to keep the judgment of the operator calibrated.

There are occasions when it is necessary to use several cameras on the same scene simultaneously. Where the acoustic perspective is of no dramatic importance, a single close-up track can be used for all the picture takes, the sound being dubbed at slightly lower level for the long-shot scenes. If, however, the perspective contributes materially to the dramatic effect, it is possible to obtain full acoustic perspective by the use of two simultaneous sound-tracts.[7] The first track has a microphone position corresponding to the closest close-up, while the second track has a position corresponding to the longest long-shot. By mixing these two tracks in the proper proportions in the dubbing process, the sound can be made to appear to come from any intermediate distance necessary to fit the picture.

Scoring Stages.—The principles of acoustic perspective and the suitable "liveness" for their application have been understood for some time. A brief review of these principles is believed necessary as an introduction to the discussion of stereophonic recording.

It has been known for some time that the best microphone positions vary from room to room even though the apparent "liveness" of the recorded sound may remain unchanged. Since it is possible to achieve approximately similar acoustic effects under varying microphone conditions, it was felt that some constant of pick-up procedure could be found that would include not only the microphone distance but the acoustics of the space as well. Such a constant has been determined and is called "liveness." In the form most useful for practical results its formula may be written as follows:[7]

$$L = \frac{1000T^2D^2}{V}$$

L = liveness.
T = reverberation time of the room (in seconds).
V = number of cubic feet of air in room or space under consideration.
D = distance between source of sound and ear or microphone (in feet).

From the results of listening tests three very interesting conclusions were drawn regarding the most desirable liveness for various types of recording:

(1) Engineers generally prefer a lower range of liveness than do musicians and the public.
(2) The range of "liveness" acceptable to any one person is broad.
(3) The average range accepted by musicians and the public at large overlaps the range acceptable to engineers.

In this connection it is interesting that, in general, the greater the liveness of the reproduced sound, the farther does the source of sound appear to be from the immediate foreground. In other words, the greater the liveness the more the sound approaches a long-shot condition. The second, but less important, factor controlling apparent distance is the loudness at which the sound is recorded and reproduced. By proper control, therefore, of the liveness and the loudness, full fore and aft perspective can be obtained.

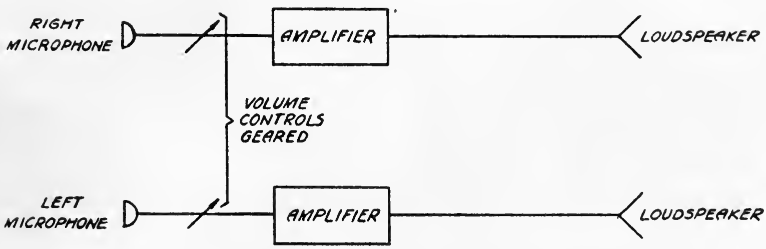


FIG. 5. Simple two-channel stereophonic system.

STEREOPHONIC REPRODUCTION[8]

It is not possible, however, by the use of these two factors to gain any sense of side-to-side movement of the sound. In order to produce the sidewise illusion it is necessary to record and reproduce at least two separate channels of sound. This type of reproduction has been termed "stereophonic."[8] The control of fore and aft perspective of stereophonic recording is similar to its control in single-channel systems, the addition of the sidewise illusion being the main characteristic of stereophonic reproduction.

Fig. 5 is a schematic diagram of a simple two-channel stereophonic system. Such a system is sufficient to illustrate all the principles involved and will therefore form the basis of discussion. The basic principles underlying stereophonic operation have already been published in some detail and will be reviewed here only as required in explanation of the practical pick-up requirements.

Briefly, the factors of practical importance may be summarized as follows:[9]

(*1*) The sidewise position of the image is dependent upon the ratio of the intensities of the direct sounds falling upon the two microphones.

(*2*) The apparent position of the sound, back of the extreme foreground, is determined mainly by the ratio of reverberant to direct sound at the microphone nearest the source.

With these two factors clearly in mind, it is possible to set up roughly a technic of operation in a six-wall enclosure such as a scoring stage.

FIG. 6. Dummy stage used for testing accuracy of sound location.

Conditions existing on an open production set are not as well understood.

It might be interesting to digress for a moment and examine a typical experiment performed to determine the accuracy of sound location by this method. Fig. 6 shows a dummy stage erected in a room whose volume is approximately 100,000 cu. ft. The two microphones are shown in the foreground. The distance between these microphones was of the order of 22 feet.

Fig. 7 shows the set-up of the loud speakers on the stage of the Academy of Music in Philadelphia, the separation of the loud speakers being approximately 35 to 40 feet. The area on the dummy stage inside the ropes, Fig. 6, represents the reproduction area.

Fig. 8 is a diagram of this area with several locations marked *1, 2, 3, 4, etc.* An experiment was carried out in which a person was asked to speak from various places in the dummy stage, accurately charting his position with respect to the ropes. Observers at various positions in the Academy of Music were asked to plot upon a map of the Academy stage the position from which the voice appeared to come. None of the observers in the Academy had any knowledge of the position taken by the speaker in the dummy stage.

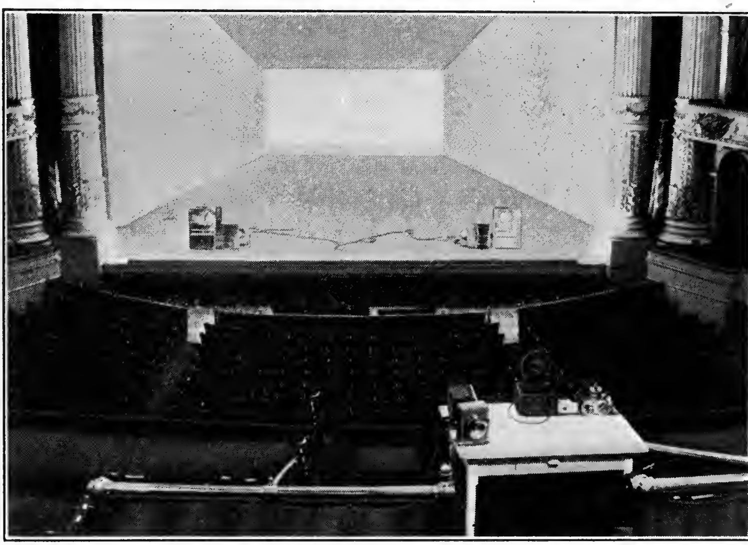


FIG. 7. Arrangement of loud speakers for stereophonic reproduction on stage of Academy of Music at Philadelphia.

From a large number of tests, the average accuracy of location was determined. The stage was then darkened and the tests repeated with a live speaker actually on the stage. Stereophonic accuracy of location was the same, within experimental error, as that obtained with the true source on the stage. It is interesting that the average error, laterally, is somewhat less than half the average error fore and aft, for both stereophonic and the real source of sound.

The question, therefore, immediately arose as to whether this illusion would be strong enough to overcome any tendency to pull the sound into position by seeing a speaker on the stage. The experiment, the set-up for which is shown diagrammatically in Fig. 9, was tried. In the upper part of the picture is shown the dummy stage. A speaker proceeded from position *1* to *2* to *3* to *4*, and finally to *5*. On the actual stage a pantomimer proceeded from position *1* to *2* to *3* to *4*, and finally to *5*. It should be noted that the pantomimer left the stage to the right, whereas the actual speaker in the dummy stage ended at the left. When the pantomimer reached the position shown at *4A* the voice jumped from him to position *4B* and proceeded off stage to the left, leaving an apparently silent pantomimer walking from *4A* to *5*. It is seen, therefore, that the acoustic illusion is

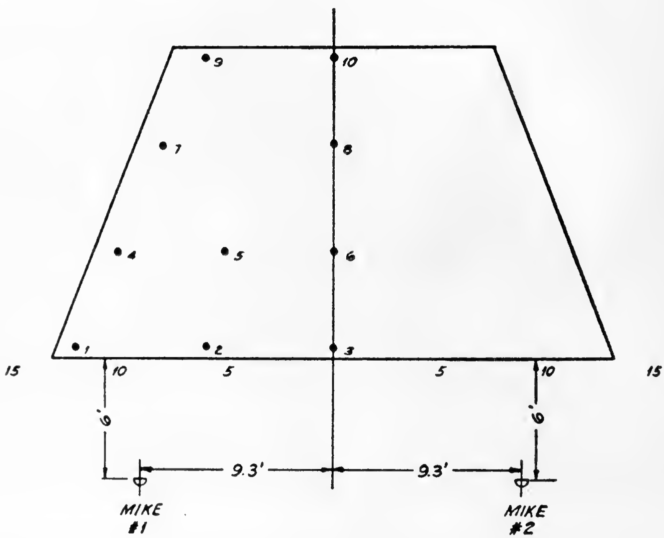


FIG. 8. Diagram of stage of Fig. 7, with positions marked for determining accuracy of sound location.

exceedingly strong and that the disconcerting effect of having the voice come from one position while the picture of the speaker is shown in another position would render a take totally uncommercial.

From a reference to the first of the two important factors controlling stereophonic location, namely, that the sidewise position of the image is dependent upon the ratio of the intensities of the direct sounds falling upon the two microphones, it is obvious that points on the perpendicular bisector of the line joining the pick-up microphones will reproduce as points lying on the perpendicular bisector of the line joining the loud speakers. This requirement causes one of the main difficulties of applying stereophonic technic to present picture production, since it is necessary that the camera axis form the perpendicular bisector of the line joining the pick-up microphones. Since the microphones in general must be located nearer the scene than the camera, this involves a very real problem on panorama shots.

