B. E. STECHBART

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APPLICATION OF MOTION PICTURE FILM TO TELEVISION*

E. W. ENGSTROM, G. L. BEERS, AND A. V. BEDFORD**

Summary.—*Motion picture film will form an important source of programs for television broadcasting. Film projectors for this use are required to meet a number of conditions peculiar to television. Methods for projecting and utilizing motion picture film are outlined. A specific film projector and associated television channel are described in some detail.*

In establishing a technic for producing films most suitable for television, equipment is needed to interpret the final results. Apparatus that will be used by broadcasting stations is described. A simpler system has been designed that may be useful for the specialized service of gauging the merit of films for television. This is described and its operation indicated.

Some very preliminary observations are included on the characteristics of films that have given good results in experimental work and in field tests.

The production and utilization of motion picture film for television programs introduce many new problems. It is the purpose of this paper to review these problems and to describe methods and apparatus for the use of film in television.

It is desirable first to review the general characteristics of two electronic television pick-up systems that are known to give practical results. In both systems the scene to be transmitted is projected upon a photoemissive area or mosaic. The resulting "electrical image" is methodically explored by electronic means, one narrow strip or line at a time, in a process called scanning. The result of this scanning process is an electrical signal which varies in accordance with the scene brightness along the scanning lines. The information residing in this signal is used at the receiver to reconstruct the image—one element at a time—in a similar synchronized scanning process.

In one pick-up system, exemplified by equipment using the Farnsworth dissector tube, only the light falling upon an element of the photoemissive area at the instant that element is being scanned is effective in producing the signal. The other pick-up system, ex-

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received May 8, 1939.

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

emplified by equipment using the Iconoscope, makes use of the principle of storage, whereby, when a particular photoemissive element is scanned, the light that has fallen upon that element since it was last scanned is effective in producing the signal.

The characteristics of these pick-up tubes determine the manner in which film can be used to provide television programs. In the system using the dissector tube, which has no storage, for every instant the signal is transmitted the film projector must supply a light image to the elemental area being scanned, though not necessarily from the entire frame. In the Iconoscope system, utilizing storage, a charge image may be built up by a very brief projection of the image upon the photoemissive mosaic, which is then scanned by an electron beam while the mosaic is dark, to produce the signal. The film pull-down occurs during the relatively long interval while the mosaic is being scanned. The detailed discussion to follow will be based on the system utilizing the Iconoscope.

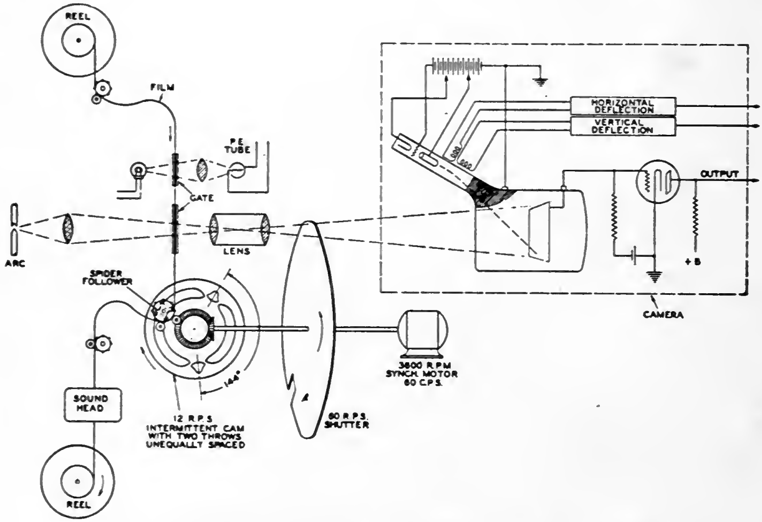

FIG. 1. Schematic of film projector for Iconoscope camera.

FILM TRANSMISSION SYSTEM UTILIZING THE ICONOSCOPE

Fig. 1 shows schematically an Iconoscope camera and a special projector adapted to project standard 24-frame-per-second film upon the Iconoscope mosaic in such way as to generate television signals according to the Radio Manufacturers Association standards: namely, at 30 frames per second and 60 fields per second, interlaced.[1] The projector must flash a still picture upon the mosaic every $^1/_{60}$ second with each flash lasting less than $^1/_{600}$ second. Since the film must run at a mean speed of 24 frames per second for proper reproduction of sound and motion, it is evident that each frame must be projected more than once to provide the required sixty flashes per second. Since sixty divided by 24 is $2^1/_2$, it would seem logical that each frame should be projected two and one-half times. This is impracticable but a very satisfactory method is to project alternate frames of film two and three times each, respectively; for example, the even frames twice and the odd frames three times. Fig. 2 shows the various steps of projection and scanning in proper relative time on a horizontal time-scale. Since the light flashes are very brief, a relatively long (approximately $^1/_{67}$ second) interval is available between flashes for the film pull-down. However, if the full time available is used, the alternate pull-downs must occur at non-uniform intervals of $^2/_{60}$ and $^3/_{60}$ second, respectively. Note from this figure that the scanning or transmission times occur *between* adjacent light flashes so that the television picture signal is actually produced and transmitted during periods when no optical image is present on the mosaic. However, during these periods an electrical image is present in the form of bound electrostatic charges on the tiny photosensitized silver globules comprising the mosaic. It is the act of neutralizing or, rather, equalizing these charges by the electrons of the scanning beam that causes the useful signal current to flow from the conducting back-coating of the mosaic plate.

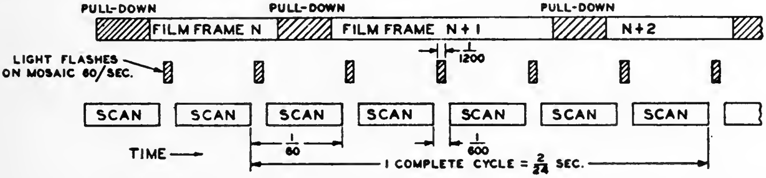

FIG. 2. Preferred sequence of events in film transmission by Iconoscope.

Referring again to Fig. 1, the film is drawn through an illuminated gate by an intermittent sprocket which is driven by an intermittent cam and spider-follower of the early Powers type. The 3600-rpm special synchronous motor drives the cam at 12 revolutions per second through a suitable gear, thus pulling the film down 24 times per second, since the cam has two "throws" instead of the customary one "throw." In order to pull the film at unequal intervals as required, the "throws" are located 144 degrees and 216 degrees apart, respectively. The film picture in the gate is projected upon the small photoemissive mosaic of the Iconoscope by a standard projection lens. The light is chopped 60 times per second by a large rotating shutter, located near the lens. The shutter is accurately timed relative to the intermittent cam so that the film is always stationary when the light flashes occur.

The generator of synchronizing signals for the television deflecting system is synchronously controlled by the same 60-cycle power supply that drives the projector synchronous motor. The phase of this signal generator is adjustable so that the operator can make the short-duration light flashes fall safely within the $^1/_{600}$-second intervals between the vertical scanning periods with some tolerance on each side for slight phase displacements such as are caused by small changes in the mechanical load on the projector or by voltage variations. This adjustment is very important, as any abrupt change in the illumination of the mosaic during the picture signal transmission time produces a spurious light streak across the received picture.

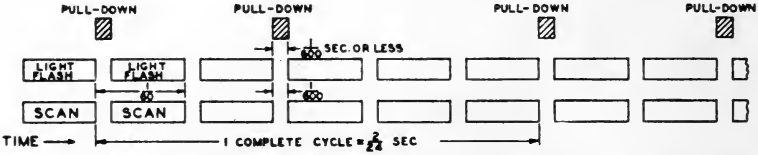

FIG. 3. Idealized sequence of events in film transmission by Iconoscope.

An ordinary 3600-rpm synchronous motor has two identical pole structures which can assume either polarity, and hence such a motor can lock into synchronism in either of two phase positions, depending fortuitously upon starting conditions. Two such lock-in positions are apart in time by one-half of a cycle of the power-supply frequency, which for a 60-cycle power system is $^1/_{120}$ second. Inspection of the diagram of Fig. 2 shows that displacing the light flashes $^1/_{120}$ second with respect to the scanning periods would cause them to occur during instead of between the scanning periods. The abrupt change in mosaic lighting caused by a flash during the scanning period would produce a serious streak across the middle of the picture as mentioned above. To prevent the frequent locking-in of the motor in the wrong position, a special synchronous motor is used which includes an additional d-c winding for fixing the polarity of the poles and thus determining the lock-in position with respect to the a-c power supply.

The sound-head used is standard, since the mean speed of the film is 24 frames per second. It has been found that a suitable fly-wheel associated with the intermittent cam prevents any detectable deterioration of the reproduced sound due to the dissymmetry of the intermittent cam.

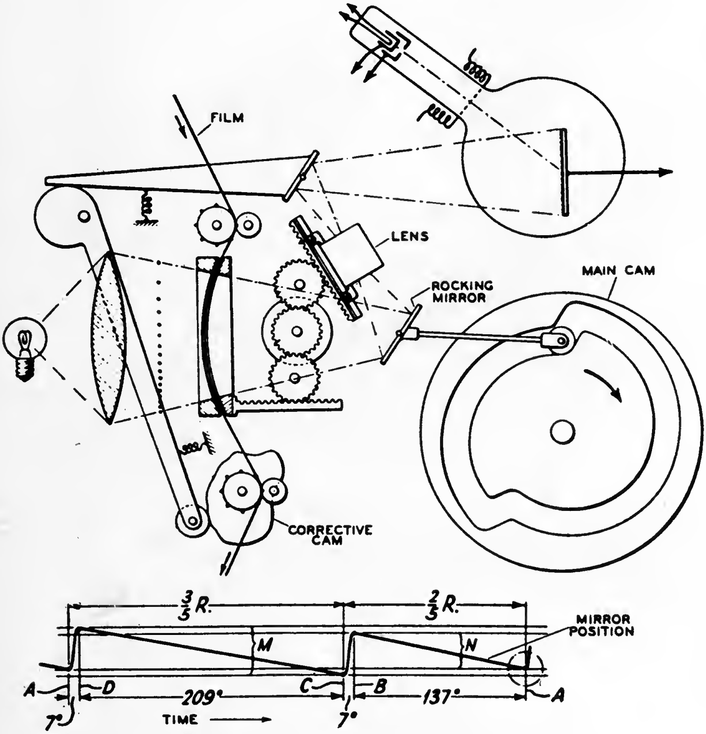

FIG. 4. Experimental rocking mirror projector.

OTHER PROJECTING SEQUENCES AND MECHANISMS

There is some evidence that the television picture transmitted by a system depending completely upon the storage principle might not be as satisfactory as one transmitted by a system in which the film image is projected upon the photoemissive mosaic either continuously or during the entire scanning period. It is natural, therefore, that investigations of the latter type of system should have been made. So far, the results obtained have not been wholly satisfactory and certainly have not been as excellent as those produced by the storage method described in the previous section. However, refinement of certain projection methods may at some time in the future make other systems of greater interest. It is, therefore, of value to digress and review some of the various schemes that have been investigated.

FIG. 5. RCA 35-mm sound motion picture projector; 30 frames per second, interlaced scanning.

For obtaining a continuous and constant light image on the Iconoscope photoemissive mosaic, a commercial type of theater projector was used, in which the film passed the picture gate at constant speed and a stationary projected image was obtained by means of an "optical intermittent." This projector employed several rocking mirrors on a rotating wheel. The lens system was properly proportioned for the projection of the small image required for the Iconoscope mosaic plate. In testing this system it was noted that the television performance was limited by various types of movement in the projected optical image and by low resolution. Motion of the optical image, in addition to causing objectionable motion in the received television picture, also contributed to loss of resolution in the picture. This is due to the storage action of the Iconoscope whereby the signal derived from each element of the mosaic in scanning is due to the summation of all the light that has fallen on that element since the preceding contact of the scanning beam. The effect is similar to that obtained when the optical image on a sensitized photographic plate moves during exposure.

Fig. 3 shows a projection sequence by which an intermittent type projector might project film on an Iconoscope for the entire scanning time provided the pull-down occurred in the almost prohibitively short time of $^1/_{600}$ second or less. This would permit projection throughout the entire scanning period. There is no apparatus now available for meeting the $^1/_{600}$ second pull-down requirement. If suitable equipment could be developed it is doubtful whether the film would withstand the stresses imposed by the rapid motion.

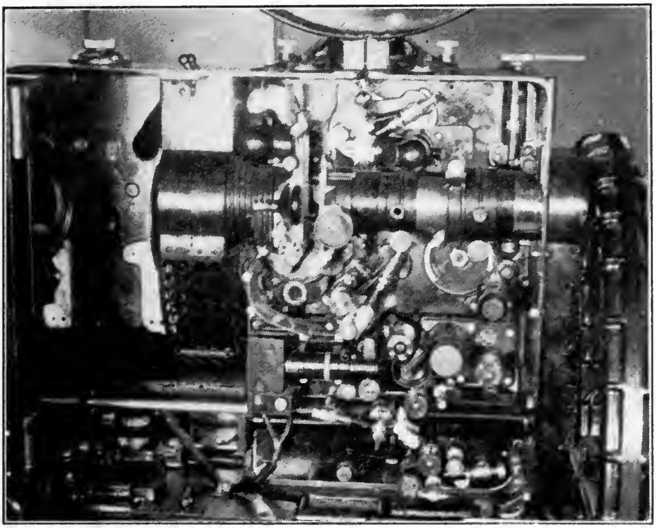

FIG. 6. Film projector, with doors open.

An experimental projector using a continuously moving film, and a rocking mirror for producing a stationary image, was built and tested. A diagrammatic view of it is shown in Fig. 4. The cam-driven mirror was arranged to neutralize accurately the film motion during the intervals marked "light flash" in Fig. 3 and to return to receive light from the next consecutive film frame during the $^1/_{600}$-second non-uniformly spaced intervals marked "pull-down." Limitations were found due to slight non-uniform illumination of the approximately two and one-half frames of film always in the picture gate. This resulted in objectionable flicker in the television picture. Also, in spite of the very small amplitude of motion required for the rocking mirror, the cam and follower-roller created a very annoying noise and were subject to rapid wear.

FILM PROJECTOR

It is of interest to return now to the method for using film which is considered best at present, and review the apparatus in more detail.

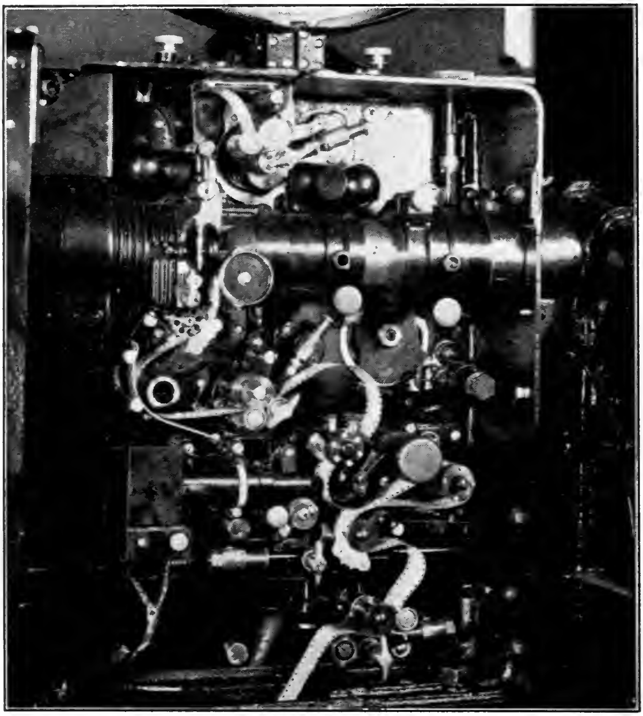

FIG. 7. View of film projector, showing film path.

Fig. 5 is a general view of a 35-mm sound motion picture projector designed for 30-frame-per-second television with interlaced scanning. This projector differs from standard theater projectors in the following major respects:

(*1*) A special shutter is used to provide efficient light pulses of very short time duration for projecting, 60 times per second, images of the film pictures onto the photoemissive mosaic of the Iconoscope.

(*2*) The intermittent mechanism is designed for the three-to-two ratio of pull-down periods required in using 24-frame film for 30-frame television.

(*3*) A special synchronous driving motor is used to assure that the projector mechanism always "locks-in" in proper time relation with the synchronizing pulses.

(*4*) An additional film gate with light-source and photoelectric cell is included near the picture gate for deriving a control potential which varies with the average density of the film.