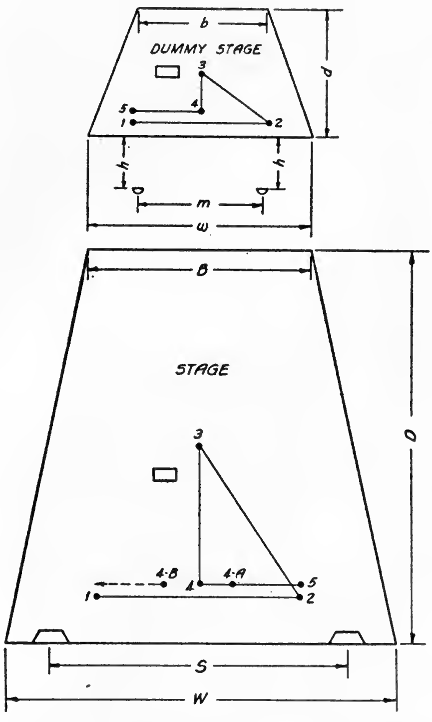


FIG. 9. Experimental stage for testing strength of acoustic illusion.

The second factor of importance indicates that the apparent position of the sound, back of the extreme foreground, is determined mainly by the ratio of the reverberant to the direct sound at the microphone nearest the source. A little consideration of Fig. 8, in which the microphones are shown only 6 feet in front of the extreme foreground of the dummy stage, will show that as a speaker moves from a position directly in front of one microphone straight across the stage to a position directly in front of the other microphone he will have been moving away from the nearest microphone up to the time he reaches the center of the stage. After that he will be continuously approaching the nearest microphone, namely, the one on the other side of the stage. By applying the second principle it is easily seen that the apparent path taken by the reproduced sound will not be a straight line parallel to the front of the stage but rather an arc concave toward the audience.

This characteristic of the system has the unfortunate effect of making close-up reproduction at the center of the stage difficult with the simple two-channel system. It was for this reason, as much as any other, that the third channel was supplied in the earlier demonstrations of stereophonic reproduction. Fortunately, for the practical application of the method, it is possible to obtain close-up stereophonic recording at the center of the stage by the use of a third microphone placed at the stage center. The output of this microphone is fed into each of the side channels through unilateral transmitting devices such as vacuum-tube amplifiers. The essential requirement in this case is absence of feedback from one channel to the other through the connection formed by feeding the output of the third microphone into both channels. Such an arrangement causes no difficulty in the problem of sound location except for extreme long-shots. Under these conditions the accuracy of stereophonic location is sufficiently low so that the pictured position of the source is more than sufficient to correct the stereophonic error.

Stereophonic effects have been synthesized in those cases where not more than one sound is present at any one time. This includes the case of dialog in which one actor speaks first and is answered by the second, and so forth. It would not apply when both actors spoke simultaneously.

Under these conditions of the single sound-source, a long-shot and a close-up sound-track are recorded separately. By a special circuit whereby the output currents from each of the two resulting records can be distributed in any desired ratio between two stereophonic channels, it is possible to make the sound apparently come from any desired point on the picture set. The skill required of the dubbing mixer to accomplish this result is probably not as great as that required for some of the trick sound effects now being handled in Hollywood.

It is believed that stereophonic technic has been carried far enough in its purely experimental phases to make it available for actual picture production when the industry feels the need of another major advance. Problems that will arise under studio conditions should be of a type that can be solved by the application of the same type of ingenuity that the sound departments of the various studios have applied in the past in adapting sound to the silent pictures.

REFERENCES

[1] MAXFIELD, J. P.: "Some Physical Factors Affecting the Illusion in Sound Motion Pictures," *J. Acoust. Soc. Amer.*, **III** (July, 1931), No. 1, p. 69.

[2] MAXFIELD, J. P.: "Acoustic Control of Recording for Talking Motion Pictures," *J. Soc. Mot. Pict. Eng.*, **XIV** (Jan., 1930), No. 1, p. 85.

[3] HEYL, P. R.: Circular No. 396, *National Bureau of Standards* (Dec., 1931).

[4] STANTON, G. T., AND SCHMID, F.: "Acoustics of Broadcasting and Recording Studios," *J. Acoust. Soc. Amer.*, **IV** (July, 1932), No. 1, p. 44.

[5] HANSON, O. B., AND MORRIS, R. M.: "Design and Construction of Broadcast Studios," *Proc. I. R. E.*, **19** (Jan., 1931), No. 1, p. 17.

[6] WATSON, L. R.: "Acoustics of Buildings," *John Wiley & Sons* (New York), 1923.

[7] MAXFIELD, J. P.: "Some of the Latest Developments in Sound Recording and Reproduction," *Technical Bulletin, Acad. Mot. Pict. Arts & Sci.* (Apr., 1935).

[8] FLETCHER, H.: "Auditory Perspective—Basic Requirements," *Electrical Engineering*, **53** (Jan., 1934), No. 1, p. 9.

[9] STEINBERG, J. C., AND SNOW, W. B.: "Auditory Perspective—Physical Factors," *Electrical Engineering*, **53** (Jan., 1934), No. 1, p. 12.

THE PHILIPS-MILLER METHOD OF RECORDING SOUND

R. VERMEULEN*

Summary.—*The first attempt at mechanographic recording and reproducing was made as early as 1891 but no successful solution of the problem was applied until the invention of J. A. Miller in 1931. The principle of this invention is described in the paper as inertia-free magnification. After the introduction of this principle, the inventor coöperated with the research laboratories of the N. V. Philips Company, of Eindhoven, Holland, in order to solve the problems involved in bringing the system to commercial use.*

The method of obtaining a mechanical amplification of forty times is described and illustrated. The mathematical and theoretical advantages of this system over photographic methods are discussed together with the film or tape that has been specially prepared for this process of recording.

Some of the difficulties or precautions that are peculiar to this system and are new to the art of recording, relating to the cutting instrument, cutting material, and also the coating of the film, are described. One type of recording machine is described, with drawings of the most interesting mechanical parts.

As early as 1891, Hymmen was experimenting at Iserlohn with a mechanical method of recording sound that was designed to produce a sound-track suitable for optical reproduction with the aid of a selenium cell. In the method adopted the sound-track was obtained by removing a black coating from a paper base. The technical means required to give this idea practical form were, however, still lacking at the time, and it has been only in recent years that J. A. Miller[1] was able to arrive at what is probably the only practicable solution of the problem. This problem was to obtain sufficiently great amplitudes at the high frequencies entailed, such amplitudes being essential to a faithful sound record.

The Research Laboratory of the N. V. Philips Gloeilampenfabrieken at Eindhoven (Holland) collaborated with the inventor in working out his proposals, and succeeded in evolving a new method of producing a faithful sound record, to which has been given the name of the "Philips-Miller method"; the inventor has also described it as the "mechanographic" method. The combination of mechanical recording and optical reproduction retains the advan-

* N. V. Philips Physics Laboratory, Eindhoven, Holland.

tages both of the sound-on-film record and of the gramophone disk, since the greater part of the difficulties hitherto encountered lie respectively in photographic recording and mechanical reproduction.

Naturally, the new method of recording sound was found to have its own peculiar difficulties, and details of how some of these have been overcome are given in the present article. A short description of the practical details, characteristics, and potential applications of the method will first be given.

Principle of the Philips-Miller Method.—A sound-track, engraved upon a strip of film, is capable of being reproduced in the same way as the track on any ordinary sound-film. The film that was found most suitable for the purpose is composed of a celluloid base (Fig. 1)

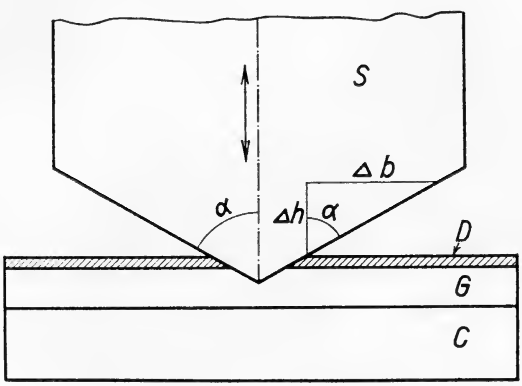


FIG. 1. Section through cutter and film tape.

which, in the place of the usual photographic emulsion, is coated with a layer of transparent gelatin about 60 microns thick, upon which is a very thin opaque coating, about 3 to 5 microns thick. A cutter in the shape of an obtuse-angled wedge, as shown in Fig. 1, is displaced perpendicularly to the plane of the film strip, in synchronism with the sound vibrations to be recorded. This cutter removes a shaving from the gelatin layer passing below it; the thin surface coating as well as some of the gelatin is removed during the process, leaving a transparent trace against an opaque background. When the cutter moves perpendicularly to the film surface, the width of the transparent trace will vary within wide limits (Figs. 2 and 3), such variations in width being, in fact, a linear magnification of the cutter motion. The magnification can readily be calculated from the apical angle 2α of the cutter wedge, *viz.*,

$$\frac{2\Delta b}{\Delta h} = 2 \tan \alpha$$

It has been found that good results are obtained with the angle α = 87 degrees. Since tan 87° = 19, the magnification is then nearly 40.

To obtain a standard sound-track of about $2b$ = 2 mm., as on ordinary sound-films, the displacement of the cutter need have a double amplitude Δh only of

$$\frac{2000}{40} = 50 \text{ microns}$$

This mechanical and inertia-free magnification is the basis of the whole method and permits a sound recorder to be built capable of satisfying every practical requirement.

The basic combination of a mechanical method of recording with the standard method of optical reproduction has various advantages,

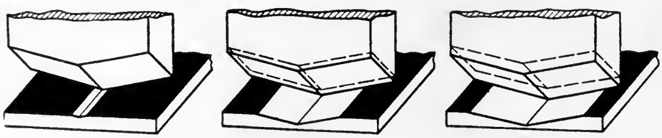


FIG. 2. Widths of track for three positions of cutter.

the chief of which is that the sound-track can be reproduced immediately after recording, without requiring any previous processing. This allows the quality of the recording to be checked almost immediately after the sound-track has been made, the delay being of the order of only $^1/_5$ second.

The majority of the inconveniences encountered in the photographic method are avoided, for the film strip can be handled throughout in ordinary daylight. The sound-track has a sharper definition, since in this case there is no graininess or diffusion of light in the emulsion. Background noise is reduced also, because the coating of the film is free from grain; and the recording of high frequencies is improved since the finite width of the light-slit required in photographic recording is absent. The cutter can be made so keen that it does not limit the frequency band even at very high frequencies (wavelength of 1 mil can be recorded). The transparency of the trace is greater, since no photographic fogging is produced and the blackening of the coating has an optimal value from the outset and the film does not need to be processed.