In the projector shown in Fig. 5, it was impracticable to locate the shutter between the light-source and the film. The shutter was, therefore, mounted just beyond the projection lens. Sufficient clearance between the shutter and lens was provided to permit limited movement of the lens for focusing. The time during which the image may be projected onto the photoemissive mosaic of the Iconoscope is limited to the vertical return time of the scanning beam. With present television standards this is not more than 10% of $^1/_{60}$ second or $^1/_{600}$ second.

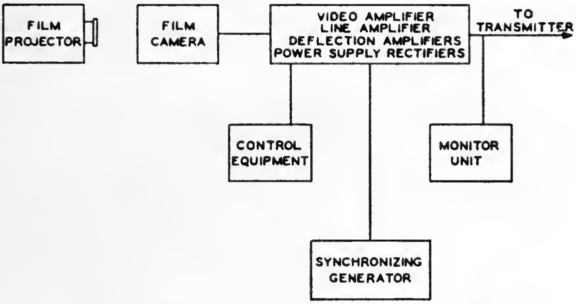

FIG. 8. Essential elements of a television film transmission system.

In order to make efficient use of the projection lens, it is necessary that the aperture in the shutter be at least as wide as the diameter of the lens. A large-diameter shutter (23 inches) is necessary to meet this requirement. This shutter rotates at 3600 rpm and has a peripheral speed of approximately $4^1/_4$ miles per minute. The shutter is enclosed in the circular housing shown at the extreme right-hand side of Fig. 5. In the shutter housing opposite the projection lens is a window through which the picture is projected. The shutter disk is made of two overlapping sections of thin metal. These two sections can be rotated with respect to each other through a small angle in order to vary the width of the aperture. Fig. 6 is a photograph showing the film side of the projector with the cover removed.

A second gate is located four frames of film above the picture gate. To the left of this gate, as shown in Fig. 6, is a lamp housing. To the right of this gate is a photocell housing which also includes an optical system for forming an image of the lamp filament on the photocell. The output voltage from this photocell is rectified, and after being passed through a suitable filter is used to control a characteristic of the synchronizing signals. The resultant variation in the synchronizing signals is used to control the average brightness of the reproduced picture. Fig. 7 shows a view of the film side of the projector with a film threaded ready for projection. Although the projector just described is equipped with a small 30-ampere arc, either an incandescent lamp or an arc may be used.

EQUIPMENT FOR BROADCASTING TELEVISION FILM PROGRAMS

In considering the production of motion picture films for television, it is important to review the apparatus that will be used in the broadcasting station. The essential elements of a system for television transmission from motion picture film are shown in Fig. 8. These include:

Film Projector
Iconoscope Film Camera
Camera Amplifier Equipment
Control Equipment
Monitor Equipment
Synchronizing Generator

The Iconoscope camera used with the film projector includes deflecting circuits and a pre-amplifier for the video signals. This pre-amplifier provides a signal level suitable for transmission over a coaxial cable to the camera amplifier equipment. The camera is usually mounted on one side of a wall, with the film projector located on the other side. The picture is projected through a window in the wall into the camera onto the photoemissive mosaic of the Iconoscope.

The camera amplifier equipment includes apparatus for amplifying further the video signals from the camera and a line amplifier to prepare these signals for transmission over coaxial cable to any desired location. Amplifiers providing suitable wave-shapes for horizontal and vertical deflection of the Iconoscope beam are included as well as the power supplies for the several parts of the system. This equipment is usually rack-mounted in some convenient location.

The control equipment provides means for varying the video signal gain, the picture brightness, and the picture background illumination, and for starting and stopping the film projector. In an installation designed to provide a continuous program from motion picture film, where two or more film projectors and television channels are included, controls are also provided for switching from one channel to another. The monitor equipment includes a 12-inch Kinescope by means of which television images obtained from the film can be viewed. It includes also a cathode-ray oscilloscope for observing the wave-shapes and amplitudes of the television signals. This monitor equipment is usually located so that it may be observed conveniently by the operator manipulating the control apparatus.

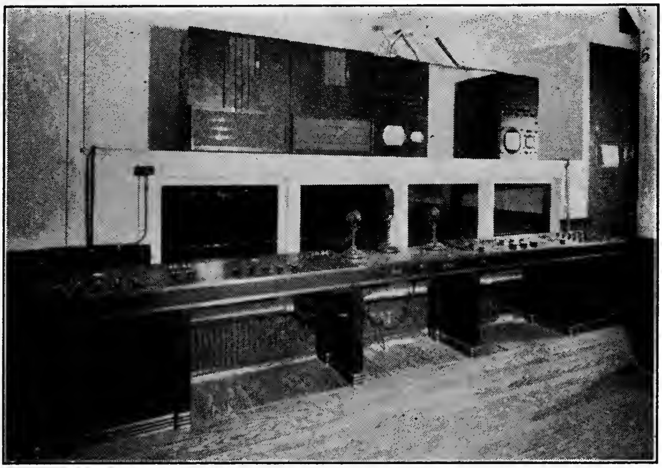

FIG. 9. Television control equipment for studio and film type cameras.

The synchronizing generator supplies the several complex waveforms required to determine the timing of scanning processes in the transmitting equipment and to synchronize the reconstruction of the images at the receivers. The wave-shapes of the synchronizing signals have been standardized by the Radio Manufacturers Association.

Views of television equipment of a type suitable for television broadcasting stations are shown in Figs. 9 and 10. Fig. 9 shows an installation of control equipment for studio and film type cameras.

This equipment is grouped on a common control console with the monitors mounted in a recess in the wall above the console. In this installation, the control engineer may look directly into the studio. Fig. 10 shows a typical installation of racks of television terminal equipment.

SIMPLIFIED TELEVISION APPARATUS

For specialized services, more simple and compact television equipment is desirable. Apparatus of this sort has been developed both for direct studio pick-up and for film applications. The simplified equipment suitable for producing television signals and television images from motion picture film will be reviewed briefly.

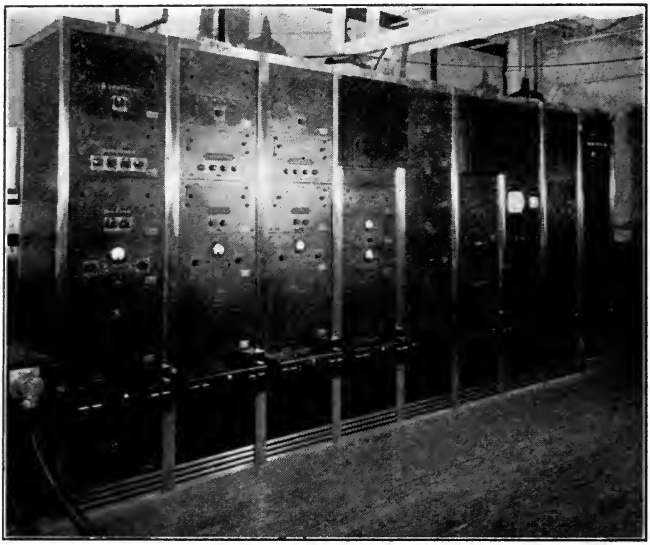

FIG. 10. Terminal equipment for television broadcasting stations.

This apparatus includes all the elements previously described, but in far more compact form. The equipment less the Iconoscope camera and the projector is included in one cabinet approximately 44 inches high, 34 inches wide, and 21 inches deep. This equipment produces a television signal that is suitable for transmission to remote viewing positions or for other uses.

This simplified equipment is not as flexible in some respects as the broadcasting type of equipment, nor does it lend itself well to large, complex systems. However, it does provide the facilities necessary for judging the merits of film for television use. In this simplification of apparatus and circuits, the synchronizing wave-shapes do not conform entirely to the Radio Manufacturers Association standards. The synchronizing signals are, however, satisfactory for the self-contained monitor and for other receivers or reproducing devices, but the adjustments may be a little more critical than would be the case with standard synchronizing signals. Fig. 11 shows a view of the equipment with the Iconoscope camera mounted on a simple wooden dolly.

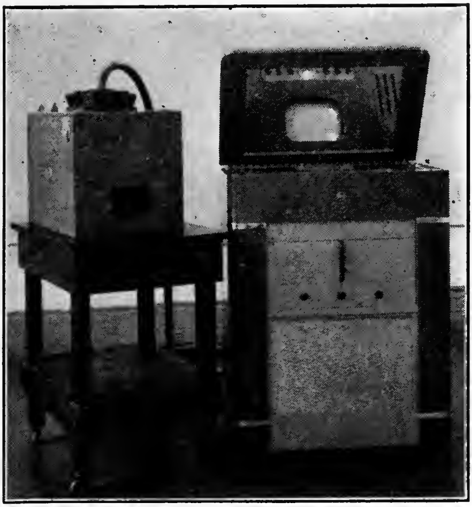

FIG. 11. Simplified television apparatus for judging the merits of motion picture film.

APPARATUS FOR JUDGING THE MERITS OF MOTION PICTURE FILM FOR TELEVISION

An earlier paper[1] reviewed some of the limitations inherent in present-day television and compared them with similar limitations in motion picture film and apparatus. Experience has indicated that the production of television pictures from a particular film is the only practicable method for judging the merits of the film as television program material. It is therefore suggested that this method be used for checking and studying motion picture films produced for television programs and for determining the usefulness of film available from other sources. Apparatus of the type used at the television broadcasting station or apparatus of the simplified type just described will be satisfactory for this service.

FILM BEST SUITED FOR TELEVISION

Laboratory work and field test experience permit some preliminary generalizations on film that has given good results for television. Comment is here directed to the technical characteristics of film and not to the entertainment qualities. It appears that film having characteristics best suited for theater projection is also generally best for television. Studio sets having all dark backgrounds should be avoided. A good number of close-ups should be used but these should be generously interspersed with long shots. Some experience may be necessary to take into account the resolution limits[1] of present-day television. Special processing of film does not seem to be necessary.

Film photographed in color directly from real life or nature appears satisfactory for television. Some cartoons in color have not given particularly satisfactory results.

Thus, it appears that there may be no really serious technical problems in the production of motion picture films suitable for television program material.

REFERENCE

[1] BEERS, G. L., ENGSTROM, E. W., AND MALOFF, I. G.: "Some Television Problems from the Motion Picture Standpoint," *J. Soc. Mot. Pict. Eng.*, **XXXII** (Feb., 1939) p. 121.

DISCUSSION

MR. MACKEOWN: Why has television adopted 30 frames a second when 24 are used in ordinary moving pictures?

MR. ENGSTROM: To explain fully the choice of 30 frames for television would be beyond the scope of the present discussion. Papers were published in the JOURNAL of this Society in January and February of this year that dealt with this particular problem.

Basically the reason is that electron beams are used for scanning at the transmitter to produce the television signals, and electron beams for scanning at the receiving or reproducing end. These electronic devices are affected by fluctuations in supply voltages and stray variations in electric and magnetic fields. The visual result is a pattern of varying brightness with respect to time that corresponds to the extraneous influence. If the frame frequency is made a whole-number submultiple of the power-supply frequency, then the visual patterns in the reproduced image are stationary and the effects are much less pronounced.

If this "whole-number submultiple" relationship does not obtain, then patterns of light and shade will travel up or down the image at a rate corresponding with the difference rate between the frame frequency and the nearest submultiple of the power supply. These moving patterns are as objectionable as true flicker.

If we did not use 30-frame television, for 60-cycle power, the designer would be confronted with very severe handicaps. For receivers, in particular, it would be difficult to find operative apparatus layouts, and certainly the cost would be increased to provide tolerable freedom from the effects just outlined.

MR. CRABTREE: At the New York meeting you demonstrated a method of projecting on a fairly large screen an image of high brightness contrast. Would it not be better to photograph the televised image onto motion picture film, process that rapidly, and then project it? What are the relative merits of the two procedures?

MR. ENGSTROM: I believe the method you suggest has been experimented with in Germany and to the best of my knowledge has not been adopted. One of the advantages that television has is the timeliness of the reproduction and it appears to those who have thought about the subject that even a matter of twenty, thirty, or forty seconds would take much interest from the program. On the other hand, to photograph the image on motion picture film and then project it involves a great deal of apparatus. We hope to find a more direct and simpler answer which will make it more generally applicable.

MR. CRABTREE: I do not think that a time lag detracts seriously in all cases from the showmanship. We in the East are quite entertained in spite of an apparent three-hour delay in the transmission of the football game from California on New Year's Day.

MR. GOLDEN: Is there any difference in definition between receiving film images and images of living actors?

MR. ENGSTROM: If as good a job is done in the television studio as one would do in producing motion picture film, then the resulting performance should be identical. There is no reason why one system should permit better contrast or better resolution than the other.

MR. LUBCKE: Our results concerning the qualifications for good film for television support those that Mr. Engstrom has outlined. In addition, we have felt that a slightly accentuated contrast between the various parts of the scene, but not too great an overall contrast range, is also desirable.

A CONTINUOUS TYPE TELEVISION FILM SCANNER*

PETER C. GOLDMARK**

Summary.—*A motion picture film scanner, the first of the continuous type to be used for television transmissions, is described. The apparatus was put into operation in New York City in the summer of 1937 and has been in use since. In its preferred form the scanner projects the image of a continuously moving film onto the cathode of a dissector tube. Five images, representing different portions of the film in the gate, produced by five stationary lenses, are superimposed one on top of the other, while a rotating shutter with concentric slots permits only one lens at a time to produce an image. The scanning is accomplished partly by the uniform motion of the film and partly by the magnetic scanning of the electron image in the opposite direction. The pictures thus obtained are completely free from shading, cover a great range of contrast, are free from flicker, and are steady. The construction of the scanner is simple and inexpensive.*

While the Iconoscope is the best device known at present to pick up scenes where the amount of illumination is limited, the same tube is not the best for the transmission of motion picture films. Devices like the scanning disk, dissector tube, projection type cathode-ray tube, *etc.*, will produce pictures of greater contrast and freedom from the shading effects that represent one of the greatest disadvantages of the Iconoscope. Film scanners which project a continuous visual image onto the Iconoscope or onto a dissector tube have been suggested and are in use. However, they all involve rotating parts such as lenses or mirrors, these parts in some cases numbering as many as forty-eight, which must be preadjusted with extreme accuracy, making subsequent corrections at the projector nearly impossible. It was therefore desirable to develop equipment in which the optical elements involved would be stationary and few in number.

Another requisite for such a film scanner is that the film should move through the gate with constant speed instead of with jerky motion, as it does in the intermittent type of projector, so that the

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 7, 1939.

** Columbia Broadcasting System, New York, N. Y.

film perforations can be maintained in good condition over a longer period of time.

The film transmitter under discussion employs no moving optical elements and operates on the following principle: The motion picture film has to pass a gate at a speed of 24 frames per second while one frame has to be scanned electrically within $^{1}/_{60}$ of a second. This means that within $^{1}/_{12}$ of a second two complete motion picture frames have to be scanned electrically five times.

In Fig. 1, frame *A*, which has just emerged from the top of the gate, is moving downward at a constant rate of 24 frames per second. At the same time a fictional scanning-light spot starts to scan the same frame from the bottom upward. After $^{1}/_{60}$ of a second the scanning spot describing horizontal lines will have covered a height of $^{3}/_{5}$ of a frame, which, plus a downward $^{2}/_{5}$ motion of the frame, equals the picture height. Position *B* indicates how far frame *A* has moved in the gate within $^{1}/_{60}$ of a second while it was scanned once from bottom to top. The scanning-beam returns now to the base-line of that frame, and while the frame continues from position *B* toward position *C*, the scanning spot, again in $^{1}/_{60}$ of a second, covers that frame. Now the frame continues to move from *C* to *D*, which trip again lasts $^{1}/_{60}$ of a second, and the scanning spot quickly returns to the base-line of *C* and moves upward, completing the third frame. By that time a new frame, *E*, appears in the gate. The scanning-

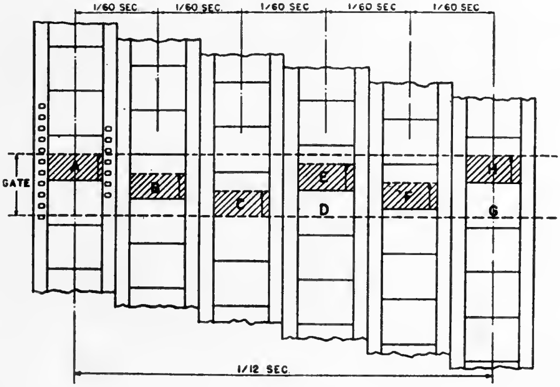


FIG. 1. Illustrating passage of film in gate.

beam instead of further describing frame *D*, continues to scan frame *E* which is on its way down from position *E* to *F*. Again the scanning spot returns to the base-line of frame *F* with a rapid jump, while this frame proceeds to position *G* and is scanned from bottom to top within $^1/_{60}$ of a second. Thus an entire cycle has been completed, consisting of the scanning of two motion picture frames five times each within $^1/_{60}$ of a second, or the total operation completed in $^1/_{12}$ of a second.