On the other hand, many of the advantages of the sound-film are retained, since these are not associated with the method of recording but with the method of optical reproduction adopted. A few of these advantages are: long playing time; ease of cutting, splicing, and editing, thus facilitating making composite films; very slight wear of the sound-track base, and avoidance of the needle-changing required with gramophone disks; absence of mechanical reaction upon the sound-film drive, which can thus be of low power, a feature facilitating the maintenance of constant speed.

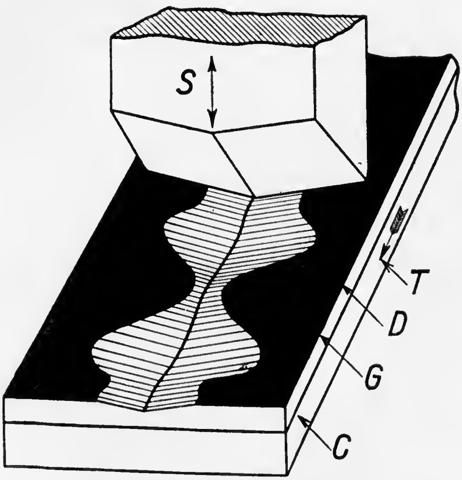


FIG. 3. Form of variable-width track produced by cutter.

Moreover, in contradistinction to recording on gramophone disks, it is customary to record on film for optical reproduction with constant amplitude for the same input at most of the frequencies to be recorded, while with disks the amplitude diminishes with increasing frequency. Particularly at higher frequencies, the amplitudes on the sound-film are thus much more likely to exceed the dimensions of the extraneous particles and inequalities responsible for background noises. The interference level would thus become considerably reduced, if other sources of interference did not obtain. But the film strip contains no photographic grain and is not subject to fogging; moreover, it is not contaminated with foreign particles, which, in spite of the greatest care, always find their way into the developing baths and are deposited upon the film. On the other hand, the freshly engraved surface on the film strip is very clean, although during subsequent use every precaution has to be taken to keep it as clean as possible.

The constancy of amplitude enhances the high frequencies and lowers the interference level, but also requires that the recording cutter have the same amplitude in high-frequency bands as in lower ones.

The Sound Recorder.[2]—This last statement is not quite complete, for while the sensitivity of the sound recorder should be the same for

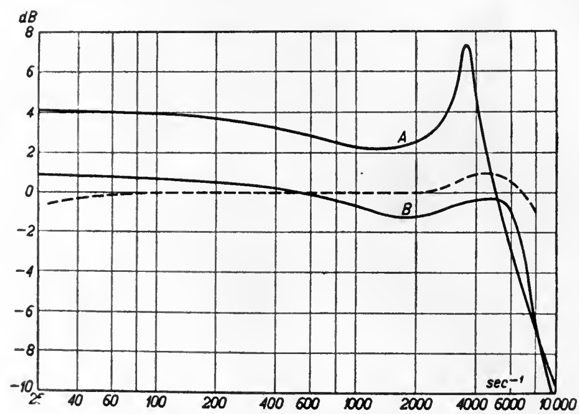


FIG. 4. Frequency characteristic of recorder: (*A*) no load, cutter oscillating freely; (*B*) in normal operation, cutting sound-track.

all frequencies, it does not need to have exactly the same large amplitudes at higher frequencies as in the band around 300 cps., for the harmonics have a much lower intensity than the fundamental tones, as indicated, *inter alia*, by measurements of Fletcher, Sivian, Dunn, and White.[3]

It will be shown below that this point is of great importance. The practical construction of a recorder having a linear frequency-amplitude characteristic up to over 8000 cps. encounters almost insuperable difficulties. The first requirement is naturally a vibration frequency above 8000 cps., *i. e.*, a large restoring force must be applied to the armature, which considerably reduces the sensitivity.

However, since modern means of amplification enable high outputs to be obtained, a small sensitivity would not be prohibitive, except that it results in limitation of the maximum amplitude to a value that would be entirely satisfactory from mechanical considerations but is determined by the heating of the coil or the distortions in the magnetic circuit. A simple calculation will show that the electrodynamic system is inadequate.

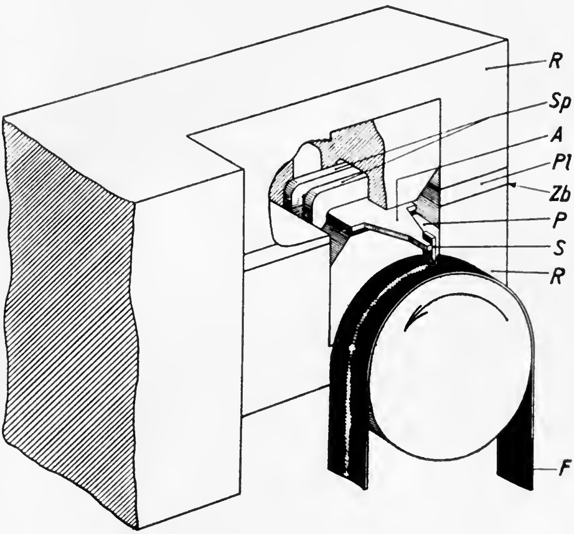


FIG. 5. Interior of driving system:

P, pole-pieces	*Sp*, energizing coils
R, base frame	*Pl*, clamping plates
A, armature	*Zb*, spacing plates
S, cutter	*F*, film

The amplitude a of an electrodynamic system is given by:

$$a = 0.1\,HlIc = \frac{0.1\,HlI}{m\omega^2} = 0.1\,\frac{Hi}{\rho\omega^2}$$

if all masses other than that of the oscillating coil are neglected. In this expression H is the field intensity in the air-gap, I the current intensity and i the current density, l the length of wire on the coil, m the mass of the coil, c the compliance of the system, ω the resonance frequency times $2\,\pi$, and ρ the density of the coil wire.

Even if the high values $H = 15\,000$ gauss, $i = 10$ amperes per sq. mm. are taken, and aluminum ($\rho = 3$ gr. per cu. cm.) is used, an amplitude a of only 10 microns is obtained at a resonance frequency of a mere 3500 cps. This amplitude is not sufficient for modulation of the normal track width of 2 mm. on the sound-film although the magnification of the Miller cutter is 40-fold.

An electromagnetic system, which can not be subjected to a similarly simple calculation, is more suitable for our purpose, since amplitudes of 30 microns can be obtained at a frequency above 5000 cps. without fear of over-modulation; in fact, by a rational design of the constructional elements, further increase in the frequency or amplitude is not out of the question.

The fact that in the frequency band above 5000 cps. full modulation is never required, now assumes very great importance since it makes it permissible to increase the amplification above 5000 cps. and in this way to compensate to a marked extent for the frequency

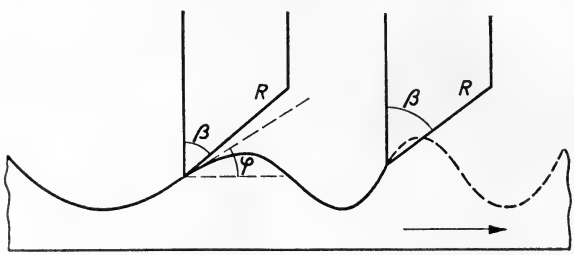


FIG. 6. Diagram showing limitation of cutter amplitude: (*left*) $\varphi + \beta < 90°$ possible; (*right*) $\varphi + \beta > 90°$ impossible.

characteristic of the recorder, without over-modulation of the amplifier and what is more important, of the recorder. The characteristics obtained are reproduced in Fig. 4, while the construction of the recorder is shown in Fig. 5. Since from considerations of sensitivity, the air-gaps between the armature and pole pieces are required to be small the armature is made in one piece with the clamping plates *Pl* and the torsion links, and in addition is carefully ground flat. The pole-pieces are also ground flat in one operation together with those parts of the frame *R* securing the clamping plates. On fixing the armature, thin spacing plates *Zb* are inserted between the ends of the frame and the armature. The four air-gaps are thus quite accurate without further adjustment.

The Cutter.—In photographic recording the finite width of the light-slit limits the high frequencies. In the Philips-Miller method this limitation is absent, since the cutter is made so sharp that it has no finite width. Nevertheless, a limitation is still encountered in the high-frequency band owing to the shape of the cutter, as indicated in Fig. 6. The toughness of the cutter requires that the cutting angle be as large as possible; but if the cutter angle β is too great the rear of the cutter is likely to damage the track already traced should the slope of the track become complementary to the cutter angle. The fact, already mentioned, that at higher frequencies full modulation is never required, also affords relief in this direction. It has been found[3] that an angle $\beta = 55$ degrees is satisfactory with a track 2 mm. wide, and that the cutter is sufficiently tough provided the proper material is selected. The cutter material must not only be very hard but must also be completely homogeneous, whence only single-crystal materials are of use. Homogeneity is a prime consideration, as otherwise a perfectly straight cutting edge can not be obtained. The special significance of a straight cutting edge will be evident when it is remembered that it determines the ratio between the vertical motion of the cutter and the width of the track.

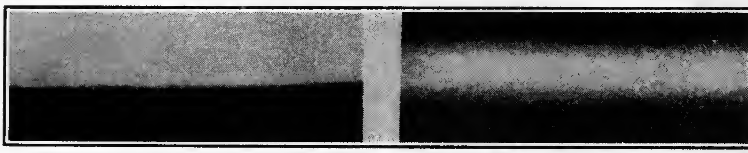
FIG. 7. Attachment of cutter to armature extension of sound recorder.

The attachment of the cutter to the extension of the armature is shown in Fig. 7; it permits the cutter to be changed readily as well as accurate alignment to be obtained without difficulty.

The Recording Strip.—The grinding of the cutter edge is a very delicate process, as minor deviations result in distortion. After the accurate tests in the factory the edges can be guaranteed to be perfectly straight. It would, however, be serious if the cutter edge should suffer deformation during recording.

Investigations have shown that nearly all wear and damage sustained by the cutter may be traced back to inhomogeneities and foreign particles in the coating on the film. This problem has also been examined, and a suitable, although not altogether simple, solution has been found. Gelatin was selected as a base for the recording strip, as it could be converted into a suitable material by partial decomposition. the addition of oil, thorough filtering, and other means. The resulting product gave a well-defined sound-track, a satisfactory and coherent shaving, and very sharp track edges, and contained extremely few foreign particles and was quite homogeneous. The excellent definition of the edges is the most striking characteristic of a film strip sound-track. This is produced by a coating of only 3 to 5 microns in thickness, which is free from grain and has a minimum density 1.4 in the infrared. A higher density would be of little use, as it would not increase the intensity of the signal furnished by the photoelectric cell. The density increases rapidly with diminishing wavelength of the incident light, this being an important advantage as regards the photographic printing of the film strip positive.[5]

The edge of a Philips-Miller sound-track is compared with a photographic record in Fig. 8.



(*a*) (*b*)

FIG. 8. (*a*) Edge of unmodulated Philips-Miller sound-track (100 ×); (*b*) micro record of stationary track on experimental film of good quality (photographic process).

If the thickness of the film strip varies, the width of the track will also vary, and on a scale 40 times as great. Should the thickness vary gradually over the length of the film, only the width of the unmodulated trace and hence the permissible coefficient of modulation would be altered. But if the thickness variation occurs on a short length of film, there is always the possibility that this would be detectable in the sound delivered by the loud speaker.

The film strip is manufactured by such processes that the total variation in thickness does not exceed about 6 microns, and over short lengths not more than about 4.5 microns, while the thickness of the track coating is never less than the minimum required for full modulation.

The Mechanical Recorder.—Although the efficiency of sound-film recording and reproducing apparatus has been brought to a high level, new problems had, nevertheless, to be solved in developing the Philips-Miller method of recording. The method of reproduction is the same as with other sound-films; yet during recording the film strip is required to sustain considerable mechanical stresses that are entirely absent in photographic recording. However, the existence of a mechanical force, as also occurs in recording on disks, is not an insuperable obstacle. By coupling the recording medium tightly to a sufficiently heavy flywheel, the speed can be made as constant

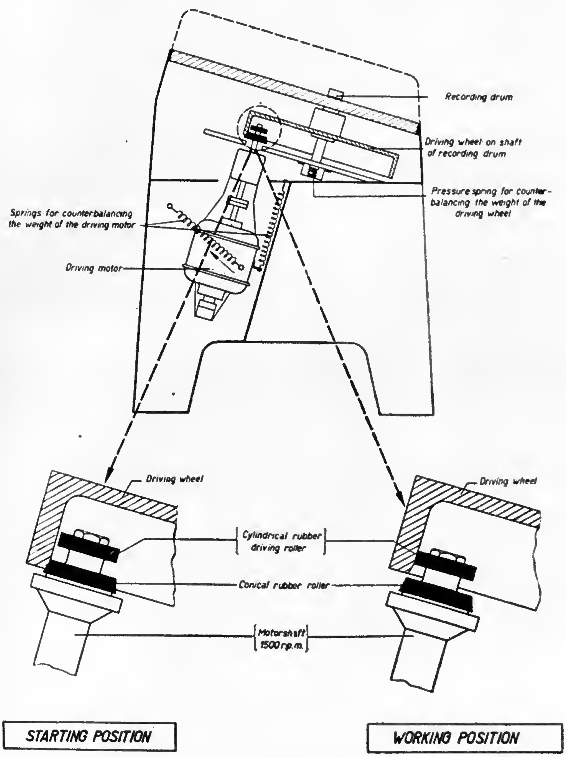


FIG. 9. Driving system for the film tape.

as desired. The sprocket-holes as provided in standard films would appear to offer the most suitable, and in fact, the indispensable medium through which the coupling could be effected. Nevertheless, practical experience has not confirmed this, for the pitch of the sprocket-holes was found not sufficiently accurate. Even if the film were made with the greatest care excessive variations were still found to result from the contraction of the celluloid. That these variations constitute a more serious drawback in the present case than in photographic recording may be gathered from the following:

The forces that are applied to the film during the cutting of the track will pull the film abruptly from one sprocket-tooth to the next as soon as it is released by the first sprocket-tooth. When no force, or only a slight force, is applied to the film the change from one tooth to the next might take place more or less gradually in view of the friction operating, the departure from uniform motion being then reduced. In photographic recording as well as in reproduction, the modern tendency, however, is to eliminate even these reduced

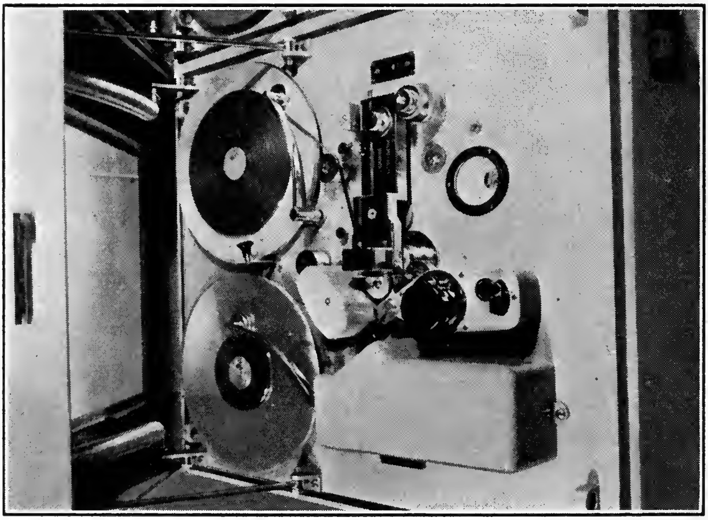


FIG. 10. Recording and reproducing machine for broadcasting use.

deviations and to avoid using the sprocket-holes when possible, as they always introduce modulation of the reproduced tone at the sprocket-hole frequency.

It was, therefore, gratifying to find that, contrary to expectation, it was possible to engrave the film on a smooth drum, provided the film could be pressed with sufficient force against the drum by means of pressure rollers. It was found advantageous to cover the pressure rollers with rubber. Naturally, the recording drum could not be covered in the same way, as the compliance of the surfaces would result in distortion of the track. The variable force on the strip during recording also introduces additional difficulties in driving the flywheel to which it is coupled. To ensure that the flywheel fulfills its proper function, the driving force must be transmitted by a flexible coupling capable of absorbing irregularities in motion, so that the flywheel rotates at constant speed. The greater the resilience of the flexible coupling, the less will fluctuations in the motion affect the flywheel, and hence the greater will be the degree of uniformity obtained in the motion of the strip.

The speed of the strip must satisfy two conditions: In the first place, the speed must not be subject to rapid fluctuations, since the ear is particularly susceptible to such variations. It is stated that with 3 changes per second a difference in pitch of 0.3 per cent is still discernible. Second, the absolute value of the pitch must not differ to a great extent from the original value, since evidently many persons are capable of detecting differences of less than 3 per cent, even when spread over considerable periods.[6]

The action of the flexible coupling is, however, such that an alteration in velocity must accompany a change in the applied load, since the tension of the flexible coupling must be increased in order to supply the greater driving force; hence the flywheel must be retarded. Regarded from this point of view, it is desirable to make the coupling as rigid as possible, so that the linkage between the flywheel and the rotating field of the synchronous motor drive becomes as tight as possible. Calculation shows that the conditions governing the permissible acceleration and the permissible speed variation place two restrictions upon the rigidity of coupling. Both conditions can be satisfied simultaneously only if the imperfections in the drive are not too great.

The designer of the recording machine, J. C. Hardenberg, has arrived at a solution that fully meets the formulated requirements. Coupling is made so direct, and the resultant accuracy is so great, that mechanical smoothing by added inertial mass can actually be dispensed with, the intrinsic inertia and elasticity sufficing to ensure maintaining the requisite constancy of speed. Transmission from the high-speed motor shaft to the low-speed shaft of the recording drum is through a friction wheel gearing, thus dispensing with toothed wheels altogether (Fig. 9). The low-speed wheel is of very large diameter. In contact with the inside of the flange runs a wheel mounted on the motor shaft. The outer periphery of this wheel has a specially prepared rubber surface. During starting, the rubber wheel might be subject to abnormal wear, to avoid which a second, conical, wheel is used in its place during the starting period. This conical wheel runs in contact with the lower edge of the flange. On starting, the starting resistance is first cut out by rotating a handwheel; on further turning the handwheel, the motor drops a little, so that the conical wheel becomes disengaged and the drive is continued through the cylindrical wheel.

The type of mechanical recorder constructed for radio purposes and which is in use in some European radio transmitters is shown in

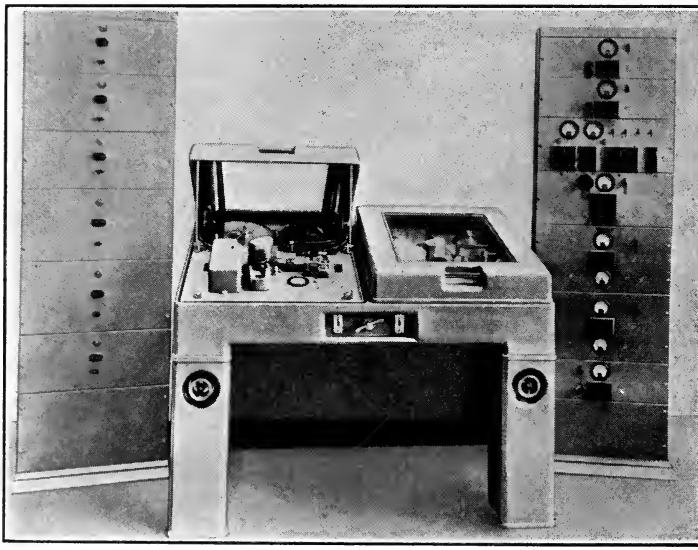


FIG. 11. Complete Philips-Miller radio broadcasting equipment. In the center is the recording and reproducing machine; on the right the amplifier track, and on the left the power supply rack.

Figs. 10 and 11. For continuous recording and reproduction, the plant is duplicated so that it is possible to change over from one machine to another without interruption.