The scanning spot will now start to scan frame *H* which appears at the top of the gate, and thus start a new cycle.

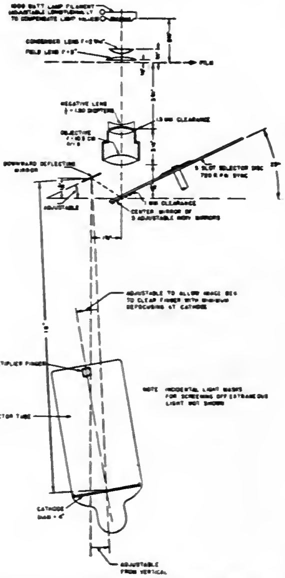


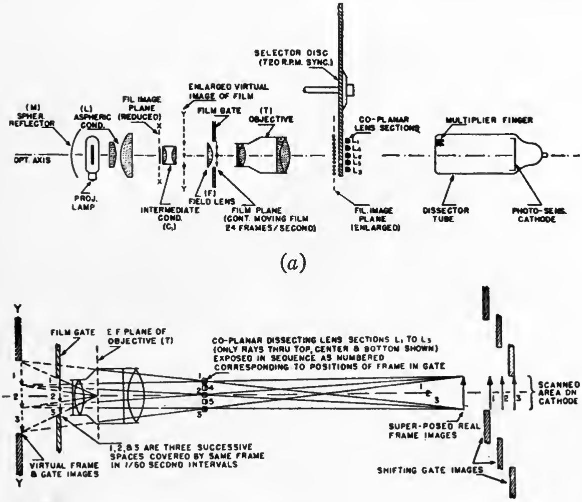
FIG. 2. Schematic layout of scanner using five mirrors.

This principle can be applied in several ways in practice, some of which will be mentioned here. A luminous scanning pattern can be produced on the flat end of a high-intensity cathode-ray tube which is projected through lenses onto the moving film. With a suitable condenser lens system, light emerging through the film is collected and projected into a multiplier type of photocell. An extra pair of deflecting coils or deflecting plates fed by a rectangular current or voltage displaces the luminous scanning pattern on the tube in such a fashion that various portions of the moving film are scanned in accordance with Fig. 1. Although this method is theoretically correct, in practice difficulties are encountered due to the fact that in order to obtain five congruent images, the scanning pattern as it jumps into various positions on the screen of the tube must maintain its shape within $^1/_{1000}$ of its height and width. It is very difficult to produce a sufficiently homogeneous magnetic and electrical field that will produce identical images.

The thought occurs to produce a stationary scanning pattern and split it up into five images displaced in accordance with Fig. 1. To split up the original into five displaced images we can employ either five mirrors tilted at different angles or five lenses with their optical axes displaced, or parallel blocks of glass inclined toward the main optical axis at suitable angles.

The field-frequency of 60 frames per second conforms to the U. S. television standards and requires that five images be produced and displaced within $^1/_{12}$ of a second. A rotating shutter with five concentric slots, each slot covering an angle of 72 degrees and a disk rotating at a synchronous speed of 720 rpm permits the passage of light for only one image at a time.

Fig. 2 is the schematic layout of a scanner employing five mirrors for splitting up the beam, while Fig. 3 shows a similar layout using five lenses. The total amount of light available at the multiplier photocell when splitting up the original image is $^1/_5$ of that obtainable with the first method where the optical or electron image itself is deflected and no image-splitting takes place. However, there is sufficient light available for both methods when a suitable incandescent lamp is used.



(a)

(b)

FIG. 3. Schematic layout using five lenses: (a) arrangement of optical parts; (b) virtual images and displacement of real images by the five dissecting lenses.

Fig. 4 is a photograph of the latest film scanner using a dissector tube. In this arrangement a 1500-watt projection lamp is used as light-source which illuminates the gate evenly. In Fig. 3 the mirror *M* and the condenser lens system *L* produce an intermediate image of the filament in the plane *x*-*x*. This image is projected through the condenser system c_1 in combination with field lens F and the main projection lens T, onto the plate of the five dissecting lenses, L_1 to L_5. The main projection lens T produces an enlarged virtual image of the film behind the gate in the plane y-y. The five lens segments displace and project this enlarged image of the gate onto the cathode of the dissector tube, the displacement of the images corresponding to the displacement of the centers of the dissecting lenses relatively to the main optical axis of the entire system. Fig. 3(b) reveals the virtual images and the displacement of the real images by the five dissecting lenses.

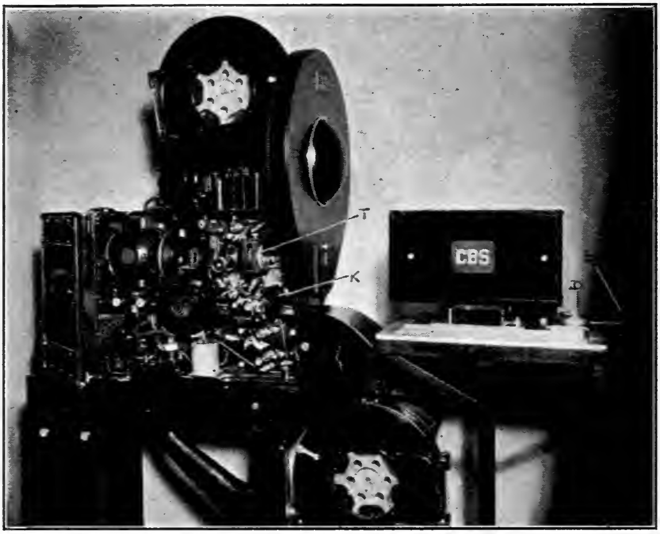


FIG. 4. Film scanner using dissector tube.

The five lens sections are rigidly mounted on a solid metal plate and are easily adjustable with the aid of small brackets and screws holding the lenses in place. The alignment of the dissecting lenses can be carried out quickly by the following method.

A reel of film of a suitable resolution chart is run through the projector while two lens sections are freed by using cardboard masks over the others. The two images thus produced on the cathode are brought into coincidence by adjusting the lens-holder and observing the monitored image on a cathode-ray tube. The other three lenses are brought into coincidence with the first pair one after the other, and the brackets holding the lenses are permanently clamped down. With this method coincidence of the five images can be obtained accurate to within a fraction of the width of a line both in the horizontal and the vertical directions. It is, of course, necessary that the film running continuously through the projector be steady within these limits. However, suitable mechanical filters make such uniform film speed possible.

There is one more important consideration in this film-scanning method that requires close attention. The distances between centers of the five dissecting lenses in the vertical direction correspond to certain distances between successive film-image centers on the film. At any distance between the plane of the dissecting lenses and the cathode of the pick-up tube sharp focus of the film picture together with most accurate coincidence of the five images must be available. However, it is known that there are rarely two reels of film that exhibit the same shrinkage, that is, the same spacing between centers of successive images. A method had to be developed whereby the system could be quickly adjusted for any shrinkage while maintaining good focus and coincidence over the entire image. It has been determined experimentally that the shrinkage of film will vary anywhere between 0 and 12 mm per 50 frames, which corresponds roughly to from 0 to 0.8 per cent. A large number of test-reels with suitable patterns, each of which showed different shrinkage between the limits

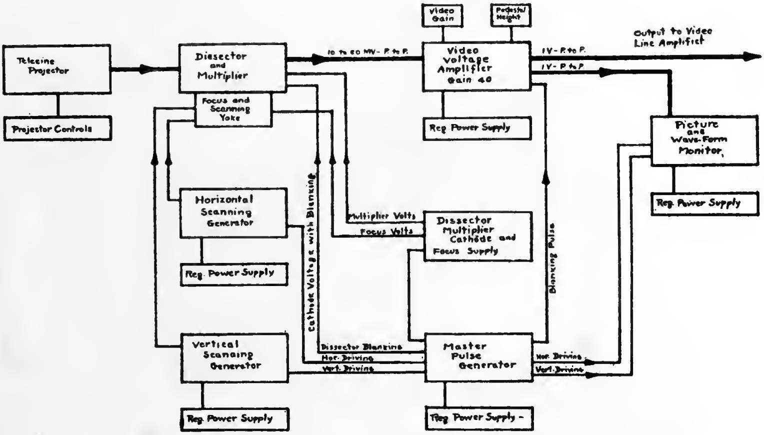


FIG. 5. Diagram of complete telecine channel employing the projector.

mentioned before, were run through the projector. Each time the distance between the dissector cathode and a fixed point on the projector was carefully adjusted until the images were motionless and in sharp focus. Through suitable gears the slight changes of the dissector distance are transmitted to a rotating dial onto which the individual positions of the cathode have been marked. From this calibration a curve has been derived which represents the film shrinkage (measured in mm per 50 frames) plotted against the distance between the dissector cathode and the projector.

FIG. 6. Electrical equipment of the telecine channel.

In practice, before a film of unknown shrinkage is used, a piece of it is held against a metal ruler on which the shrinkage can be read directly in mm per 50 frames. Then the distance adjustment screw *S* (Fig. 4) of the dissector is turned until the dial *D* of the indicator reads the corresponding distance. All that is necessary now is to focus the main projection lens *T* of the projector, when the title appears and automatically both a sharp image and exact coincidence are achieved.

Refocusing during a picture is seldom necessary. The depth of focus of the main projector lens combined with the five lens segments (the magnification introduced by the latter is 1:1) is large compared with the tolerances in the movement of the main projector lens so far as coincidence of the individual images is concerned, so that a slight focusing movement of the main lens, by means of a knob *K* (Fig. 4) brought out conveniently on the side of the projector, will always bring the image to exact coincidence and substantially not change the optical focus.

A diagram of the entire telecine channel employing this projector is shown in Fig. 5. Fig. 6 shows the electrical equipment, comprising, from right to left, synchronizing-pulse generator rack, power-supply rack, video amplifiers and scanning generator rack, and, finally, the picture and wave-shape monitor as well as the blanking-pulse amplifier rack. This telecine system is operated on the so-called d-c principle. The picture background component is accurately maintained in the cathode of the pick-up tube by means of horizontal and vertical blanking pulses which are injected between the cathode and the first multiplier stage of the dissector.

Thus the peaks of the blanking pulses, representing black, maintain a constant reference level all through the system. Wherever a visual picture is needed, the a-c axis of the video signal is so changed by one of several well known methods that the tops of the blanking pulses are all along a straight line establishing a definite black level in any kind of picture.

Two years of experience with the film-transmitting system just described have brought results that compare favorably to those obtained by the scanning disk method employed abroad. It is believed that this system is one of the simplest of all film-scanning devices permitting continuous and reliable operation without readjustments or breakdown.

The writer wishes to acknowledge the helpful assistance of his associates and especially of Mr. Bernard Erde of the CBS Television Laboratories.

TELEVISION STUDIO TECHNIC*

ALBERT W. PROTZMAN**

Summary.—*The studio operating technic as practiced in the NBC television studios today is discussed and comparisons are made, where possible, to motion picture technic. Preliminary investigations conducted to derive a television operating technic revealed that both the theater and the motion picture could contribute certain practices.*

The problems of lighting, scenic design, background projection, and make-up are discussed, with special emphasis on the difficulties and differences that make television studio practice unique.

An explanation is given of the functioning of a special circuit used in television sound pick-up to aids in the creation of the illusion of close-up and long-shot sound perspective without impracticable amount of microphone movement. The paper concludes with a typical television production routine showing the coördination and timing of personnel and equipment required in producing a television program.

If one were forced to name the first requirement of television operating technic and found himself limited to a single word, that word would undoubtedly be "timing." Accurate timing of devices and split-second movements of cameras are the essentials of television operation. Personnel must function with rigid coördination. Mistakes are costly—they must not happen—there are no second chances.

Why such speed and coördination? Television catches action at the instant of its occurrence. Television does not allow us to shoot one scene today and another tomorrow, to view rushes or resort to the cutting room for editing. Everything must be done as a unit, correct and exact at the time of the "takes"—otherwise, there is no television show.

Now, to discuss some preliminary investigations conducted before production was attempted, and to describe the equipment and technic used in meeting these production requirements. Technical details are deliberately omitted. Wherever possible, we shall compare

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 6, 1939.

** National Broadcasting Co., New York, N. Y.

phases of television operation with their counterparts in motion picture production.

For so new a medium as television it is, of course, an impossibility to present a complete and permanently valid exposition. Television technic and apparatus constantly advance. Some technic now current may be outmoded in a day or a month. We have only to recall the early days of motion picture production, when slow-speed film and inferior lenses were a constant limitation. So, with television, it is already possible to envision more sensitive pick-up tubes that will permit the use of smaller lenses of much shorter focal length, thus eliminating many of today's operating difficulties.

Production Technic Investigations.—In May, 1935, the Radio Corporation of America released television from its research laboratories for actual field and studio tests. Long before the first program was produced in the middle of 1936, plans were laid, based on extensive research into the established entertainment fields, for the purpose of determining in advance what technics might be adaptable to the new medium of television. From the stage came the formula of continuity of action, an inherent basic requirement of television. This meant memorized lines and long rehearsals. Prompting could not be considered, for, as you know, the sensitive microphone which is as much present in television as it is in sound motion picture production, does not discriminate between dialog and prompting.

From the motion picture studio came many ideas and technics. If television is a combination of pictures with sound, and it is, no matter what viewpoint is taken, the result spells in part and for many types of programs, a motion picture technic at the production end. However, enough has already been said about the peculiarities of television presentation to justify saying that the movie technics do not supply the final answer. There remained the major problem of preserving program continuity without losing too much of motion picture production's flexibility. Our present technic allows no time for adjustments or retakes. Any mistake immediately becomes the property of the audience. The result of the entire investigation led to what we think is at least a partial answer to the problem. This technic, we hope, will assist considerably in bringing television out of the experimental laboratory and into the field of home education and entertainment.

General Layout of Facilities.—In order to present a clearer view of our problems, we shall give a brief description of our operating plant.

The present television installation at the National Broadcasting Company's headquarters in the RCA Building, New York, N. Y., consists of three studios, a technical laboratory, machine and carpenter shops, and a scenic paint shop. Our transmitter is located on the 85th floor of the Empire State Building. The antenna system for both sight and sound is about 1300 feet above the street level. Both the picture and sound signals are relayed from the Radio City Studios to the video and sound transmitters either by coaxial cable or over a special radio link transmitter.

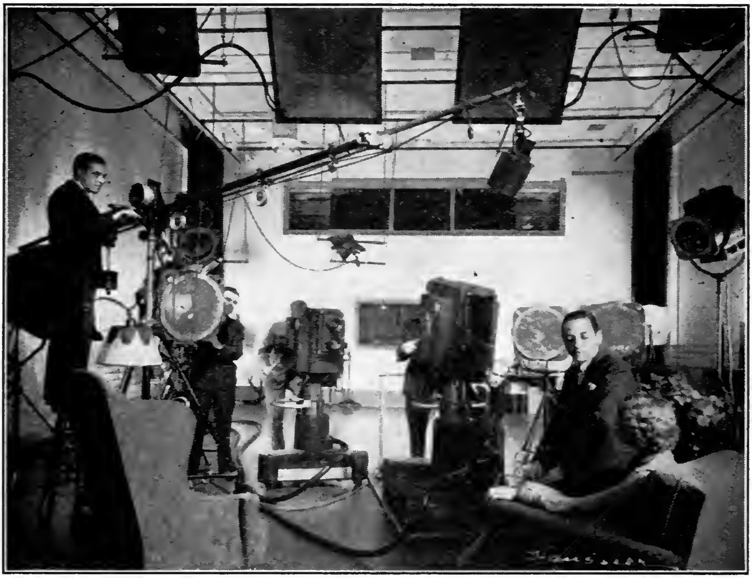

FIG. 1(*a*). General layout of live-talent studio; control room at upper rear.

One of the studios is devoted exclusively to televising motion picture film, another to programs involving live talent, and the third for special effects. It is the operation of the live-talent studio with which we are concerned in this paper.

Description of Live-Talent Studio.—Fig. 1 (*a*) shows the general layout of the live-talent studio. The studio is 30 feet wide, 50 feet long, and 18 feet high. Such a size should not be considered a recommendation as to the desired size and proportions of a television studio. The studio was formerly a regular radio broadcasting studio, not especially designed for television. To anyone familiar with the large sound stages on the motion picture lots, this size may seem small (Fig. 1(*b*)). Yet, in spite of our limited space, some involved multi-set pick-ups have been successfully achieved by careful planning. Sets, or scenes, are usually placed at one end of the studio. Control facilities are located at the opposite end in an elevated booth, affording full view of the studio for the control room staff. Any small sets supplementing the main set are placed along the side walls as near the main set as possible, and in such position as to minimize camera movement. At all times, we reserve as much of the floor space as possible for camera operations and such floor lights as are absolutely essential. At the base of the walls and also on the ceiling are scattered numerous light-power outlets to minimize the length of lighting cables. At the rear of the studio is a permanent projection room for background projection.