The film strip is driven solely from the smooth pulley on which track recording also takes place; this is possible owing to the smoothness of the friction drive to the two film reels. Guide rollers on the outside of the reels control the tension on the strip. After leaving the recording drum, the strip passes the scanning gate, which is fitted with the usual exciter lamp and photoelectric cell. This arrangement enables the quality of recording to be tested immediately after recording, the interval between recording and reproduction being extremely short.

By turning the large knob shown in the middle of the illustration, the pressure roller can be raised from the cutting pulley, while at the same time a rubber finger holds the film strip against the scanning gate. This allows the strip to be arrested in a very short time, while the motor and the whole driving system continue to run. Conversely, the strip can also be brought up to its normal speed again very quickly by releasing the rubber finger and replacing the pressure roller in contact. This avoids "howling" when switching on the strip, an important point particularly when switching over reproduction or recording from one machine to the other.

In addition to those designed for radio purposes, machines have also been built for synchronized sound accompaniment to silent films, when, in view of the fact that the drive operates through the smooth recording pulley, special means must be employed to obtain perfect synchronism between the sprocket-holes on the picture film and on the film strip. The description of these machines, as well as a discussion of the design of the accessories, is beyond the scope of the present article, which is merely to give a general outline of the new method of recording sound.

REFERENCES

[1] MILLER, J. A.: "Mechanographic Recording for Motion Picture Sound-Tracks," *J. Soc. Mot. Pict. Eng.*, **XXV** (July, 1935), No. 1, p. 50.

[2] VANURK, A. TH.: *Philips Techn. Rev.*, **1** (May, 1936), p. 135.

[3] SIVIAN, L. S., DUNN, H. K., AND WHITE, S. D.: *J. Acoust. Soc. Amer.*, **2** (1931), p. 330.

[4] CRAMWINCKEL, A.: *Philips Techn. Rev.*, **1** (July, 1936), p. 211.

[5] DIPPEL, C. J.: *Philips Techn. Rev.*, **1** (Aug., 1936), p. 230.

[6] DEBOER, J.: *Philips Techn. Rev.*, **2**, "Tonfilm," *Fischer & Lichte*, p. 250.

REPORT OF MEMBERSHIP AND SUBSCRIPTION COMMITTEE*

Summary.—*A statement of the growth of membership of the Society and non-member subscriptions for the Journal during the past six months.*

Despite the fact that we have had six months of recession since our Fall Meeting, the growth of our Society has been a steady one. Since the first of the year, 90 new members have been added—an average of approximately 26 per month or about two more per month than the average for last year. In addition, 24 applications are pending whereas at the time of our Fall Meeting only 14 were pending.

Our membership as of April 15th was 1333, the largest it has ever been in the history of the Society. Broken down into the following grades, we have:

6	Honorary Members
140	Fellow
346	Active
841	Associate
1333	Total

If the six applications for Associate grade and 18 for Active are included, the total membership is 1357. Twenty members have resigned since the first of the year.

The growth in subscriptions, we are happy to say, has likewise been very substantial. At our convention last Fall we had a total of 345 subscriptions. Since then we have added 80 and lost 3, making a total of 422 as of April 15th.

From these figures, as well as from the membership figures, it is seen that the growth of the Society has been very substantial despite the fact, as mentioned above, that we have been going through a very pronounced recession. If there is substantial improvement in business conditions during the latter part of the year, it is safe to predict that we shall have a membership of 1400 by December 31st.

E. R. Geib, *Chairman*

* Presented at the Spring, 1938, Meeting at Washington, D. C.; received April 25, 1938.

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 copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in those magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C.

American Cinematographer

19 (March, 1938), No. 3

Fred Gage Creates Great Lab at Warners' Burbank Studio (p. 96).	W. STULL
Working by Radiophone Brings New Air Thrill (p. 98).	G. BLAISDELL
Leica Gets Away from Tripod by Employing Gunstock for Platform (p. 117).	
General Electric's "New Exposure Meter for Better Pictures" Described by Expert (p. 118).	F. C. BOBIER

Communications

18 (March, 1938), No. 3

Background Noise Corrections (p. 24).	L. E. PACKARD

Electronics

11 (March, 1938), No. 3

A Versatile Level Meter (p. 13).	F. SCHUMANN
Direct Disc Recording (p. 22).	C. J. LEBEL
Television without Sync Signals (p. 33).	

International Photographer

10 (March, 1938), No. 2

Tradewinds. (Duplex Super Camera, Hugo Meyer Cine Lens, Leica Gun, Balsley and Phillips Sound Adaptation equipment for 16-Mm. Film) (p. 5).
New Aerial Lens (Bausch & Lomb) (p. 10).
Disney Multiplane Camera (p. 18).
Lighting Sets—Super Light Sought (p. 27).
Multiple Toning (p. 29).

Home Movies

6 (March, 1938), No. 10

The "Sonodisc" System (p. 435).

International Projectionist

13 (March, 1938), No. 3

The Geneva Intermittent-Movement: Its Construction and Action (p. 7). — A. C. SCHROEDER

Television and the Electron (p. 16). — V. K. ZWORYKIN

Analysis of Modern Theatre Sound Reproducing Units (p. 19). — A. NADELL

Chaotic Status of Laws Anent Projection Technic, Equipment, Rooms, Revealed by Nation-Wide Survey (p. 27).

Proceedings of the Institute of Radio Engineers

26 (March, 1938), No. 3

Radio Progress During 1937 (Three Parts) (p. 277).

Excess-Energy Electrons and Electron Motion in High-Vacuum Tubes (p. 346). — E. G. LINDER

BACK NUMBERS OF THE TRANSACTIONS AND JOURNALS

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

	No.	Price		No.	Price		No.	Price
1920	10	$1.00	1925	21	$1.25	1927	29	$1.25
1921	12	1.00		22	1.25		32	1.25
	13	1.00		23	1.25	1928	33	2.50
1922	14	1.00	1926	24	1.25		34	2.50
	15	1.00		25	1.25		35	2.50
1923	16	2.00		26	1.25		36	2.50
1924	19	1.25		27	1.25	1929	37	3.00
	20	1.25		28	1.25		38	3.00

Beginning January, 1930, the JOURNAL of the Society has been issued monthly, in two volumes per year, of six issues each. Back numbers are available at $1.00 each, a complete yearly issue totaling $12.00. Single copies of the current issue may be obtained for $1.00 each. Orders for back numbers of *Transactions* and JOURNALS should be placed through the General Office of the Society and should be accompanied by check or money-order.

HIGHLIGHTS OF THE SPRING CONVENTION

WARDMAN PARK HOTEL, WASHINGTON, D. C.
APRIL 25–28, 1938

The first meeting of the Society in Washington was the organization meeting held in 1916. The next meeting there was not held until 1926, ten years later. About 1930, however, the Government became more interested in motion pictures, and thereafter Conventions were held in Washington almost at regular intervals—May, 1930; May, 1932; October, 1935; and April, 1938.

The number of Governmental departments interested in producing, handling, or storing motion picture is increasing, and the quantity of film involved is extremely large. Among the departments of the Government engaged in motion picture activities are the War Department, Department of the Interior, Department of Commerce, Department of Agriculture, the National Archives, Department of Education, and others.

In view of this, it is appropriate that the Society hold Conventions at the Nation's capital at fairly frequent intervals. The attendance at the Convention just ended, including registered members, guests, and visitors, was well in excess of 300, and the technical sessions were uniformly well attended. Approximately 180 members registered, and about 200 persons were present at both the luncheon and the banquet. Approximately 60 projectionists were present at the Projection Session on Wednesday.

TECHNICAL SESSIONS

The Convention opened at 10 A.M. on Monday, April 25th, with introductory remarks by President Wolf and several Committee reports. Then followed a paper by E. S. Phillips on some of the "Problems Involved in Full-Color Reproduction of the Growing Chick Embryo." The problems discussed related particularly to lighting and photography, and the Kodachrome film shown at the conclusion of the paper was a fine example of such work.

The Progress Report, summarizing the technical progress of the industry during the past six months, and a paper on "Sound Stages and Their Relation to Air-Conditioning" by C. M. West and L. L. Lewis focused attention upon several outstanding developments of the past year. The latter paper presented data on many factors that must be considered by the ventilation engineer when designing air-conditioning installations in modern studios.

At noon of the same day the usual informal get-together luncheon was held, attended by approximately 200 members and guests. Seated at the Speakers' table, in addition to President Wolf and other officers of the Society, were the Honorable Daniel C. Roper, Secretary of Commerce; the Honorable Clarence F. Lea, Congressman from California; and Col. Daniel I. Sultan, Engineer Commissioner for the District of Columbia. Col. Sultan welcomed the Society to

Washington and Congressman Lea spoke briefly on behalf of Senator W. G. McAdoo, who unfortunately was prevented from attending. The luncheon proceedings concluded with a very interesting address by Secretary Roper.

The afternoon session of Monday was devoted to photographic and laboratory problems, and opened with a tutorial paper by L. A. Jones on the subject of "The Determination of Correct Exposure in Photography." W. J. Albersheim's paper on "Latent Image Theory" presented data both of theoretical and practical interest relating to the fundamental mechanism of image formation in photography, and stimulated a very interesting discussion. The "Effect of Aeration upon the Photographic Properties of Developers" was discussed by Messrs. J. I. Crabtree and C. H. Schwingel, with particular relation to the fundamentals of aeration; and a paper by C. E. Ives and C. J. Kunz discussed the problem of suitable devices for agitating solutions with compressed air. S. E. Sheppard and R. C. Houck presented a paper on "The Influence of pH on the Washing of Processed Films," a subject of interest in relation to film storage.

The evening of Monday was devoted to a lecture by H. E. Ives on "The Transmission of Motion Pictures over a Coaxial Cable," followed by a showing of *The Adventures of Marco Polo* and several short subjects. Dr. Ives' lecture described work done on the transmission of television signals over an experimental circuit between New York and Philadelphia.

The morning session of Tuesday, April 26th, was devoted to color cinematography, the first three papers representing an exhaustive study of color in the abstract. "The Inter-Relationship of the Various Aspects of Color" was discussed by L. A. Jones; "The Fundamentals of Color Measurement" by D. L. MacAdam; and "The Theory of Color Reproduction" by A. C. Hardy. In view of the increasing use of color in motion pictures, these subjects, relating to the determination and specification of color, are of great importance at this stage of development and commercialization. The session concluded with a description of "The Multiplane Crane for Animation Photography," introduced recently for photographing the feature-length cartoon *Snow White and the Seven Dwarfs*. The special equipment required was described in considerable detail.

The afternoon session opened with two papers on ultraviolet records, G. L. Dimmick and L. T. Sachtleben describing "An Ultraviolet Push-Pull Recording Optical System for Newsreel Cameras," and J. O. Baker a proposed method for "Processing Ultraviolet Recordings on Panchromatic Films." The paper by G. Friedl, Jr., entitled "A New Sound System," described in detail some of the features of the new Simplex sound system and the considerations involved in developing a high-quality system for small and large theaters. The report of the Standardization Committee of the Research Council of the Academy of Motion Picture Arts & Sciences, on "Specifications for the Design of New Theater Reproducing Equipment," read by S. W. Colledge, aroused considerable controversial discussion. The session concluded with a presentation of the fundamentals of "Push-Pull Recording with the Light-Valve," by J. G. Frayne; and a discussion of the methods of "Multiple-Channel Recording," using a multiplicity of recording channels later to be dubbed into one track by the mixer. The latter system was recently used in the production *One Hundred Men and a Girl*.

The evening of Tuesday, April 26th, was devoted to a symposium on educational and industrial applications of motion pictures, with demonstration films;

and a paper by R. W. Seawright and W. V. Draper, describing some of the trick effects used in the recent picture production *Topper*.

The morning session of Wednesday, April 27th, was devoted to optics and projection. A very interesting presentation was that of "The Water-Cooled Quartz Mercury Lamp," by E. B. Noel and R. E. Farnham. The structure and application of the lamp were described with particular reference to motion picture projection and photography and the lamp itself was demonstrated.

The report of the Projection Practice Committee was an outstanding one. It contained the facts gathered from the survey recently conducted by the Committee, of approximately 600 theaters, covering the factors involved in constructing theaters according to the principles of viewing pictures. These factors include such dimensional data as determine the viewing angles, the obstruction of vision, the proportions of the theater, and projection characteristics.

Much interest was aroused in a paper by O. Reeb, of Berlin, Germany, entitled "A Consideration of the Screen Brightness Problem." This paper took into account not only the papers published in the JOURNAL, notably by the Projection Screen Brightness Committee, but also a number of recent German works. It was interesting to note the spirit of collaboration that existed in all this work among the various authors working independently and in various countries, and also the close agreement between the values of screen brightness arrived at by all these workers and by the Projection Screen Brightness Committee.

The afternoon of Wednesday was devoted to a symposium on 16-mm. film and equipment. Papers by J. A. Maurer and W. Bach on "The Shrinkage of Acetate-Base Motion Picture Films," and by J. A. Maurer and W. H. Offenhauser, entitled "A Criticism of the Proposed Standard for 16-Mm. Sound-on-Film," aroused considerable discussion. E. K. Carver, Chairman of the Standards Committee, in commenting on the latter paper thanked the authors for their valuable contribution to the subject and requested others to assist the Committee whenever possible by experimental data. When such critical tests are in progress the Standards Committee is always interested to know about them.

The latter part of the afternoon was devoted to the apparatus symposium. Among the equipment described and demonstrated should be mentioned "A New Indicator for Sound-Level Measurements," by S. K. Wolf and S. J. Begun. This device consists of a glass tube approximately 18 inches long and 1 inch in diameter, so arranged that sections of the tube fluoresce in different colors according to the intensity of the impressed audio signal. A "New Background Projector for Process Cinematography," particularly adapted for Technicolor work, was described by G. H. Worrall.

On the evening of Wednesday, April 27th, the semi-annual banquet and dance of the Society was held. President Wolf opened the proceedings and introduced the guests at the Speakers' table. Those seated at the Speakers' table were as follows: S. A. Lukes, Chairman of the Mid-West Section of the Society; O. Reeb, of Osram G. m. b. H., Berlin, Germany, who delivered a brief message from the Deutsche Kinotechnische Gesellschaft; Dr. C. E. Kenneth Mees, Vice-President in Charge of Research and Development of the Eastman Kodak Company, Rochester; President S. K. Wolf; Dr. Alexander V. Dye, Director of the U. S. Bureau of Foreign and Domestic Commerce; Mr. E. D. Kuykendall, President of Motion Picture Theater Owners of America; Congressman Charles

Kramer, of California; and Dr. J. G. Frayne, of Hollywood. Present at the banquet also was Mr. Thomas Armat, Honorary Member of the Society.

After the introductions, Dr. Mees presented the address of the evening: "Research—the Yeast of Business." It was clearly pointed out that industries that set aside funds for and conducted research usually were more progressive and weathered depressions better than those that did not. The speaker made a strong plea that more research be organized in order to ensure more securely the future of industry in this country. The evening was concluded with dancing.

Both the morning and afternoon sessions of Thursday, April 28th, were devoted to sound. E. D. Cook described "A Method of Determining the Scanning Loss in Sound Optical Systems," prefacing his remarks with a discussion of aperture and optical losses. A comparison method was discussed of segregating film loss from other losses under specified conditions. "An Optical System for the Reproduction of Sound from 35-Mm. Film"—a slitless system—was described by J. H. McLeod and F. E. Altman. Further progress on the problem of film preservation was reported by J. G. Bradley, Chairman of the Committee on Preservation of Film, who described proposed recommendations on handling and winding films, safe and economical storage, vent sizes, and printers for old and shrunken films. Messrs. F. L. Hopper and H. R. Kimball presented papers dealing with electrical networks used in sound recording and reproducing.

ACKNOWLEDGMENTS

Conventions of the Society are made possible only through the coöperation and collaboration of a large number of officers, members, friends, and companies. The general facilities of the Convention were arranged by Mr. W. C. Kunzmann, *Convention Vice-President;* Messrs. H. Griffin, J. Frank, and G. Friedl, Jr., in charge of projection facilities; Mr. N. D. Golden, *Chairman*, Local Arrangements Committee; Mr. R. Evans, *Chairman*, the Banquet Committee; Mrs. R. Evans, *Hostess;* and Mr. E. R. Geib, *Chairman*, Membership Committee.

Credit for the papers program and technical arrangements are due to Mr. J. I. Crabtree, *Editorial Vice-President*, and Mr. G. E. Matthews, *Chairman*, Papers Committee.

Among the companies who contributed in equipment and service to the Convention were the following: International Projector Corporation; National Carbon Co.; Hertner Electric Co.; General Electric Supply Co.; Raven Screen Co.; Eastman Kodak Company; Harry H. Strong Co.; Bausch & Lomb Optical Co.; Electro-Acoustic Products Co.; J. E. McAuley Manufacturing Co.; and National Theater Supply Co.

Thanks are due also to the officers and members of Local 224 I. A. T. S. E. for providing the projectionists for the Convention.

The Society is indebted to the following companies for the films loaned for the motion picture performances held on the evenings of Monday and Tuesday, April 25th and 26th—RKO Radio Pictures; Metro-Goldwyn-Mayer Corp.; Twentieth Century-Fox Film Corp.; Technicolor Motion Picture Corp.; United Artists Corp.; Walt Disney Productions, Ltd.; and U. S. Steel Corp.

Acknowledgment is due also to Warner's *Uptown* and *Earle* Theaters, RKO *Keith's* Theater, and Loew's *Capital, Palace*, and *Columbia* Theaters for supplying passes to members and guests during the week of the Convention.

PROGRAM*

SPRING, 1938, CONVENTION, WASHINGTON, D. C.

WARDMAN PARK HOTEL

MONDAY, APRIL 25th

10:00 a. m. **Business and General Session; S. K. Wolf,** *Chairman.*

Opening Remarks by S. K. Wolf, *President.*

Report of the Convention Committee; W. C. Kunzmann, *Convention Vice-President.*

Report of the Membership Committee; E. R. Geib, *Chairman.*

Report of the Papers Committee; G. E. Matthews, *Chairman.*

Society Business.

"Progress in the Motion Picture Industry;" Report of the Progress Committee; J. G. Frayne, *Chairman.*

"Problems Involved in Full-Color Reproduction of Growing Chick Embryo;" E. S. Phillips, Cornell University, Ithaca, N. Y. (*Demonstration.*)

"Sound Stages and Their Relationship to Air-Conditioning;" L. L. Lewis and C. M. Wert, Carrier Corp., Syracuse, N. Y.

"Documentary Film Study—a Supplementary Aid to Public Relations;" A. A. Mercey, School of Public Affairs of American University, Washington, D. C.

12:30 p. m. **Informal Luncheon.**

For members, their families, and guests.

Addresses by:

Hon. Daniel C. Roper, Secretary of Commerce.

Hon. Clarence F. Lea, Congressman from California.

Col. Daniel I. Sultan, Engineer Commissioner for the District of Columbia.

2:00 p. m. **Photographic and Laboratory Session; J. I. Crabtree,** *Chairman.*

"The Determination of Correct Exposure in Photography;" L. A. Jones, Eastman Kodak Co., Rochester, N. Y.

"Latent Image Theory and Its Application to Low-Intensity Photographic Exposure;" W. J. Albersheim, Electrical Research Products, Inc., New York, N. Y.

"Some Studies in Monochrome Images;" K. Famulener, Afga Ansco Corp., Binghamton, N. Y. (*Demonstration.*)

---

* As actually followed at the sessions.

"Solution Agitation by Means of Compressed Air;" C. E. Ives and C. J. Kunz, Eastman Kodak Co., Rochester, N. Y.

"Effect of Aeration on the Photographic Properties of Developers;" J. I. Crabtree and C. H. Schwingel, Eastman Kodak Co., Rochester, N. Y.

"Maintenance of a Developer by Continuous Replenishment;" R. M. Evans, Eastman Kodak Co., Rochester, N. Y.