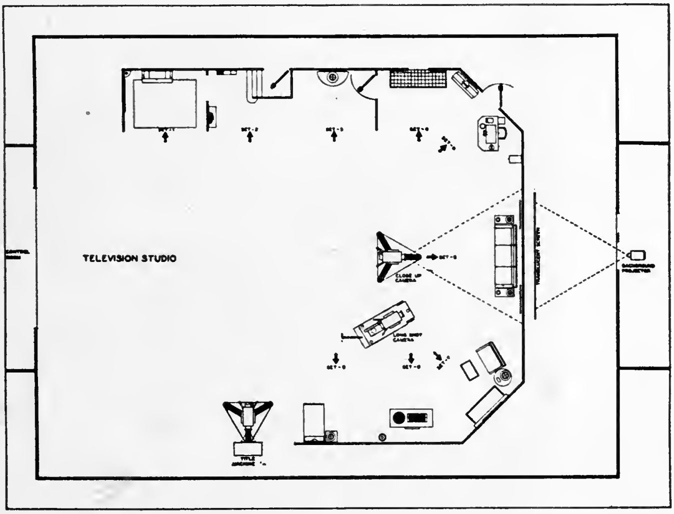

FIG. 1(*b*). Television studio floor plan.

Camera Equipment.—The studio is at present fitted for three cameras. To each camera is connected a cable. This cable is about two inches in diameter and fifty feet long; it contains 32 conductors including the well known coaxial cable over which the video signal is transmitted to the camera's associated equipment in the control room. The remainder of the conductors carry the necessary scanning voltages and current supplies for the camera amplifiers, interphone system, signal lights, *etc.* From this description, it is apparent that adding another camera in a television studio involves a much greater problem than that of moving an extra camera into a motion picture studio. In television, it is necessary to add an extra rack of equipment in the control room for each additional camera.

Movement of Cameras.—One camera, usually the long-shot camera using a short focal length lens, is mounted on a regular motion picture type dolly to insure stable movements. The handling of the dolly is done by a technician assisting the camera operator. It is impracticable to lay tracks for dolly shots as is often the motion picture practice, because usually each camera must be moved frequently in all directions during the televising of a studio show. Naturally, dolly tracks would limit such movement. The other television cameras utilize a specially designed mobile pedestal (Fig. 2). Cameras mounted on these pedestals are very flexible and may be moved in and out of position by the camera operators themselves. Built into the pedestals are motors which elevate or lower the camera; this action is controlled with push-buttons by the camera operators. A panning head, similar to those used for motion picture cameras, is also

FIG. 2. Studio camera.

a part of the pedestal. It is perhaps needless to stress here that one of the strict requirements of a television camera is that it must be silent in operation. In the electronic camera proper there are no moving parts other than those used for focusing adjustments; hence, it is a negligible source of noise. When camera pedestals were first used they were the source of both mechanical noise and electrical disturbance when the camera-elevating motor was in use. Since then this problem has been overcome, and it can be stated that the entire camera unit is now free of objectionable mechanical noise or electrical surges.

Lens Complement:—Each camera is equipped with an assembly of two identical lenses displaced 6 inches vertically. The upper lens focuses the image of the scene on a ground-glass which is viewed by the camera operator. The lower lens focuses the image on the "mosaic," the Iconoscope's light-sensitive plate. This plate has for its movie counterpart the film in a motion picture camera. The lens housings are demountable and interchangeable. Lenses with focal lengths from $6^1/_2$ to 18 inches are used at present. Lenses of shorter focal length or wider angle of pick-up can not be used since the distance between the mosaic and the glass envelope of the Iconoscope is approximately 6 inches. Lens changes can not be effected as fast as on a motion picture camera, since a turret arrangement for the lenses is mechanically impracticable at present. However, it is probably safe to say that future advances in camera and Iconoscope design will incorporate some type of lens turret. Ordinarily, one camera utilizes a $6^1/_2$-inch focal length lens with a 36-degree angle, for long shots, while the others use lenses of longer focal lengths for close-up shots. Due to its large aperture, the optical system used at present has considerably less depth of focus than those used in motion pictures, making it essential for camera operators to follow focus continuously and with the greatest care. This limitation will probably be of short duration, since more sensitive Iconoscopes will permit the use of optical systems of far greater depths of focus.

It is desirable here to point out a difference in focusing technic between motion picture cameras and television cameras. "Follow-focus" in motion pictures occurs practically only in making dolly shots. For all fixed shots, the lens focus is set, the depth of focus being sufficient to carry the action. Also, it is the duty of the assistant cameraman to do the focusing. This relieves the cameraman of that responsibility and allows him to concentrate on composition, action, and lighting. In television, the camera operator must do the focusing for fixed shots and dolly shots alike. This added operation, at times, is quite fatiguing.

Vertical parallax between the view finder lens and the Iconoscope lens is compensated for by a specially designed framing device at the ground-glass that works automatically in conjunction with the lens-focusing control. It may be of interest to note here that at first the television camera had no framing device. This meant that images, in addition to being inverted as they are in an ordinary view-finder, were also out of frame. The camera operator had to use his judgment in correcting the parallax. With this new framing device, the operator now knows exactly the composition of the picture being focused on the mosaic in his camera. The framing device can be quickly adjusted to accommodate any lens between $6^1/_2$ and 18 inches focal length.

Because of the fact that several cameras are often trained on the same scene from various angles, and because all cameras are silent in operation, performers must be informed sometimes—such as when they are speaking directly to the television audience—which camera is active at the moment. Two large green bull's-eye signal-lamps mounted below the lens assembly are lighted when the particular camera is switched "on the air."

Set Lighting.—There are two outstanding differences between television lighting and motion picture lighting. A much greater amount of key light is required in television than in motion pictures. Also, a television set must be lighted in such a way that all the camera angles are anticipated and properly lighted at one time. Floor light is held to a minimum to conserve space in assuring maximum flexibility and speed of camera movements. Great care must also be taken to shield stray light from all camera lenses. This task is not always easy, since, during a half-hour performance, each camera may make as many as twenty different shots. Just as excessive leak-light striking the lens will ruin motion picture film, it has a definitely injurious effect upon the photosensitive mosaic and upon the electrical characteristics of the Iconoscope. A direct beam of high-intensity light may temporarily paralyze a tube, thus rendering it useless for the moment.

Sets.—(Fig. 3) Television sets are usually painted in shades of gray. Since television reproduction is in black and white, color in sets is relatively unimportant. Chalky whites are generally avoided because it is not always possible to keep "hot lights" from these highly reflective surfaces which cause a "bloom" in the picture. This, in turn, limits the contrast range of the system. Due to the fact that the resolution of the all-electronic system is quite high, television sets must be rendered in considerable detail, much more, in fact, than for a corresponding stage production. As in motion picture production, general construction must be as real and genuine as possible; a marked difference, for instance, can be detected between a painted door and a real door. On the legitimate stage, a canvas door may be painted with fixed highlights; that is, a fixed perspective, because the lighting remains practically constant, and the viewing angle is approximately the same from any point in the audience. But, in television the perspective changes from one camera shot to another. Painted perspectives would therefore be out of harmony with a realistic appearance. This is also true in motion picture work. Sets must also be designed so that they can be struck quickly with a minimum effort and noise because it is often necessary to change scenes in one

FIG. 3. Typical television set.

part of a studio while the show is going on in another part. At present, we find it desirable to construct television sets in portable and lightweight sections without sacrificing sturdiness.

Background Projection.—The problems of background projection in television differ somewhat from those encountered in motion pictures. More light is necessary because of the proportionately greater incident light used on the sets proper (Fig. 4).

Considering the center of a rear-screen projection as zero angle, we must make it possible to make television shots within angles of at least 20 degrees on either side of zero without appreciable loss of picture brightness. This requirement calls for the use of a special screen having a broader viewing angle than those used in making motion picture process shots. Also, in motion pictures, the size of the picture on the screen can be varied to the proper relation to the foreground for long shots or close-ups. For television, the background picture size can not be changed once the program starts. Our back-

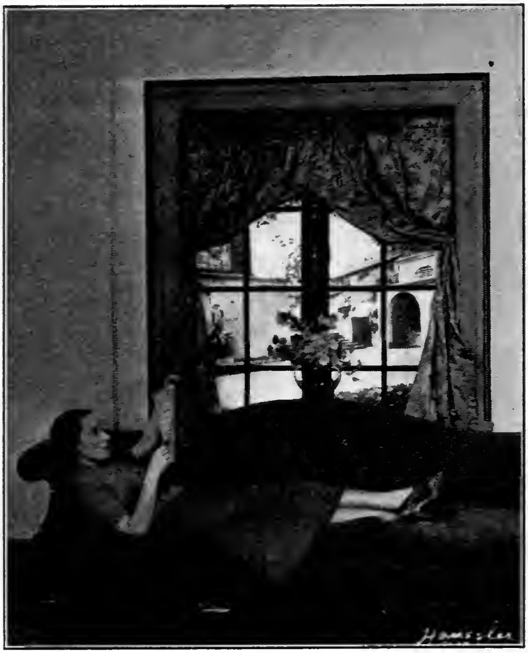

FIG. 4. Background projection window shot.

ground subject matter must also be sharp in detail and high in contrast for good results.

At present, only glass slides are used. A self-circulating water-cell is used to absorb some of the radiant heat from the high-intensity arc. Also both sides of the slide are air-cooled. These precautions permit the use of slides for approximately 30-minute periods without damage.

Make-Up.—This may be a suitable time to correct some erroneous impressions concerning the type of make-up used in television. It has never been necessary to use gruesome make-up for the modern all-electronic-RCA television system. At present, No. *26* panchromatic base, similar to that used for panchromatic film, and dark red lipstick is being used satisfactorily. From the very beginning, we have made tests to determine the proper color and shades of make-up, keeping in mind that a color closely approximating the pigmentation of the human skin is most desirable from the actor's psychological standpoint.

FIG. 5. The television control room. Note the two Kinescope monitors in the upper left corner.

The Control Room.—Now, a few words about the operations in the studio control room during a televised production (Fig. 5). All camera operators in the studio wear head-phones through which they receive instructions from the control room. Directions are relayed over this circuit by the video engineer or the production director. Here the televised images are observed on special Kinescope monitors and necessary electrical adjustments are made. Alongside each of these monitoring Kinescopes is a cathode-ray oscilloscope which shows the electrical equivalent of the actual picture. Two monitors are provided in order that one may be reserved for the picture that is actually on the air, while the other shows the succeeding shot as picked up by a second or third camera. This enables the video engineer to make any necessary electrical adjustments before a picture goes on the air.

Seated immediately to the left of the video engineer is the production director whose responsibility corresponds to that of the director of a motion picture. He selects the shots and gives necessary cues to the video engineer for switching any of the cameras into the outgoing channel. The production director has, of course, previously rehearsed the performance and set camera routines in conjunction with the camera operators and the engineering staff. The camera operator has no control to switch his camera on the air. All camera switches, which are instantaneous, are made by electrical relays controlled by buttons in the control room. At present, the video engineer's counterpart in motion picture work is the editor and the film processing laboratory.

To the left of the production director sits the audio control engineer whose responsibility is entirely separate from that of the video engineer. He also is in a position to view the monitor, and may communicate by telephone with the engineer on the microphone boom. The audio engineer is responsible for sound effects, some of which are dubbed in from records. His job is somewhat similar to that of the head sound engineer on a motion picture production. Thus, we have the control room staff—three men who have final responsibility for the success of the completed show.

An assistant production man is also required on the studio floor. Wearing headphones on a long extension cord, he is able to move to any part of the studio while still maintaining contact with the production director in the control room during a performance on the air. Actors require starting cues, titles require proper timing, and properties and even an occasional piece of scenery must be moved. The assistant director supervises these operations and sees that the instructions of the production director are properly carried out.

Members of the studio personnel also to be mentioned include lighting technicians, the property man, and scene shifters, whose responsibilities parallel those of their motion picture counterparts. Specially trained men are also needed for operating title machines. In the future all titling will undoubtedly be done in a separate studio inasmuch as operating space in a television studio is at a premium. Today, however, title machines do operate in the studio and require the utmost care in handling. Types of titles used include dissolves and wipes similar to those used in moving pictures.

Sound Reproduction.—As in motion picture work, a microphone boom is used in television production, and is operated in a similar way. Perspective in motion picture sound is accomplished by keeping the microphone, during a long shot, just out of the picture and moving it down closer to the action as the camera moves in for a close-up, thus simulating a natural change in perspective. In television this is not always possible because there are always three cameras to consider. This same condition prevailed in the early days of motion pictures when it was thought desirable to take a complete scene, shooting both long-shot and close-up cameras, at one time. In the television studio at least one camera is always set for a long shot while the others are in position for closer shots. If the microphone is placed in such a position as to afford a "natural" perspective for close-ups, the succeeding switch to a long shot would reveal the microphone in the shot. You in motion pictures can order a retake; in television broadcasting we can not rectify the mistake. It is quite obvious, therefore, that the man on the boom can not lower his microphone to the "natural" position for each camera shot. We therefore place the microphone in a position just out of range of the long shot. In order to accomplish some sense of perspective between long and close-up shots, a variable equalizer that drops the high and low ends of the spectrum is automatically cut into the audio circuits when the long-shot camera is on the air. In this operation, sufficient change in quality and level is introduced to aid the illusion of long-shot sound perspective. Of course, when a close-up camera is switched in, the audio returns to the close-up perspective quality once more. This may be called remote control sound perspective.

Special sound effects, music, *etc.*, from the studio picked up from recordings are mixed in the control room. In motion pictures, some of the effects and most of the music are dubbed in after the actual shooting of the scene.

The general acoustical problems in a television studio are similar to those in a motion picture sound-stage. Walls and ceiling should be designed for maximum absorption to permit faithful exterior speech pick-up. A stage or studio must be designed to enable presentation of an exterior or an interior scene. With the studio designed for maximum absorption, illusions of exterior sound characteristics can be created. For interiors, the hard surfaces of the sets and props offer sufficiently reflective surfaces to create the indoor effect.

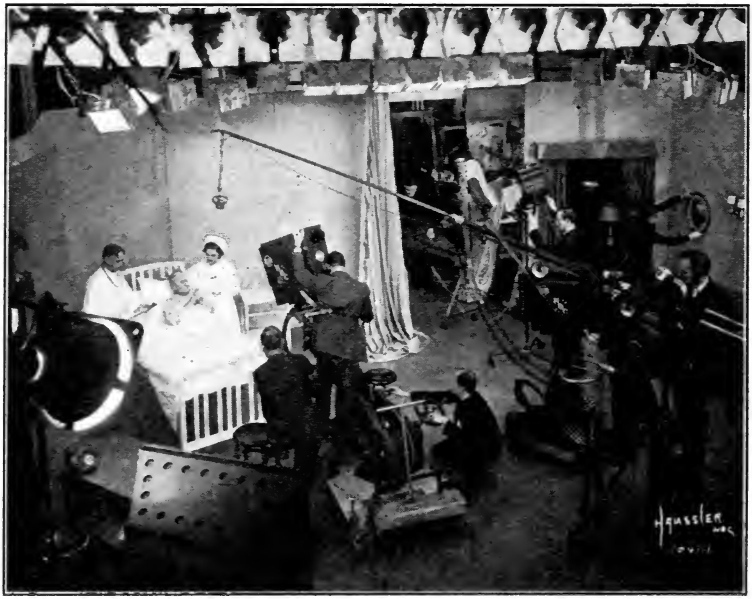

FIG. 6. (*Left*) Scene on the air; (*right*) setting up for next scene.

Typical Production Routine.—After the foregoing discussion of the equipment and personnel, it may be interesting to follow an actual production from the beginning of rehearsal to its final presentation. For this example, assume that we are to produce a playlet (Fig. 6). When the scenery has been erected, the first rehearsals begin without the use of cameras or lights. Besides familiarizing the actors with their lines, the rehearsals afford the production director and the head camera operator an opportunity to map out the action of the play.

All action, including camera shots, cues, and timing, is noted on a master script which thereafter becomes the "bible" of the production. Timing is very important because of the necessity of having a particular act time in with the other acts or film subject.