"The Influence of *p*H on the Washing of Processed Films;" S. E. Sheppard and R. C. Houck, Eastman Kodak Co., Rochester, N. Y.

"A New Densitometer;" H. Neumann, Klangfilm G. m. b. H., Berlin, Germany.

8:00 p. m. **Lecture and Motion Pictures; S. K. Wolf,** *Chairman.*

"The Transmission of Motion Pictures over a Coaxial Cable;" H. E. Ives, Bell Telephone Labs., Inc., New York, N. Y.

Showing of recent motion pictures.

TUESDAY, APRIL 26th

9:30 a. m. **Color Session; A. C. Hardy,** *Chairman.*

"The Inter-Relationship of the Various Aspects of Color;" L. A. Jones, Eastman Kodak Co., Rochester, N. Y.

"The Fundamentals of Color Measurement;" D. L. MacAdam, Eastman Kodak Co., Rochester, N. Y. (*Demonstration.*)

"The Theory of Color Reproduction;" A. C. Hardy, Massachusetts Institute of Technology, Cambridge, Mass.

"Screen-Film Negative-Positive Process;" T. T. Baker, Dufaycolor, Inc., New York, N. Y. (*Demonstration.*)

"The Multiplane Crane for Animation Photography;" W. E. Garity, Walt Disney Productions, Inc., Hollywood, Calif. (*Demonstration.*)

2:00 p. m. **Sound Session; A. N. Goldsmith,** *Chairman.*

"An Ultraviolet Push-Pull Recording Optical System for Newsreel Cameras;" G. L. Dimmick and L. T. Sachtleben, RCA Manufacturing Co., Inc., Camden, N. J. (*Demonstration.*)

"Processing of Ultraviolet Recordings on Panchromatic Films;" J. O. Baker, RCA Manufacturing Co., Inc., Camden, N. J. (*Demonstration.*)

"A New Sound System;" G. Friedl, Jr., International Projector Corp., New York, N. Y. (*Demonstration.*)

"Specifications for Design of New Theater Reproducing Equipment"—Report of Standardization Committee of the Research Council of the Academy of Motion Picture Arts and Sciences, Hollywood, Calif.

Report of the Standards Committee; E. K. Carver, *Chairman.*

"Push-Pull Recording with the Light-Valve;" J. G. Frayne and H. C. Silent, Electrical Research Products, Inc., Hollywood, Calif. (*Demonstration.*)

"Multiple-Channel Recording;" H. G. Tasker, Universal Pictures Corp., Universal City, Calif. (*Demonstration.*)

8:00 p. m. **Educational and Industrial Applications of Motion Pictures; N. D. Golden,** *Chairman.*

"The Educational Value and Preparation of U. S. Army Training Films;" Captain R. T. Schlosberg, Signal Corps, U. S. Army, Washington, D. C. (*Demonstration.*)

"New Uses for Instructive Motion Pictures;" H. Roger, Rolab Photo-Science Laboratories, Sandy Hook, Conn. (*Demonstration.*)

"Producing Industrial Films;" J. A. Norling, Loucks & Norling Studios, New York, N. Y. (*Demonstration.*)

"An Industrial Visual Instruction Section;" J. G. T. Gilmour, General Electric Co., Schenectady, N. Y. (*Demonstration.*)

"Photographic Effects in the Feature Production 'Topper';" R. W. Seawright and W. V. Draper, Hal Roach Studios, Culver City, Calif. (*Demonstration.*)

WEDNESDAY, APRIL 27th

9:30 a. m. **Optics and Projection Session; L. A. Jones,** *Chairman.*

"A Higher-Efficiency Condensing System for Motion Picture Projectors;" F. E. Carlson, General Electric Co., Cleveland, Ohio.

"The Water-Cooled Quartz Mercury Lamps;" E. B. Noel and R. E. Farnham, General Electric Co., Cleveland, Ohio.

"Theory *vs.* Practice;" F. H. Richardson, Quigley Publishing Co., New York, N. Y.

Report of the Exchange Practice Committee; A. W. Schwalberg, *Chairman.*

Report of the Projection Practice Committee; H. Rubin, *Chairman.*

"A Consideration of the Screen Brightness Problem;" O. Reeb, Osram G. m. b. H., Berlin, Germany.

"Wide-Screen Projection at the 1937 Paris International Exposition;" H. Griffin, International Projector Corp., New York, N. Y.

"Good Tools Pay for Themselves;" J. R. Prater, Congress Theater, Palouse, Washington.

"A Technic for Testing Photographic Lenses;" W. C. Miller, Paramount Productions, Inc., Hollywood, Calif.

2:00 p. m. **16-Mm. Symposium; H. Griffin,** *Chairman.*

"Some Unusual Adaptations of 16-Mm. Equipment for Special Purposes;" J. L. Boon, Eastman Kodak Co., Rochester, N. Y.

"A New 16-Mm. Projector;" H. C. Wellman, Eastman Kodak Co., Rochester, N. Y.

"The Shrinkage of Acetate-Base Motion Picture Films;" J. A. Maurer and W. Bach, The Berndt-Maurer Corp., New York, N. Y.

"A Criticism of the Proposed Standard for 16-Mm. Sound-on-Film;" J. A. Maurer and W. H. Offenhauser, Jr., The Berndt-Maurer Corp., New York, N. Y. (*Demonstration.*)

"A Continuous Optical Reduction Sound Printer;" M. G. Townsley and J. G. Zuber, Bell & Howell Co., Chicago, Ill.

3:30 p. m. **Apparatus Symposium and Manufacturers' Announcements; E. A. Williford,** *Chairman.*

"An Automatic Camera Timer for Time-Lapse Cinematography;" H. Roger, Rolab Photo-Science Laboratories, Sandy Hook, Conn.

"A Basically New Framing Device for 35-Mm. Projectors;" H. A. DeVry, Herman A. DeVry Corp., Chicago, Ill.

"A Film Cement Pen;" R. J. Fisher, Rochester, N. Y.

"New Piezoelectric Devices of Interest to the Motion Picture Industry;" A. L. Williams, Brush Development Co., Cleveland, Ohio.

"Characteristics of Supreme Panchromatic Negative;" A. W. Cook, Agfa Ansco Corp., Binghamton, N. Y.

"A New Indicator for Sound-Level Measurements;" S. K. Wolf and S. J. Begun, Acoustic Consultants, Inc., New York, N. Y. (*Demonstration.*)

"New Background Projector for Process Cinematography;" G. H. Worrall, Mitchell Camera Corp., Hollywood, Calif.

"A Roller Developing Rack with Stationary Drive;" C. E. Ives, Eastman Kodak Co., Rochester, N. Y.

"A New Projector Mechanism;" H. Griffin, International Projector Corp., New York, N. Y.

"A Device to Promote Safety in Motion Picture Projection Rooms and Auditoriums;" E. R. Morin, Department of State Police, Hartford, Conn.

"The Resonoscope;" S. K. Wolf and L. B. Holmes, Acoustic Consultants, Inc., New York, N. Y.

7:30 p. m. **Semi-Annual Banquet.**

Address: "Research—the Yeast of Business;" by Dr. C. E. Kenneth Mees, Vice-President in Charge of Research and Development, Eastman Kodak Co., Rochester, N. Y.

Entertainment and dancing.

THURSDAY, APRIL 28th

10:00 a. m. **Sound Session; J. G. Frayne,** *Chairman.*

"A Study of the Processing Conditions for Variable-Width Sound Recordings on High-Resolution Films;" J. O. Baker, RCA Manufacturing Co., Inc., Camden, N. J. (*Demonstration.*)

"Sound Recording by Color Modulation (Van Leer System);" A. L. Williams, Brush Development Co., Cleveland, Ohio. (*Demonstration.*)

"Tracing-Distortion in Sound Reproduction from Phonograph Records;" J. A. Pierce and F. V. Hunt, Cruft Laboratory, Harvard University, Cambridge, Mass.

"Application of Non-Linear Volume Characteristics to Sound Recording;" J. O. Aalberg and J. G. Stewart, RKO Radio Studios, Inc., Los Angeles, Calif.

"Silent Gasoline Engine Propelled Apparatus;" J. E. Robbins, Paramount Pictures, Inc., Hollywood, Calif.

"Variable-Matte Control (Squeeze-Track) for Variable-Density Recording;" G. R. Crane, Electrical Research Products, Inc., Hollywood, Calif. (*Demonstration.*)

2:00 p. m. **Sound Sessions; S. K. Wolf,** *Chairman.*

"A Method for Determining the Scanning Loss in Sound Optical Systems;" E. D. Cook, General Electric Co., Schenectady, N. Y., and V. C. Hall, Eastman Kodak Co., Rochester, N. Y.

"An Optical System for the Reproduction of Sound from 35-Mm. Film;" J. H. McLeod and F. E. Altman, Eastman Kodak Co., Rochester, N. Y.

Report of the Committee on Preservation of Film; J. G. Bradley, *Chairman.*

"Electrical Networks for Sound Recording;" F. L. Hopper, Electrical Research Products, Inc., Hollywood, Calif.

"The Application of Electrical Networks to Sound Recording and Reproducing;" H. R. Kimball, Metro-Goldwyn-Mayer Pictures, Culver City, Calif.

"Permanent-Magnet Four-Ribbon Light-Valve for Portable Push-Pull Recording;" E. C. Manderfeld, Electrical Research Products, Inc., Hollywood, Calif.

"Overload Limiters for the Protection of Modulating Devices;" R. R. Scoville, Electrical Research Products, Inc., Hollywood, Calif.

"The Philips-Miller Method of Sound Recording;" R. Vermeulen, Philips Gloeilampenfabrieken, Eindhoven, Holland.

SOCIETY ANNOUNCEMENTS

SMPE STANDARDS

A complete proposed revision of the SMPE Standards was published in the March, 1938 issue of the JOURNAL. These proposals were published for the purpose of soliciting comments and criticisms from the membership of the Society and any others interested in the subject.