After several hours of rehearsing, the first equipment rehearsal is called. Cameras are checked electrically and mechanically. Focus controls and framing devices are lined up so that correct focus on the ground-glass is also correct focus on the mosaic plate. This completed, the cameras are ready for rehearsal. With the scene properly lighted, the camera operators begin working out movements to pick up the desired shots in the proper sequence. The production director instructs the staff and personnel from the control room, speaking over a public-address system. Each shot is worked out and its camera location marked on the floor. At times, the actors may unconsciously depart slightly from the rehearsed routine during an actual show; the camera operator must be prepared and alert to make the best of the situation regardless of all previous floor markings. Continuity is so planned that while one camera is taking the action, another camera is moving to a new location and composing a new shot to be switched on at the proper time. This frees the first camera, which can now move to a third location, and so on. Sometimes during a twenty-minute performance each camera may take twenty different shots. Of course, besides different floor locations, the height and angle of the cameras must be varied to comply with good composition. During rehearsals, timing must frequently be revised to allow for the actual camera movements.

Finally, a dress rehearsal is scheduled. The complete program is televised, including any film subjects or slides that may be needed to complete the program. Frequently the program will begin with a short film leader, followed immediately by a newsreel or a short subject, the film portion of the program coming from the film-televising studio. While the film is running, the live-talent studio is continuously warned as to the time remaining before it must take over the program. Once the studio program goes on the air the production director is no longer able to use the public address system to communicate with the personnel in the studio. Instead, he uses a telephone circuit to his assistant in the studio, and, through the video engineer, communicates by phone with the camera operators.

Another standby warning is usually given when there is one minute to go. Then, as the cue to begin comes, the green light on the title camera is lighted. From this point, continuity must be rigidly preserved. As titles move from one to another, appropriate music is cued in and actors are sent to their opening positions.

With the completion of titles, the image is faded out electrically and cameras are switched to the opening shot. Performers begin their action on a silent cue from the assistant director, who is instructed from the control room. During this first scene, the camera previously picking up titles moves quickly into position to shoot a second view of the action. Again cameras are switched, permitting the first to move to a new position; and so the action proceeds. If the play has several scenes, the concluding shot of the first scene is taken by one camera while others line up on the new scene and wait for the switch. Frequently, there are outdoor scenes. These are filmed during the first stages of rehearsal for transmission from the film studio at the proper time during the performance. The switch to film is handled exactly as another camera switch, except that the switch is to the film studio instead of to one of the studio cameras. The projectionist must be warned in advance to have his projector up to speed and "on the air" at the proper instant to preserve the production continuity. This requires very critical timing, as you can well appreciate. When the film is completed the studio cameras again take over the next interior scene.

Upon completion of the studio portion of the program, one camera lines up on the final studio title, which usually returns the program to the film studio for a concluding film subject.

Since the first program on July 7, 1936, many television programs have been produced. Each has been a serious attempt at something new. Although much has been accomplished, there remain a vast number of unknowns to be answered before it can be said that television's potentialities have been even partially realized. Today, as this paper has indicated, television bears many points of similarity to motion pictures. As a matter of fact, it is likely that television would be somewhat handicapped if it were unable to borrow heavily from a motion picture production technic that has been built up by capable minds and at great expense over a period of many years. Infant television is indeed fortunate to have such a wealth of information at its disposal. Possibly continued experimentation will lead us toward a new technic distinctive of television. During its early years, however, television must borrow from all in creating for itself a book of rules. The first chapter of that book is scarcely written.

TELEVISION LIGHTING*

WILLIAM C. EDDY**

Summary.—*Lighting a television production presents many problems peculiar to this new field of public entertainment. These problems have necessitated the redesign of lighting equipment and the establishment of a simplified technic for handling the equipment that differs radically from moving picture practice.*

To cope properly with the lighting requirements of the continuous action sequences, characterizing television productions, a system employing inside silvered incandescent lamps in a standardized unit was developed by NBC engineers. Based on multiple standardized group of $1^1/_2$ *kw each, these units are used in both the foundation light and modeling equipment of the television studios in Radio City, thus insuring quantitative as well as qualitative control of lighting by the personnel.*

With cameras generally in motion and an average duration of pick-up from one camera a matter of seconds, the problem of modeling in the sets becomes acute. This appears to be satisfactorily solved by the technic now in use wherein the major interest is centered around the close-up camera. Even this solution, however, required new and ingenious equipment to maintain light in the sets and still give floor precedence to the cameras and sound equipment.

While NBC at the present time has appeared to have standardized on the inside silvered lamp, exhaustive tests were carried out in an attempt to utilize more orthodox equipment. Actual tests under production conditions proved, however, that certain requirements of space, weight, and flexibility could not be had without a serious sacrifice of foot-candles on the set, resulting in the present set-up of equipment and personnel that are handling the television lighting assignment in the East.

Under these circumstances, our producers—relying on their scientific skill, the richness of their facilities and resources, and the variety and range of talent available to them in every field—will, it would seem, be well advised to stress most strongly in the foreign markets the factor of the superior quality of American films. We should export only pictures of unquestioned excellence. High quality will continue to retain for American motion pictures an exceedingly worth-while place in the markets of the world.

Although the practical application of lighting to the presentation of television studio programs will admittedly be subject to further improvement, the imminence of a public television service warrants a description of the lighting equipment and operating technic which

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 13, 1939.

** National Broadcasting Co., New York, N. Y.

the National Broadcasting Company has worked out as a result of several years of experimentation in this field.

This description covers primarily the lighting developments since 1935 when the Radio Corporation of America launched an extensive experimental field-test of television. Of considerably greater scope than previous tests, it was designed to permit a pre-commercial analysis of the art through a combined appraisal of the laboratory-reared electrical system and a comprehensive survey of the problems introduced by regular production of programs.

Starting with studio lighting equipment similar to that used in moving pictures, we have gradually evolved a reasonably satisfactory solution of our illumination problem that has resulted in a new and interesting layout of equipment applicable to the demands imposed by television studio operation. This was achieved largely through simplification of the equipment and the technic involved in handling it.

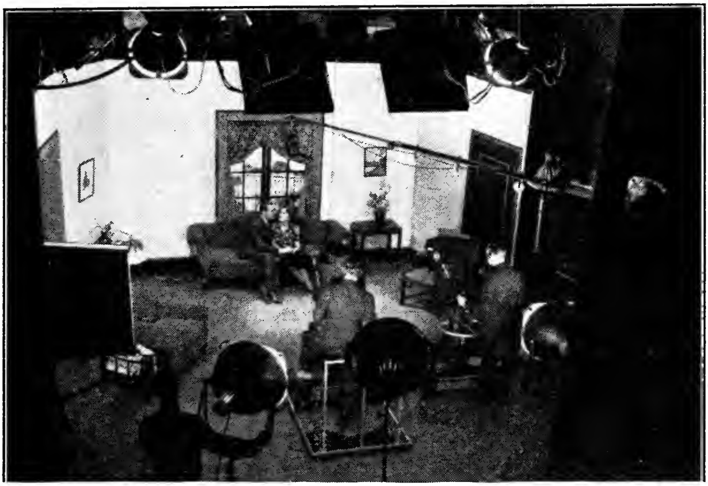
To permit both engineer and director to discuss the lighting set-up with a common terminology, and thus facilitate presentations, we also simplified the existing abstract definitions of light into two separate and distinct classifications: namely, foundation and modeling light.

Foundation light, according to our standards, is the non-characteristic flat illumination of a set, irrespective of its origin or amount. It is primarily the light energy necessary to create an electrical picture in the cameras and provide a foundation to which we can add the characteristic or dynamic quality of modeling light.

Modeling light is any illumination that adds to the contrast or delineation of the picture. It may be from overhead, from the floor, or from the back, but according to our definition, it must create some characteristic highlight or shadow, as opposed to the flat illumination function of the foundation lights.

It was, then, the creation of a satisfactory lighting installation for television rather than the adaptation of equipment and technics geared to an older art that paced our developmental work. It may help to follow the reasoning behind our transition from motion picture lighting into the present installation of incandescent sources, if we consider chronologically the television studio work at Radio City during the formative period from 1935 to the fall of 1938.

A rough analysis of the requirements for a satisfactory system seemed to indicate that flexibility and efficiency were the paramount



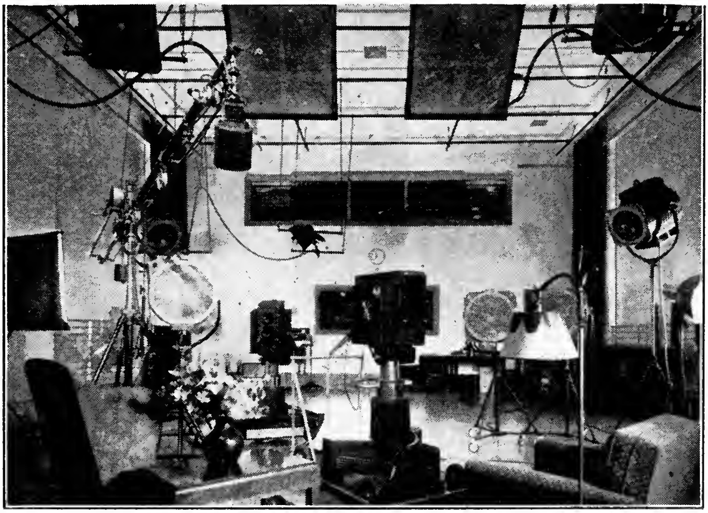


FIG. 1 (*Upper*). A stage set-up in the television studio.
FIG. 2 (*Lower*). View of studio showing equipment.

factors to be considered, although glare and radiant heat from the units had to be taken into account. Of necessity, the light produced had to be a high-level diffused illumination in quantities encountered only in the color-film studios. In addition, television required that the operation, upkeep, and maneuvering of this light be of such simplicity that one or two men could satisfactorily handle routine productions. We naturally turned to the standardized fixtures of the moving picture lots for our first tests. In the Radio City studio we installed routine spots and broads. Due to the limitation of a nineteen-foot ceiling, a practical light bridge was out of the question. As a substitute, the major portion of our lighting equipment was installed on portable stands. Figs. 1 and 2 show the arrangement of the apparatus for our first television program from Radio City in 1936. From a quantitative standpoint, we had little to criticize in this installation, but it was immediately apparent that the excessive glare and operational requirements of such a battery of lights precluded their general use in television. An attempt was made to redesign and redistribute these units, but with little or no success, indicating conclusively that equipment of such power and concentration could not be left unattended throughout a television sequence and that the proper manipulation of this type of illumination required a lighting personnel of considerable magnitude.

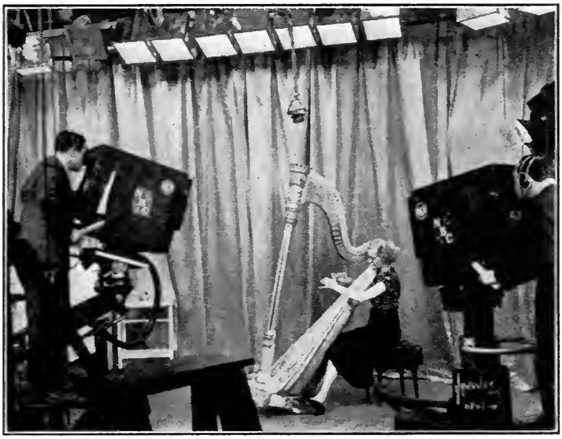


FIG. 3. Illumination by battery of 500-watt units.

Our next step was a gradual conversion from the concentrated type of unit to the more diffused and uniform light produced by scoop reflectors and floor broads. Focusing spots and suns were still maintained in the studio, but their function was limited to modeling rather than producing the foundation illumination. Lack of space for operation, weight, and their general inefficiency coupled with unbearable glare on the set soon proved their impracticability even though the unattended light produced by high-efficiency lamps met the requirements of the production staff. During this period, little attempt was made to do more than spill into the sets a predetermined quantity of shadowless light lacking the characteristic modeling that might prove embarrassing in certain sequences. Such a technic reduced the personnel to a minimum, to be sure, but it also produced a television picture in the field that was flat, non-dimensional, and on the whole, highly unsatisfactory from the program standpoint.

Our next experimental step toward a television lighting system came with the installation of a battery of 500-watt units (Fig. 3), each equipped with separate reflector and lens systems. These lights were positioned on a gridiron over a single set in such a manner that they would produce a cube of uniform, nondirectional illumination that, it was hoped, would approximate the character and modeling obtained under high-intensity diffused light. Needless to say, the resultant picture showed the effect of flat front lighting. Again the spots and suns were brought out the storeroom and put into operation as modeling units in an attempt to create above this pedestal of 1500 foot-candles the highlights and shades that had been destroyed by the basic arrangement of the foundation-light installation. Because this system of multi-unit lighting was the first radical departure from orthodox lighting practice and the forerunner of our present

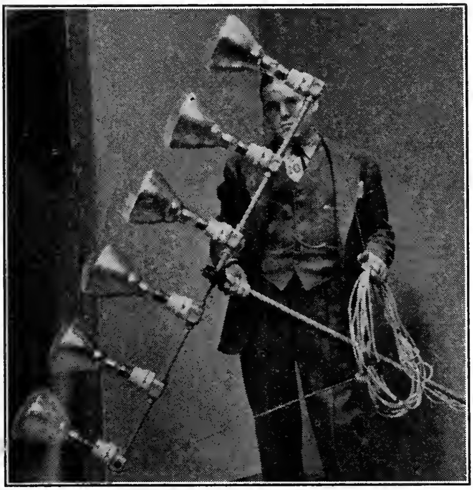


FIG. 4. The single-six mounting.

studio equipment, it might be well to go into more detail concerning its advantages and shortcomings.

Coupled with the failure of this installation to produce the required quality of light were several equally important deficiencies: namely, lack of flexibility, excess weight, and great heat radiation. By reason of the bulk of the single unit alone it was necessary to select a certain area to be illuminated, a limitation that required the program group to parade their subjects within the confines of a limited stage. This placed a definite limitation on the efforts of this program group. The weight of the installation closely approached the safe load limit of our acoustical ceiling, making impossible the addition of further equipment above the set to reinforce the existing light or to create special light effects. The unit inefficiency of each lamp, lens, and exterior reflector created an ambient heat problem that severely taxed the air-conditioning service to this particular studio. These deficiencies made the adoption of this system inadvisable but did indicate the direction of our next step.

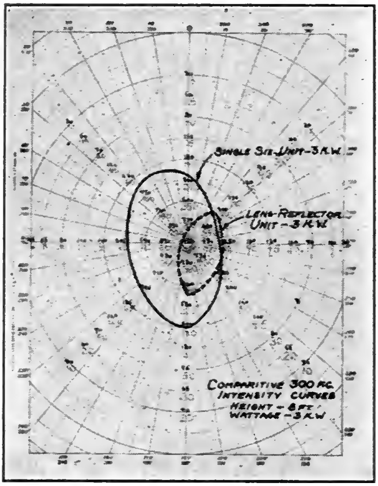


FIG. 5. Light distribution curves of single-six unit and lens reflector unit.

Photometric tests, conducted in the studio, have already indicated that the new inside silvered spotlight would deliver into an area more light per watt than the lens, lamp, and reflector assembly or the standard incandescent bulb and exterior scoop. This new bulb was light in weight and of relatively small envelope size in the wattage required. It remained to design a fixture that would permit simple adjustment in elevation and direction to satisfy the requirements of the multi-set productions proposed by the program staff. Fig. 4 shows such a mounting, known as the "single six." It incorporates six 500-watt spotlights on a framework of thin-walled steel tubing, so arranged that the center-to-center distance between lights is ten inches. This insures that the light-beams interlock at a distance of eight feet from the fixture and that the light arriving on the set is relatively free from spots and

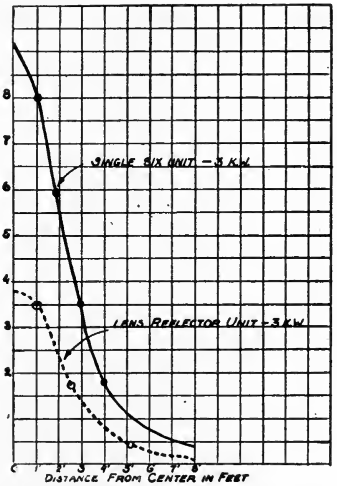


FIG. 6. Photometric distribution of the beam about the center-line.

secondary shadows. The total weight of the fixture, equipped with spots, is slightly less than 19 pounds and lamped for three kilowatts produces an index of 18,000 units, compared with an index of 7650 units registered by an equivalent grouping of lens, lamp, and reflector units. Roughly, this amounts to an increase in usable light per watt consumed of approximately 240 per cent. The distribution of these two test fixtures is best demonstrated by referring to polar coördinate curves projected on an area of approximately 200 square-feet from a height of eight feet. In Fig. 5 the 300-foot-candle intensity curve for the "single six" is indicated by the solid line; that of the competitive fixture is shown dotted. Areas within these limits serve to indicate relative efficiencies, as the wattage, arrangement, and length of throw were held constant in obtaining the data. Fig. 6, with the solid line again indicating the "single six," gives a general idea of the photometric distribution of the beam about the center line.

FIG. 7. The double-three unit.

The mechanical arrangement for flexibility consists of a universal clamp for attaching the supporting arm to a gridiron, with rotational freedom possible at the fixture itself. A single adjusting screw allows the operator to set the bank for any desired angle or direction of throw with the framework arranged either horizontally or in a vertical position relative to the studio floor.

The first of the standardized installations consisted of eighteen of these "single-six" units mounted on the gridiron in such a manner that they could quickly and easily be brought into play on any acting area selected by the production group. As a space-conserving measure a few of these long units were reassembled in two rows of three (Fig. 7), designated as "double threes." In certain sets where the light-concentration was high and space at a minimum, this arrangement was found to be more satisfactory from an operational standpoint. This type of construction was later mounted on portable stands for use as floor broads.

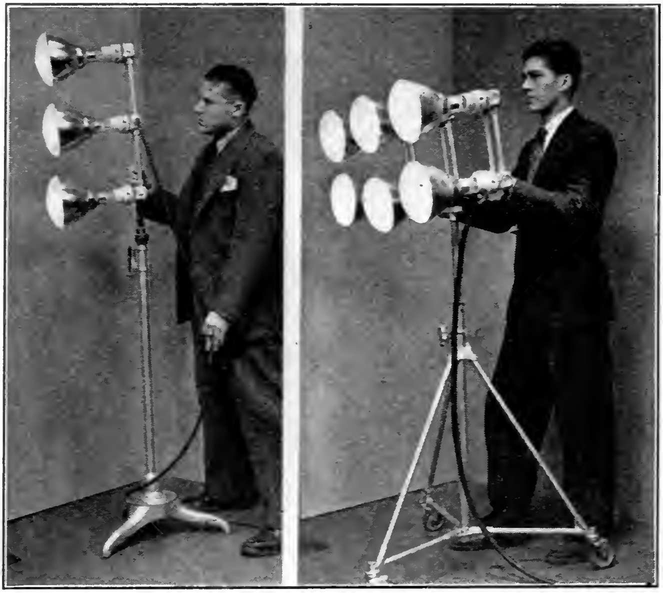


FIG. 8 (*Left*). The single-three unit.
FIG. 9 (*Right*). The floor broad.

The "single three" (Fig. 8), one-half of the "single six," was next brought into use for reinforcing light, background flooding, and as a general-purpose strip-light of minimum dimensions.

By standardizing the construction of our unit assembly we were assured of uniform spectral characteristics and distribution from each fixture rather than a spotty heterogeneous mixture of several types of light requiring careful blending on the set. A common standard of light-producing unit also allowed us to familiarize ourselves with the operation of the fixture and, by simple addition or subtraction, to meet the studio's quantitative light problems.

Shortly after completing the foundation-light installation we turned to the more complex problem of supplying the characteristic, or modeling, light from the floor. Here again, several problems confronted us, resulting in a partial redesign of the standardized mounting

FIG. 10. Portable foot light.

The floor broad (Fig. 9) is identical with the overhead array except that it is mounted on a portable floor stand. Two of these units are used normally as reinforcing lights from stage right and left to create a rough modeling angle or to temper the shadows on the backdrops. In all cases, however, it was required that the operation of these lights should give floor precedence to camera movement. They are, therefore, brought into play and taken out frequently during the course of a single sequence. The diffused characteristic of this light permits such an unorthodox procedure to be satisfactorily carried out without leaving an apparent hole in the set illumination.

FIG. 11. The hand light.

Our modeling equipment is completed by the addition of two other units, the portable foot light (Fig. 10) and the hand light (Fig. 11). This floor light, working with and ahead of the close-up camera, is maneuvered to highlight the subject properly from this camera angle.

Such a technic decrees that the intimate close-ups which produce the best delineation of halftone value shall benefit by the best lighting. It is impossible, of course, to light each shot of each camera from the optimum angle in a studio where we find the duration of pick-up from a single camera sometimes a matter of seconds. We have, therefore, made it a practice to work toward the camera that best displays our wares, after making sure that the foundation lighting over the set is so arranged as to supply satisfactory illumination for the other cameras.

The hand light (Fig. 11) is used to reinforce floor light in such sequences where a single camera shot can be safely modeled to the contrast limit. It is normally used on the wide-angle close-up camera and can be fitted with either a spotlight for contrast highlights or a diffusing lamp for the more subtle modeling.

We do not attempt to approach the contrasts common on the stage and in motion pictures. In television we are confronted with a highly compressed contrast range that permits modeling, to be sure, but also holds as a penalty for exaggeration a wash-out or a complete black. It is therefore necessary that we work well within these limits, since the review and criticism of our lighting technic is by the audience in the field rather than by a cutting-room jury. This, however, has not restricted the use of modeling light; the trend, on the other hand, being toward the greater contrast that the electrical system will accept, in preference to the flat non-dimensional pictures of past years. Experience gained by operation and observation appears to be the only rule in the use of these modeling fixtures even though we have endeavored to take guesswork out of the equipment.

Our failure to mention back-lighting does not mean that we have overlooked the possibilities of this type of illumination. In the studio sets we have yet to arrive at a reasonable system of back-lighting that will answer all the requirements of flexibility, weight, and operation. It is true that we now are using, in our main studios, an advanced type of remotely controlled ceiling light that appears to solve the problem, but since our findings to date are not conclusive, we felt that discussion of this system should be held for the future.

We make use of one other type of light that merits consideration. This equipment is known as the "portrait table," used as the name implies: in cases where the picture is primarily a portrait. Four lights are arranged at the outer rim of the announcing desk on flexible goosenecks adjustable as to height, angle, and throw. By substitution of various types of bulbs and variation of the wattage, detailed modeling of the face can be effected with a minimum of difficulty. This equipment also has portable back-lighting, which again is controllable, making the work shot of this table the television equivalent of a studio portrait.

This enumeration completes the catalog of our lighting technics and equipment in the National Broadcasting Company television studios. We have tested all reasonable systems of light production and are still carrying on these investigations. Lately we have been interested in vapor-lamps as a possible adjunct to the system, but the complications inherent in a three-phase power-supply and a water-cooling system would appear to make further consideration of present models impracticable.

There have been many statements and many more conjectures as to the light used in television studios. We quote pertinent figures based on our last six-month period of operation. Our average set illumination was in the neighborhood of 1200 foot-candles of incident light. Our average modeling ratio was 2 to 1, while the average light load was slightly more than 50 kw of 110-volt d-c. Our lowest foundation lighting level was 800 foot-candles, a play in which the contrast throughout the set was carried to the upper limit of the Iconoscope. The highest foot-candle reading recorded was slightly less than 2500 foot-candles, a continuity where, obviously, little modeling was attempted.

In our work of the past three years, we feel that we have established a substantial foundation in television studio lighting on which we hope to base an even simpler system. If we appear to have standardized certain assemblies and particular light-sources, this does not mean that our developmental work has ceased. It continues with renewed vigor as we see our experiments bearing fruit.

DISCUSSION

MR. ROBINSON: The liquid mercury lamp of the high-pressure type seems to offer good possibilities for the high level of illumination required in television studio lighting. This lamp has been briefly described before the Society. It is reported that in some tests recently in Schenectady, a very useful unit was maintained using three lamps in a single unit. We used it on three-phase alternating current and no objectionable flicker was present.

MR. RICHARDSON: I have been wondering why the television people have not been using the color-photography (C.P.) lamps? They have been working with what we would presumably call lamps operating at a normal tungsten temperature but it seems that they might advance their technic to some degree by using modern "C.P." lamps, which have almost twice the photographic value. I believe it is the purpose of the "C.P." lamp to produce a light on the side of the blue.

MR. ROBINSON: The Don Lee Studio uses the "C.P." lamp.

MR. CRABTREE: A question was asked at our New York meeting why it would not be better to photograph all of the scenes on motion picture film and then televise from the film thereby reducing the amount of light required as well as the heat. We were advised that the sensitivity of the tubes was quite equal to that of the photographic film.

MR. ENGSTROM: I think one of the reasons why there is an apparent discrepancy between the sensitivity of the Iconoscope and that of present-day film is that recent advances have been made in film speed. A second reason involves the dimensions of a film frame as compared with the dimensions of the Iconoscope photoemissive mosaic. In the Iconoscope this is approximately five inches by four inches and the shortest lens focal length is six and one-half inches. Depth of field is an important limitation in direct pick-up for television. So far, increases in Iconoscope sensitivity have been used to permit smaller settings of lens numerical aperture and thus increase depth of field. It has been considered more important to have greater freedom of action in the studio than to reduce the lighting. We appreciate that both the light and heat levels of today's television studio are too high.

MR. LUBCKE: I might be able to satisfy Mr. Crabtree in some measure by reciting an accident that took place in our studio some months ago. The main lighting fuse on the d-c circuit blew about one and one-half minutes before the end of a "Vine Street" episode. A 500-watt indirect lamp remained lighted, being the ordinary 110-volt, d-c circuit. The latter part of the scene was apparent on the television screen as taking place in a very dense fog.

MR. ENGSTROM: The brightness range in television images may be limited in several portions of the system but the present practicable limit is in the cathode-ray tube used for reproducing the picture. Factors that determine the limit include the bulb-shape, the conductive coating on the inner walls, and total reflections from the glass-air boundary. These limit the range to about 50 to 1 for large areas and to something considerably less than this between adjacent elements of detail. That this is not a permanent limit is indicated by results from experimental tubes that have had considerably greater range between large areas and particularly between small details.

MR. RICHARDSON: I think that most of us have observed that the television pictures appear rather flat as compared with good photographic images. In analyzing the writer's paper, it appears that the method described of quickly shifting the television camera from scene to scene all set up on a single stage presents a serious limitation to the ultimate image as seen by the observer. Would it not be possible as the art progresses to establish the scenes on separate stages or in completely separate areas which would permit a more perfect lighting of each successive scene and eliminate the difficulties which television producers are apparently encountering when they attempt to light their scenes with a rather inflexible lighting system?

If the technic of radio studios was possible, artistic individual lighting would seem to be more readily accomplished.

MR. ENGSTROM: The author of this paper has outlined experiences with the present limited facilities. We must remember that a production technic for television has yet to be developed. I believe that the methods outlined by Mr. Richardson will be tried.

MR. YOUNG: What is the general opinion of the new method that is being considered now by the Zenith Company of Chicago, that is, the direct continuity method of making television programs? Do you care to express yourself on that?

MR. RICHARDSON: Probably we had better leave that for the author.

MR. YOUNG: I have a method near enough to it that I would be glad to show the members so that they can see what it is like.

AN INTRODUCTION TO TELEVISION PRODUCTION*

H. R. LUBCKE**

Summary.—*The current television technical facilities of the Don Lee Broadcasting System in Los Angeles are briefly described. A mosaic type camera and accompanying Don Lee control equipment are used. A coaxial cable conveys the signal therefrom to the W6XAO sight-sound television transmitters, operating on daily schedule on 45 and 49.75 megacycles, respectively.*

The routine of production of a dramatic comedy serial entitled, "Vine Street," in its forty-eighth biweekly episode at this writing, is utilized as an example. A total time of twenty hours of one or more members of the dramatic unit is required to prepare and present one fifteen-minute episode.

The sequence of production is as follows: preparation of script; construction or modification of props and scenery; cast memorization of lines; cast rehearsals; camera, sound, sound-effects, light rehearsal with production staff; make-up; the performance itself, including visual-aural introduction of the act; the performance proper with overall supervision of lighting, microphone, and television adjustments by a television-producer at a distant receiver; closing announcement; written and verbal report of errors or advances in technic made during the performance.

Specifications for the physical instrumentalities and the current television technic are covered for each of the above factors of production.

The television transmitter, *W6XAO*, of the Don Lee Broadcasting System, Los Angeles, went on the air on the ultra-high frequency of 44.5 megacycles on December 23, 1931. It has been on the air without notable exception daily, except Sundays and holidays, since that time. In this period more than 11,000,000 feet of motion picture film have been telecast, and for over a year, experience has been gained in live-subject production. This paper is concerned with the latter activity.

A mosaic type camera and accompanying camera control equipment are located in a 25 by 50-foot studio of the Don Lee Building in Los Angeles. Fig. 1 shows the interior of the studio during a television production. The camera is seen mounted on an arm-type dolly, especially adapted for television by our organization. Com-

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 6, 1939.

** Don Lee Broadcasting System, Los Angeles, Calif.

plete panning, tilting, and elevating adjustments are available, by means of which it is possible to orient the camera in any position at elevations from $1^1/_2$ to 6 feet from the floor. Focusing is accomplished by a precision mechanism operated by a knob at the right rear of the camera case. A built-in view-finder which allows the image appearing on the sensitive camera tube plate to be viewed, and at times a motion picture type view-finder on the side of the camera, are utilized for camera manipulation.

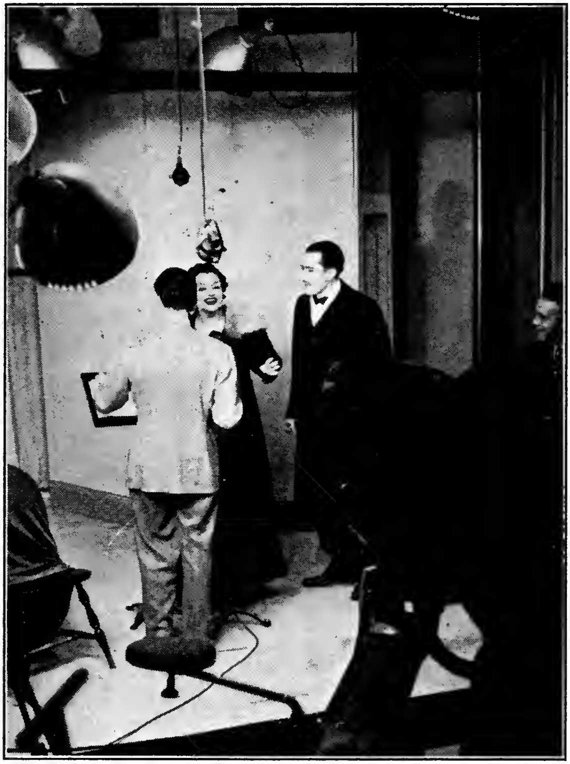

FIG. 1. Don Lee television studio during a production.

The camera control equipment, portable along with the camera, is shown at the right of Fig. 2. In this equipment, voltages are supplied to the camera, and the image signal therefrom is amplified and modified as required for the production of a television signal, complete with synchronizing and other pulses. An image monitor is also part of this control equipment.

From the television studio, which is located on the second floor of the Don Lee Building, a coaxial cable carries the amplified signal to the eighth floor, where the television transmitters proper are located. These are shown in Fig. 3. The transmitters comprise the ultra-high frequency sound unit operating on 49.75 megacycles, common control equipment, and the visual unit operating on 45 megacycles, of which only half may be seen in the figure. The sound from the studio is handled by the regular facilities of the Don Lee Broadcasting System, and is conveyed to the sound transmitter over sound circuits of the usual type.

FIG. 2. Pick-up equipment, showing camera control unit. This unit is of the depressed chassis and panel type of construction, with only operating controls on the front.

The subject matter of this paper will be presented by describing the routine of the production of the Don Lee dramatic-comedy serial entitled, *Vine Street,* now in its 48th biweekly episode at this writing.

The *Vine Street* group composes what we call a "dramatic unit." We found, early in our live-subject television work, that it was desirable to organize our various dramatic productions into such units. Units are organized in the following manner: A person or persons selected for television performances are interviewed, and a type of production decided upon which is best suited to the talents of the persons in question and also fitted to the program needs of the station at the time. The necessary cast is then assembled, and at least one writer. A week or two are utilized in the preparation of a sample script and in conferences with the television production department. A dress rehearsal is then held and needed modifications made. With the subsequent actual performance of the show the unit is then in production.