No comments were received regarding any of the proposed Standards with the exception of *DS35-7-1* and *DS16s-7-1*, relating to sound-track dimensions for 35- and 16-mm. film. In view of this, and upon the recommendation of the Standards Committee, the Board of Governors at a meeting held at Washington, D. C., on April 24th, validated all the proposals as SMPE Standards with the exception of the two mentioned above. The two sound-track drawings will be revised by the Standards Committee at the next meeting.

FALL CONVENTION

The next convention of the Society will be held at Detroit, Mich., October 31st to November 3rd, inclusive. Headquarters will be the Statler Hotel, where excellent accommodations and rates are assured to SMPE delegates and guests.

The Papers Committee, under J. I. Crabtree, *Editorial Vice-President*, and G. E. Matthews, *Chairman*, has already begun to solicit an outstanding program of papers and presentations, and W. C. Kunzmann, *Convention Vice-President*, is making arrangements for the general convention facilities.

All those who contemplate presenting papers at the Convention are urged to communicate promptly with the Chairman of the Papers Committee. Full details of the arrangements and program will be contained in succeeding issues of the JOURNAL.

JOURNAL AWARD AND PROGRESS MEDAL

The following regulations pertaining to the Journal Award and the Progress Medal of the Society of Motion Picture Engineers are published in accordance with the provisions for such publication contained therein. Members of the Society who wish to nominate recipients for either or both the Awards should communicate their nominations to the General Office of the Society as promptly as possible.

JOURNAL AWARD

The Journal Award Committee shall consist of five Fellows or Active members of the Society who shall be appointed by the President and confirmed by the Board of Governors. The Chairman of the Committee shall be designated by the President.

A cash award ($50, or other sum as may be appropriated by the Board of Governors) shall be made at the Fall Convention of the Society to the author or authors of the most outstanding paper which is originally published in the JOURNAL of the Society during the preceding calendar year. This Award shall be known as the Journal Award. An appropriate certificate shall be presented to the author or to each of the authors, as the case may be.

A list of five other papers shall also be recommended for honorable mention by the Committee.

A majority vote of the entire Committee shall be required for the election to the Award. Absent members may vote in writing.

The Committee shall be required to make its report to the Board of Governors for ratification at least one month prior to the Fall Meeting of the Society.

These regulations, a list of the names of those who have received the Journal Award, the year of each award, and the titles of the papers shall be published annually in the JOURNAL of the Society. In addition, the list of five papers selected for honorable mention shall be published in the JOURNAL of the Society during the year current with the Award. The chairman of the Committee is H. G. Tasker.

The Awards in previous years have been as follows:

1934—Peter Andrew Snell, for his paper entitled "An Introduction to the Experimental Study of Visual Fatigue." (*Published May, 1933*)

1935—Loyd Ancile Jones and Julian Hale Webb, for their paper entitled "Reciprocity Law Failure in Photographic Exposure." (*Published September, 1934*)

1936—E. W. Kellogg, for his paper entitled "A Comparison of Variable-Density and Variable-Width Systems." (*Published September, 1935*)

1937—D. B. Judd, for his paper entitled "Color Blindness and Anomalies of Vision." (*Published June, 1936*)

PROGRESS MEDAL

The Progress Award Committee shall consist of five Fellows or Active members of the Society, who shall be 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 shall 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 of Motion Picture Engineers 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.

The Committee shall meet during the month of July. Notice of the meeting of the Committee held for the purpose of considering the award of the Progress Medal shall appear in the June issue of the JOURNAL. All proposals shall reach the Chairman not later than June 20th.

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 for ratification at least one month before the Fall Meeting of the Society.

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.

The regulations, a list of the names of those who have received the medal, the year of each award, and a statement of the reason for the awards shall be published annually in the JOURNAL of the Society.

The Progress Medal Award Committee for the current year is as follows:

A. N. GOLDSMITH, *Chairman*

J. I. CRABTREE
A. C. Hardy
W. B. RAYTON
S. K. WOLF

The 1935 Award was made to Edward Christopher Wente, for his work in the field of sound recording and reproduction (*cf. issue of December, 1935*).

The 1936 Award was made to Charles Edward Kenneth Mees for his work in photography (*cf. issue of December, 1936*).

The 1937 Award was made to Edward Washburn Kellogg for his work in the field of sound reproduction (*cf. issue of December, 1937*).

ADMISSIONS COMMITTEE

At a recent meeting of the Admissions Committee, at the General Office of the Society, the following applicants for membership were admitted to the Associate Grade:

BILLINGS, C.
208 O St., S. W.,
Washington, D. C.

BOSCH, F.
69-02 67th St.,
Glendale, L. I.

BRUNNER, C. E.
1305 12th Ave.,
Altoona, Penna.

CARR, H. B.
3131 N. Pershing Dr.,
Arlington, Va.

DAME, R. B.
3604 T St., N. W.,
Washington, D. C.

DEDOMINICIS, C.
Via Giacomo Boni, 1,
Rome, Italy.

DREW, R. O.
RCA Manufacturing Company,
Camden, N. J.

DUPORT, R.
145 Valley St.,
Belleville, N. J.

FARLY, G. M.
1036 N. Orange Grove Ave
Los Angeles, Calif.

FISHER, S. T.
1261 Shearer St.,
Montreal, Canada.

GAGLIARDI, G.
385 Pleasant Ave.,
Grantwood, N. J.

GIROUX, G. R.
Technicolor Motion Picture Corp.,
1016 Cole Ave.,
Hollywood, Calif.

GRAF, D.
330 W. 42nd St.,
New York, N. Y.

GRIFFIN, E. E.
865 Beach Ave.,
Inglewood, Calif.

GUTHSCHE, T.
101 Gleneagles Court,
Killarney, Johannesburg,
South Africa.

HALL, J.
Argentina Sono Film,
Uruguay 641,
Buenos Aires, Argentina.

HANSON, W. T., JR.
Eastman Kodak Company,
Rochester, N. Y.

HODGES, C. E.
42 Theobald's Rd.,
London, W. C. 1,
England.

HUNT, H. E.
11 Severance St.,
Lynn, Mass.

KLEINDIENST, A. F.
65 Elm St.,
Worcester, Mass.

KREGER, L. A.
44 South Hawk St.,
Albany, N. Y.

M'AVENNE, T.
50 Boydfield Ave.,
Prestwick, Ayrshire,
Scotland.

MYERS, S. H.
1100 Underhill Rd.,
Oakland, Calif.

PATERSON, P. F.
P. O. Box 929,
Harrisburg, Penna.

REED, C. T.
1405 N. Front St.,
Harrisburg, Penna.

SAWYER, G. E.
727 N. Alta Vista Blvd.,
Hollywood, Calif.

SCHROTER, E.
Philips' Gloeilampenfabrieken,
Eindhoven, Holland.

SIMON, W.
Lumiton S. A. Munro F.C.C.A.,
Buenos Aires, Argentina.

SMITH, M. A.
Box 68, Balboa Heights,
Canal Zone.

STRIKER, M. S.
Room 60 F,
1819 Broadway,
New York, N. Y.

TAENZER, E.
1601 Ave. N.,
Brooklyn, N. Y.

TALBOT, L. M.
57 Wilson St.,
West Lawn, Penna.

WHITNEY, T. G.
Alpine, N. J.

YOUNG, H. M.
1576 Mineral Spring Rd.,
Reading, Penna.

The following applicants were admitted by vote of the Board of Governors to the Active grade, at the meeting held at Washington on April 24th:

REEVES, H. E.
1600 Broadway,
New York, N. Y.

TAKATS, Z.
170 Cherry St.,
Bridgeport, Conn.

In addition, the following members were approved for transfer to the Active grade:

CHAMBERLIN, M. H.
3720 Motor Ave.,
Los Angeles, Calif.

CHASE, L. W.
Eastman Kodak Company,
6706 Santa Monica Blvd.
Hollywood, Calif.

EDISON, T. M.
Calibron Products, Inc.,
51 Lakeside Ave.,
West Orange, N. J.

JACOBSEN, I.
Balaban & Katz Corp.,
175 N. State St.,
Chicago, Ill.

SONNENBERG, A. C.
3130 S. Karlov Ave.,
Chicago, Ill.

STRYKER, G. E.
5825 Malvina St.,
Chicago, Ill.

UNDERHILL, C. R., JR.
RCA Manufacturing Company,
1206 Plaza Building,
Pittsburgh, Penna.

YAHR, M. J.
RCA Manufacturing Company,
Camden, N. J.

TOWNSLEY, M. G.
4045 N. Rockwell St.,
Chicago, Ill.

and the following members for transfer to the grade of Fellow:

BAKER, T. T.
30 Rockefeller Plaza,
New York, N. Y.

STARKE, H. A.
325 S. Cochran Ave.,
Los Angeles, Calif.

TUTTLE, H. B.
Eastman Kodak Co.,
Rochester, N. Y.

COLOR COMMITTEE

Supplementing the list of SMPE Committees published in the May issue of the JOURNAL, the Personnel of the Color Committee is as follows:

R. M. EVANS, *Chairman*

H. E. BRAGG
A. C. HARDY
B. J. KLEERUP
G. F. RACKETT

ERRATUM

In the April issue of the JOURNAL, the paper by F. T. Bowditch and A. C. Downes, entitled "Spectral Distributions and Color-Temperatures of the Radiant Energy from Carbon Arcs Used in the Motion Picture Industry," beginning on p. 400:

The captions of Figs. 2 and 4 on pp. 401 and 402, respectively, should read as follows:

"Fig. 2. Spectral energy distribution of d-c. Suprex arc—Positive crater radiation only (6-mm. Suprex positive, 5-mm. Suprex negative). One square represents 4 microwatts per sq. cm. at 10 feet."

"Fig. 4. Spectral energy distribution of d-c. Suprex arc—Positive crater radiation only (8-mm. Suprex positive, 7-mm. Suprex negative). One square represents 8 microwatts per sq. cm. at 10 feet."

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

AUTHOR AND CLASSIFIED
INDEXES

VOLUME XXX
JANUARY–JUNE, 1938

AUTHOR INDEX, VOLUME XXX

JANUARY TO JUNE, 1938

CLASSIFIED INDEX, VOLUME XXX

JANUARY TO JUNE, 1938