After the unit has staged a few productions, the routine of production becomes well established, and, in general, and in the *Vine Street* group in particular, adheres to the following pattern:

Episodes of *Vine Street* are presented twice weekly on Tuesday and Friday evenings. They are of 15-minute duration. At least two and often three episodes are prepared in advance. The content and action of the forthcoming episodes are determined by a story conference of cast and writers. The general theme of the serial is considered; the ideas, dialog, and scenes are evolved. The writing is done subsequently by Mr. Wilfred H. Pettitt, chief writer for the unit. The script is complete with respect to dialog, and camera shots and special effects are indicated. At times, and with other units, sketches are included of the scenes as they are to be taken by the camera. In writing, cognizance is taken of the fact that large and elaborate sets are beyond the present scope of television economically, if not otherwise, and that physically impossible actions must not be imposed upon the cast.

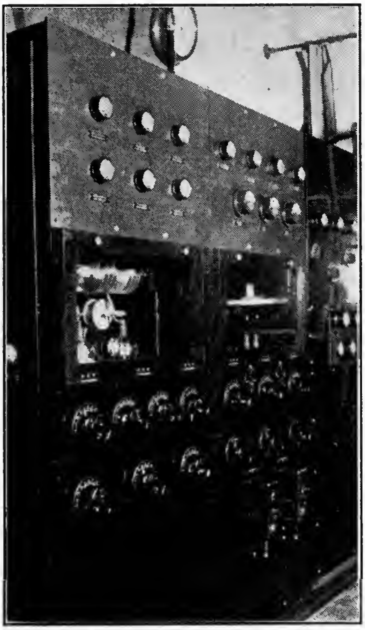

FIG. 3. *W6XAO* sight-sound transmitters. Each transmitter is crystal controlled. Only half of the visual unit, on the right, is shown.

Through the use of miniatures, however, otherwise impossible action has been televised. In a recent episode, a considerable portion of the action took place in close shot with the characters in an airplane winging their way over the Pacific. Ultimately running out of gasoline, they go into a tail-spin and crash on land. The first scene was taken with the characters and life-size properties. The nose-dive was done by means of a miniature airplane, handled by wires, and the crash scene, previously set up on another set, was occupied by the characters during the transition through the miniature.

The characters learn only one episode at a time, and the necessary properties are assembled at this time or ordered if new construction is involved. The principals spend several hours two days preceding the broadcast in memorizing their lines, and a short period going through the dialog together and establishing postures and action to fit.

The day before the broadcast, an hour is spent in refining the recitation of the dialog. That evening, the complete staff rehearsal is held. This includes the camera and lighting crew, the sound supervisor and sound-effects man, under the direction of our television producer, Charles Penman, who is also the production manager of the Don Lee Broadcasting System.

The first activity at this meeting is the distribution of scripts to all concerned and a résumé of the important camera shots and actions, special lighting, and sound effects, as recommended by the cast. These recommendations are modified by any of the several staff members as required. Necessary changes are agreed upon and the important aspects of the episode tested under television transmission conditions. Following this, a dress rehearsal is held to familiarize the operative production staff with the action. It is in this portion of the production that the greater part of what appears on the television screen is formulated. The appearance of the properties is checked on the television monitor screen and the lighting arranged on the properties modified, until a satisfactory delineation is secured. The lighting and positioning of the cast and the camera angles are also determined. Microphone positions are established and sound effects tested.

We have found that real properties invariably televise satisfactorily, although suitable illumination may be required for emphasis. In painted properties, such as background, windows, and fireplaces, the delineation of the object from the general tone of the background should be sharp, and the width of lines comprising the structures bold. This is shown by the character of the door in the shipboard scene of Fig. 4. A certain amount of defocusing is usually obtained on the background, often for the purpose of centering attention on the principal characters, who are in sharp focus. The background properties are therefore televised in subdued tones as desired.

For multi-character scenes, the long shot is often used with complete settings, such as a room, which may assist in the story. If small items of interest are to be displayed, however, the scene may be modified from what would normally be a long shot to one showing only half or two-thirds of the principals involved. One scene may be changed into the other by moving the camera, or by moving the principals. A park bench scene used in one of the early episodes is shown in Fig. 5. Artificial grass and a subdued woodland background were utilized. This background must be within three feet of the principals in order to televise sharply. On many scenes a rather high camera is utilized, that is, with the lens 4 or 5 feet from the floor. A notable exception to this was a camera shot for an up-in-the-tree sequence, where the principals were supposed to be broadcasting a football game from the vantage point of height. Here the lowest camera position possible, coupled with the considerable elevation of a property tree, gave the desired effect of persons quite high off the ground. Changes from long shot to close-up may be made once or twice during an episode. Changes of scene are usually accomplished by panning, under which conditions two sets are established on opposite sides of the general stage area.

FIG. 4. A shipboard scene from *Vine Street*. The background is painted in sharp strokes.

The technic of lighting for television appears to be one of the most fruitful in creating pleasing artistic effects. So-called "flat lighting" will give television pictures, but ones having little interest and sparkle compared to those televised with more elaborate lighting. By flat lighting is meant, of course, that nearly all the light to illuminate the scene comes from the front of the set and perhaps also from the top of the set at the front.

The advanced technic appears to be limited only by the number of lighting units available, and the possibility of maneuvering them as required for the changing conditions brought about by motion of the performers on the set. This problem is complicated by the fact that in television, illumination must be continuous for the total duration of the act. In motion picture technic, each portion of action may be made as a separate take and ample time allowed for skillful placement of the lights.

In our studio, a portable switching panel is installed that provides control of individual or limited groups of all the lights utilized. With this device the lighting supervisor can vary the lighting considerably without touching any unit. This control is usually supplemented by changing diffusers, changing the angle of the unit, or by change of position of mobile units by lighting assistants. A considerable number of the lighting units are fixed in position near the ceiling, each in the proper direction for usual action as has been determined by experience. A few mobile floor units are utilized.

FIG. 5. Park bench scene: artificial grass, painted back-drop, real bench and actors. Note the dark eye shadow on the man.

Hard back lighting has feen found to be a very desirable component in the lighting pattern. This must be supplied by lens-reflector units of the type of the *MR-210*. General lighting is properly supplied by lamps in dull finish reflectors, and modeling lights for the face must be diffused with one or more diffusing screens.

The camera photoelectric tube suffers a form of overload similar to overexposure, if the illumination on the subjects is too great. This usually occurs first on the faces of the performers, giving a "washed-out" effect, in which the sharpness of the features is lost. This condition is eliminated by either reducing the amount or hardness of the light, or stopping down the lens aperture. Make-up also is a factor in this effect, and lighting, camera aperture, and make-up must be correlated in order to achieve desirable results. It has further been found that the spectral characteristic of the light exercises an important effect on the resulting image. A pure white light is the ideal.

The microphoning for an episode is determined by the action that takes place. Two methods of microphoning have been evolved, first the boom or moving microphone method, wherein a comparatively light microphone boom is utilized and moved to keep the microphone reasonably close to the performers. Such a boom is shown in Fig. 2. The usual microphone position is overhead and in front of the performers and as close to them as possible without appearing in the picture.

The second method of microphoning utilizes up to four stationary microphones. These are arranged at strategic points on the scene of action, and the change-over from microphone to microphone is accomplished by fader operation by the sound monitor superviser. This method does not require production assistants for moving the microphone boom.

Four microphones placed according to this technic may be seen in Fig. 1. One is above background, the second above foreground, the third is on a floor stand, and the fourth in front of the camera. All are the Western Electric type *618A* on this set. The floor-stand microphone is also a property in this scene. All modern microphones have been tested in our work. The type used in any performance depends upon the performance, and changes from time to time as the developmental work proceeds.

On the night of the broadcast, the principals arrive an hour or two before the time scheduled for the episode. Last-minute modifications and confirmations are made with the operating staff and new recommendations from the staff are received, if required. The production department in coöperation with the stage manager ascertains how the properties and scenery should be handled with respect to the rest of the television program of the evening. Usually *Vine Street* is the last act on the program. The scenery and properties are often placed on a set prior to the broadcast, and this set not used for other acts.

The cast is next made up. Make-up is most important in long shots. In close-ups street make-up is sufficient, although accentuated make-up may be utilized by increasing the light intensity. An example of no make-up is given in Fig. 6. This is a photograph made on a receiver 20 miles from the transmitter. A ten-second exposure was utilized, during which time inescapable movement of the subject may have dimmed the photograph.

A base paint approximately No. *29* panchromatic is utilized as a start. Eyebrows are accentuated with black or dark brown liner. Artificial eyelashes and eyeshadow are used. Special Max Factor lipstick of a brownish-violet shade is applied. This color has been found more desirable then the red, because the camera tube exhibits increased sensitivity to the red and also because red light energy is particularly predominant in the incandescent illumination utilized.

FIG. 6. Photograph made on a receiver 20 miles from the transmitter. No make-up used; camera exposure, 10 sec.

Visual and aural introduction to the episode are provided by means of theme music, miniature stage, and appropriate introductory paragraph prepared by the writer of the script. In motion picture title fashion, a miniature stage starts the performance by the raising of the main curtain, the draping of a side curtain, and the retraction of side wings, displaying a sign reading, "*Vine Street*, by W. H. Pettitt." The side wings are then moved to obscure the sign, which is immediately replaced by a second sign reading, "Starring Shirley Thomas as Sandra Bush." In the same manner a photograph of the star is next displayed, and then a sign reading, "and John Barkley as Michael Roberts," followed by a photograph of Mr. Barkley. Simultaneously with this visual action, an off-stage announcer ties the forthcoming episode to the previous action and introduces the episode.

Cues for visual and aural production are given by arm and hand signals by the television producer. The camera then pans to the scene and the action starts. At substantially every episode that has been telecast, the action is continued to the conclusion of the episode without a break that could have been noted by the usual looker. Occasional lighting of subject or camera irregularities have required modifications of what was telecast, as compared to what was rehearsed, but these have been undetectable except to those intimately concerned with the production of the serial. A prompting system has been arranged, but it is almost never called upon.

It has been found that excellent overall supervision of all the processes of television operation and production can be exercised by a suitably trained director, who observes the program at a sight-sound television receiver located at a representative point in the service area of the television station. He talks by conference-circuit telephone to the television studio supervisor, television transmitter control operator, and possibly to other members of the operating staff. Defects in lighting, camera technic, microphoning or television control, or transmitter adjustments are instantly apparent to this director. Constructive criticisms are made to the person involved and conditions that can be cured are speedily adjusted. Monitors are provided in the studio and also at the transmitter, the latter operating by radiation from the transmitting antenna. Satisfactory monitoring of the performance can be achieved by the use of these monitors alone; however, the typical audience reaction secured at a distant receiver under home-receiving conditions, the effects of slight interference, and other practicalities entering into the picture as it is unfolded on the screens of the many lookers, are all present on the screen of the distant director, who is usually the writer.

On cue, the closing fade-out of the episode is made, and the camera switched to a sign reading, *Vine Street.* The fade is made electrically, and this means is usually utilized also in changing from scene to scene. Fades may be made as long or as short as desired. Other fades are used, known as out-of-focus fades and as lighting fades. The former is accomplished by rapidly turning the camera focus control so far out of focus that the scene becomes a blur of light and then reversing the process in coming into the succeeding scene. The latter is accomplished by dimming or extinguishing the lighting units used to illuminate the scene.

Coincidentally with exhibiting the sign, the theme music for *Vine Street* fades in for a short interval at full volume, then fades down, while the announcer gives the closing comments on the episode. At the conclusion thereof, the music is again raised to full volume for a few more bars. During all this activity, sets may be changed for any act that may follow.

Reports on the pattern configuration of the lighting units, microphoning, or other production factors may be requested at this point by the distant director. Concluding observations or suggestions may also be made. Following the complete broadcast, a written report is prepared by the director. This includes tabulation of various technical readings, and the artistic observations on the merit of the camera shots and lighting. The body of the report consists, however, of one or two paragraphs summarizing the merit of the broadcast as a whole; procedures are formulated to prevent errors that may have been made by the operating staff. The report concludes with definite instructions to members of the staff involved, concerning constructional or operational changes that are to be made prior to the next broadcast and are to be subsequently tested during the next broadcast. This report is read by all concerned. It constitutes a running record of the television activities and has proved invaluable for correlating activities and for reference to the operational aspects of past performances. The sheets are retained and bound once a year. In combination with the transmitting log, the written announcements, and the scripts utilized in the performances, a complete record of television operations is obtained.

The author is glad to acknowledge the loyal and effective work of Mr. W. E. Thorp, Mr. W. S. Klein, Mr. H. W. Jury, and Mr. R. L. Pitzer of the television technical staff; Mr. C. Penman, Mr. D. Confrey, Mr. P. Faux, Mr. K. Simon, Mr. J. Peoples, Mr. W. Waldegrave, Mr. H. Billheimer, Mr. D. Crandal, Mr. A. Haberman, and Mr. H. Huber of the operative staff; Mr. T. C. Sawyer, Mr. R. Williams, and Mr. F. Bingham of the announcing staff; Miss W. Urdahl for script make-up; and the writing and acting staffs of *Vine Street*, *The Gibbons Family*, *The Tele-Theatre Guild*, *The University of Southern California on Parade*, *Dramas of Youth*, *The Rainbow Review*, *Betty Jane Rhodes*, *The Singing Strings*, *The Tico Tico Trio*, *The Singing Chimes*, *Jean Markel*, *Fashions*, *Norma Young*, *Happy Homes*,

and numerous individuals, who, with the above, form the regular entertainment staff of *W6XAO*.

DISCUSSION

MR. LOWNER: May I ask if the backgrounds are painted in formal black and white or are they in color?

MR. LUBCKE: They can be either. We usually use black and white and shades of gray in which the ship scene was painted. The forest scene was painted in color. The color rendition is approximately the same as that of the present-day panchromatic film but with an unusual accentuation of red.

MR. LOWNER: You mentioned in your paper that you preferred a white light source. Do you mean that the yellow or the reddish tendency of normal daylight tends to be detrimental?

MR. LUBCKE: The yellowness and more especially the redness of the low-temperature tungsten lamps aggravates the camera's red spectral response; consequently the high-temperature, white motion picture type lamps are the preferred incandescent sources. We have experimented with and used mercury-vapor lamps and others particularly rich in blue. A certain amount of color correction can be achieved in the overall system by such methods. There appears to be an actual loss of detail with too much red light. With a white incandescent source or something toward blue the clarity is better.

MR. ROSS: Since it is unusually receptive to red, would it not be possible to obtain color shading by merely using different depths of red; in other words, different tones of red.

MR. LUBCKE: Yes; however, red and its derivatives as a whole come out as white. For a time in the make-up department we utilized red lining for highlights; however, because the actors looked grotesque and this reacted unfavorably emotionally upon them, we discontinued this practice and now use a white or cream color for highlighting the faces.

From practical experience, I would say that we would not all want to use shades of red as a means of getting different shades of tone. We much prefer to work in black, white, and shades of gray, staying away from a very bright white. At times a very brightly illuminated white sheet of paper or similar thing will overload the television camera tube and even the transmitter or amplifier. Last night, however, one of our acts was portrait sketching by an artist who, at the conclusion of his act, held up his sketch, which was in black and white on a perfectly white paper. It was very well televised.

MR. TREMAINE: Do you use a-c or d-c for lighting your sets?

MR. LUBCKE: We use d-c. We have used a-c on usual motion picture type incandescent lamps, and have not found a discernible hum pattern on the television screen. With mercury-vapor lamps on single-phase a-c there is a pronounced dark and light band effect, however.

DESIGN PROBLEMS IN TELEVISION SYSTEMS AND RECEIVERS*

ALLEN B. DUMONT**

Summary.—*A discussion is presented of the present-day television standards as adopted by the Radio Manufacturers Association, stressing their importance in relation to the design and production of television receiving equipment.*

Emphasis is placed upon the limitations of the standards and the possibility of their obsolescence in the future. It is claimed that the lack of flexibility embodied therein is very likely to cause serious difficulties for the industry in the future, for the transmission of a video signal is a much more complex problem than the transmission of an audio signal as in modern radio broadcasting where standards were relatively unimportant.

As an aid to circumventing many of the limitations of the present tentative standards, a new system of television transmission standards is proposed which will greatly simplify the considerations involved in the design of television receivers.

The fundamental consideration for a system for transmitting motion pictures by radio demands in principle a system for the conversion of lights and shadows into electrical impulses, the transmission of these impulses over a distance, and their reconversion into lights and shadows with a minimum amount of distortion caused by the operation.

To accomplish this objective, standards must be set up defining the method of operation. These standards must be sufficiently definitive to provide satisfactory reproduction of the intelligence at the receiving end consistent with contemporary engineering advances. They must be flexible enough that their adoption will not prevent future improvements from being made in the art because of their rigidity and the consequent obsolescence of existing equipment and investments based upon their restrictions. Finally, the standards must be capable of providing a system for transmitting the intelligence at minimum cost and with minimum disturbance to other radio services. The last requirement demands that the radio-frequency band-width of

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 14, 1939.

** Allen B. DuMont Company, Passaic, N. J.

the signal be as narrow as possible in order that the signal may be transmitted as efficiently as possible and that there may be as many stations as possible in a given transmitting band.

The present standards that have been set up by the Radio Manufacturer's Association provide for the transmission of two separate carrier signals, one carrying the video signal, and the other the audio signal. The frequency-separation of the two carriers is specified in order that single-control tuning to any transmitter may be accomplished.

These RMA standards provide for the transmission of a video signal of negative polarity composed of 441 lines per frame, with 60 interlaced fields and thirty frames per second. The television signal transmitted in accordance with these standards occupies a transmission band of approximately six megacycles. Synchronizing pulses are transmitted for controlling the sweep circuits that deflect the electron beam to generate the raster that develops the picture.

FIG. 1. Television film projector, DuMont station *W2XVT*.

The receiver designed for such a transmission system must have circuits designed for this type of signal alone. Any variation from the standards will destroy the picture, and if any such variations were to be adopted in the future they would cause the obsolescence of all existing receiving equipment.

Engineering progress comes only through constant, continued research and development. It is obvious, therefore, that at some future date our present-day so-called high-definition television will compare only with the crystal detector, head-phone days of radio. At that time, however, there will be a tremendous investment by the public in television receiving equipment, and the obsolescence of such an investment will not be very cordially received. It is necessary, however, that such changes take place, and the problem of the present-day engineer is to design his receiving equipment in anticipation of such changes.

It is impossible for any man to predict the future, but it is possible for the engineering profession to exert every effort to eliminate, if possible, or to reduce to a minimum, every future trouble that may conceivably occur. When this reasoning is applied to our present set of tentative television signal standards, they fall far short of this ideal.

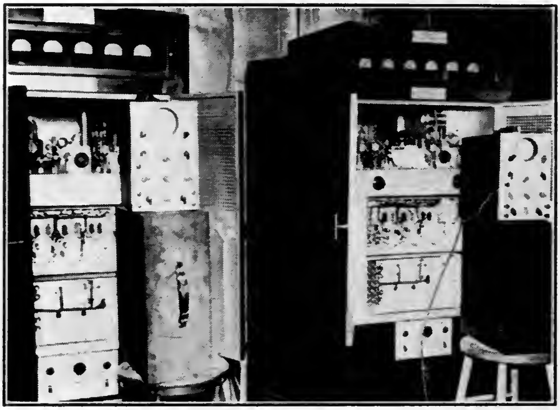

FIG. 2. Film pick-up panel.

All advances in television receiver design will be directed toward increased picture detail. As the result of engineering activity, it is quite possible that within the next few years developments in intermediate-frequency amplifier design, and in video amplifier design will readily permit the economical reception of pictures having detail corresponding to an 800-line picture. With standards adopted, however, for a 441-line picture, and with every television receiver on the market equipped with synchronizing and deflection circuits capable of operating at only these scanning frequencies, little advantage can be made of engineering progress.

The problem that arises is slightly different from the one that existed when radio broadcasting began. The system of transmission was obvious; and while different systems have been proposed and higher-quality transmission could be employed with the adoption of such proposals, the fact remains that equipment manufactured twenty years ago is still capable of producing intelligible results from present-day transmissions, and this has occurred despite the fact that the fidelity of these transmissions is vastly superior to that when radio broadcasting first began.

The situation is further relieved, in regard to broadcasting, with respect to the maximum allocated transmission-band width. The standards that were adopted twenty years ago provided for a ten-kilocycle separation of station carriers permitting a maximum modulation frequency of five kilocycles. The present policy of the Federal Communications Commission has been to assign carrier frequencies in a given area on widely separated channels. The tendency is to provide a limited number of stations serving a certain area at high signal level, and to the exclusion of more distant transmitters. Under this policy, the five-kilocycle band-width limitation fails to hold, and modern broadcasters continually provide program service of a much higher quality.

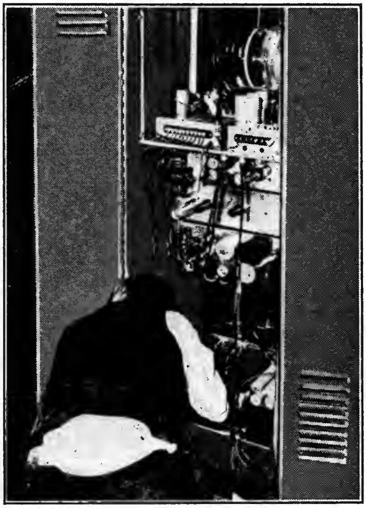

FIG. 3. Synchronizing generator panel.

If a modern receiver is capable of reproducing the high-fidelity transmissions radiated by present-day broadcasters, the full advantage of years of engineering is obtained by the listener. But this service is not gained at the expense of those who have large investments in radio receiving equipment purchased years ago. In spite of the high-quality transmissions now radiated in contrast to the distorted signals for which these receivers were designed, the receivers still function satisfactorily.

Any television transmission must necessarily occupy a wide frequency band in comparison with standard broadcast transmissions;

and the number of available channels is therefore limited. With the exception of some unforeseen and radically new method for the transmission of pictures by radio, future development must go forward along the lines of improving the transmission within the existing channel widths, and the present broadcast policy of providing high fidelity by widely separating the stations in a small area can not be followed. Development must, therefore, proceed along the lines of improving transmission and reproduction within the available channels.

FIG. 4. Sound and picture radio transmitters.

This can not be the case with the present proposed television transmission system. This system rigidly defines line frequency, frame frequency, and interlace ratio, which are the only factors affecting picture definition, with the exception of band-width which must be defined to give the system any semblance of order. This proposed system further provides for the transmission of synchronizing pulses to control the frequency of oscillation of the horizontal and vertical oscillators, and except for ten per cent of the time during which the beam is blanked out, these oscillators are free running. During the time they are free running, difficulties are experienced in obtaining both horizontal and vertical resolution of the picture.

FIG. 5. Fourteen-inch DuMont console receiver.

A system of transmission has been proposed by Allen B. DuMont Laboratories that effectively removes many of the limitations of the present RMA standards. It is definitive enough to permit commercial television broadcasting to commence at the present time, yet it is flexible enough to permit engineering progress to advance. This is accomplished, in brief, by defining carrier separations and band width, which must be standardized, but it permits the television signal to be transmitted with any number of lines and frame frequency, and any interlace ratio.

By dispensing with the sweep oscillators ordinarily required in the television receiver designed for reproduction of RMA standard transmissions, the problems of properly designing the deflection circuits are greatly simplified. They are no longer required to match accurately the operation of the deflection circuits of the transmitter while running free during ninety per cent of their operating cycle. In lieu of this type of operation, this new system provides for actual transmission of the deflection voltages during their entire operating cycle.

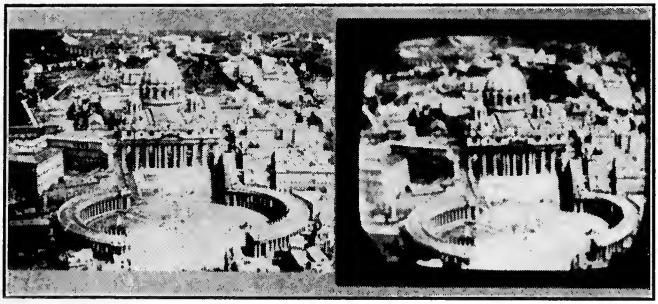

FIG. 6. Comparison of received picture and original film.

If a receiver be properly designed for operation from the DuMont system of transmission, the deflection circuits consist only of amplifiers having the requisite gain and voltage output to generate any type of voltage-wave shape that may be employed to develop the television picture. With such a system of transmission, the deflection of every receiver operating from a given transmitter is under the control of the circuits at the transmitter for 100 per cent of the operating cycle. Because of this control, the position of the beam at the receiver can not deviate from the position of that at the transmitter and resolution problems due to such inaccuracies are practically eliminated.

With the electron beam at the receiver under complete control of the transmitter, it can be operated upon in any manner desired. In areas where the income from the service does not justify the investment necessary in a high-definition television transmitter, or in cases where, for some other reason, definition corresponding to the RMA

441-line transmission is not required, the transmitter may radiate a sweep signal of lower frequency, and it will be readily reproduced by a standard, readily available, commercial receiver designed in accordance with the proposed DuMont system. This same receiver may be used for reproduction of transmissions having 441-line detail. In the light of future developments, this same television receiver, designed in accordance with the proposed standard, will still be capable of reproducing the television signal transmitted in accordance with such future developments. The interlace ratio may be controlled accurately at the transmitter to prevent the pairing of lines found in the present system when the sweep circuits are free running. The interlace ratio and the line and frame frequencies are determined at the transmitter and may be varied to provide any transmission detail desired.

FIG. 7. Received picture from Paramount newsreel over DuMont transmitter.

Plans for design and production of television receivers are undertaken, at the present time, with certain misgivings in regard to what may be expected in the future. The design of equipment in accordance with such a rigid set of specifications as are proposed for the RMA system of transmission must be unnecessarily detailed; and the production manufacture of such equipment will be much more costly than might be anticipated by drawing a comparison between the modern television receiver and the modern radio receiving set. Further, the manufacturer of such television receiving equipment may be justifiedly worried that his reputation will be destroyed by the complete obsolescence of such equipment after it has been marketed.

At the present time, the fundamental design consideration of a television receiver is, "Will it work five years from now?" With this thought in mind, the DuMont television system has been proposed. It is believed that this television transmission system offers much to the engineering profession in establishing a balance between rigid, restricting, fundamental definition and the maximum possible flexibility consistent with providing a service to the public.

DISCUSSION

MR. LUBCKE: In 1936 we were utilizing what is generally known as the usual television system, in contradistinction to the DuMont television system. In one of our demonstrations we found that the number of lines transmitted by the transmitter had accidentally changed by five per cent during the demonstration. We at the receiver did not know of it until after the demonstration, when I was informed of it by the transmission operator. The point is that the usual synchronizing-pulse type of television system in rather general use throughout the world is capable of "hanging on" at the receiver to changes that even spasmodically occur at the transmitter. With slight readjustment at the receiver, perhaps a ten or fifteen per cent change could have been accommodated; and with a visit from a competent service man, perhaps as much as fifty or one hundred per cent.

MR. RYDER: There has been a lack of information here with respect to large-screen televising, although some of us are aware of the fact that large-screen televising is being done in England. We would welcome more information with respect to large-screen television. The picture in normal "so-called" instantaneous television is actually out of synchronism with the sound. This results from the picture-image storage in either or both the camera and receiving tube. The delay is about equivalent to a frame and a half of motion picture film as observed by those of us familiar with "out-of-synchronism" in terms of motion pictures. An interesting fact in this regard is that in television the picture lags behind the sound, whereas in ordinary speech the sound lags behind the picture or the image. This has great importance as we consider large-screen picture projection. We are quite aware of the fact that in small-screen projection this "out-of-synchronism" condition will not cause annoyance, but it is one of the problems that should be given serious consideration with respect to instantaneous televising of picture and sound.

MR. ENGSTROM: The only system on which I have enough information to comment is the cathode-ray optical projection method. The Baird equipment is of this type. A small but bright image is produced on a cathode-ray tube and then enlarged by optical projection onto a screen.

I would judge the performance of such a system in the present state of the art, as being very roughly equivalent to a not-too-good 16-mm. film projected onto a large screen at somewhat too low a screen brightness. Performance might be considered adequate because of novelty (television) or because of timeliness. I think the method and performance must be improved before permanent interest could be maintained in the theater field. And I am confident that advances will be made and that it is just a matter of time to work out the various problems.

Member: What are the possibilities of either eliminating the curved surface of the cathode-ray tube, with its distortion, or of eliminating the introduction of complementary distortion by optical projection. Television is young and it will take many years to perfect it; many of the defects we see at present certainly will be overcome in the future.

Mr. Green: Apropos of that distortion I think Mr. Engstrom's company now has a tube which will overcome some of this trouble. In this tube I think the ratio between the dark point and the light point together exceed 102. That is one way of eliminating the curve effect. Another way that seems fairly obvious and which I think has been done would be to project the cathode-ray beam on to a phosphorescent screen, a flat screen, and look at it. There is a window in the tube. Of course, you get distortion of somewhat the same type as if you took a movie projector and shot it up at an angle. I just wondered if this line had been carried very far. If we see the image on the side where the light is being generated it is always clearer than it would be if laid on the back side which is what we would do with ordinary television. I do not know whether this is being carried forward or not but it will certainly eliminate the effect that is being objected to.

Mr. Joy: In England the Baird and the Scophony systems are being used for projecting television images on large screens. Is the Scophony system being used in this country? If so, who is experimenting with it?

Mr. Williford: It is being investigated but I do not know what has been done about it.

Mr. Smith: A certain amount of confusion is permissible in transmission in comparison with that required by moving picture work. Television, apparently, can stand a good deal more. I wonder if anyone has any figures on that.

Mr. Green: Assuming that your lens were of such high quality that you could disregard the minute size of the circle of confusion, what would then be the limiting factor, or what is the size of the scanning dot? That in turn is found in the number of lines which is 300 out here* and 441 in the East. We can also take into consideration the size of the screen and television camera. I do not know what it is exactly but I believe it is four and a half inches by six inches. On that basis the circle of confusion would probably be large with regard to photographic standards. However, it seems to be good enough for the present.

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* Changed to 441 lines, May 15, 1939.

REPORT OF THE TELEVISION COMMITTEE*

Summary.—*A report on the aims and work of the Committee, with partial reports by the two sub-committees: (A) on Television Production and Reproduction Technic, O. B. Hanson, Chairman, and (B) Film Properties and Laboratory Practice, O. Sandvik, Chairman. The scopes of activity of the sub-committees are described, and their program for the coming year. Among the items covered by these scopes are (1) glossary, (2) bibliography, (3) tutorial material, (4) dimensional practices, (5) normal equipment and procedure, (6) special problems such as inter-industry coördination, future equipment needs, and specifications, etc.*

On March 9, 1938, the organization meeting of the Television Committee was held at the Hotel Pennsylvania, New York, N. Y. Since that time, considerable study has been given to the range of activity of the Committee, its scope of interests, and the manner in which its work is to be conducted. Although a limited number of meetings have been held, aside from the organization meeting and the meetings of the Sub-Committee Chairmen, much preparatory work has been done by conference and correspondence. The result of this work is not forthcoming at this time in specific form, because of several reasons: first, it is necessary that the Committee and its Sub-Committees adjust their viewpoints with respect to the relation between the motion picture industry and the television art; second, most of the subjects engaging the attention of the Committee are long-term projects; and, third, the television art is in so marked a state of flux at the present time that great care must be taken to differentiate between accepted practice and transient developmental steps.

In view of these facts, the present report of the Committee will be concerned mainly with its organization and scope of activities, with the expectation that by the time of the Fall Convention of the Society, the Committee will be able to report more specifically on at least some of the projects described below. In reporting on the state of the art, it is the purpose of the Committee to avoid causing undue or unjustified concern to the motion picture industry or giving inaccurate

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ideas as to the imminence of large-scale commercial television developments or the mode of utilization of the products of the motion picture industry. As a matter of policy, only factual (scientific and technical) matter is to be included in these reports, opinions being avoided so far as possible; and no attempt is to be made at any time to issue either reassuring or alarming statements or non-technical generalities. In any statements made by the Committee, at least for the present it should be definitely understood that these reports do not represent any ideas of permanence or finality in the practices of standards discussed. The reports are intended solely as informative guides for motion picture and television engineers.

Scope of Activity.—The Committee will endeavor to collect, formulate, clarify, and disseminate useful information to the motion picture industry as to television film and pictorial requirements, and to the radio television groups as to motion picture capabilities and availability. It is hoped to avoid conflicting standards or practices in the two arts. The membership of the Committee includes prominent members of both industries so that an automatic liaison will exist without the necessity of delegating any particular agency or person for the purpose.

Reports will be made at timely intervals, as developments may direct, by the Committee as a whole or by the Sub-Committees. The first aim of these reports is to be historical and instructional, and, accordingly, to collect and collate existing material. The second object is to guard against misunderstanding misstatements in the press, unnecessary conflicts of aims or opinions, and to obviate or reconcile these wherever possible. The third purpose is to act as one guiding agency in directing technical activities common to the two industries and furthering interchange of mutually helpful data.

Two Sub-Committees have been established—Sub-Committee A on Production and Reproduction Technic, under the Chairmanship of O. B. Hanson; and Sub-Committee B on Film Properties and Laboratory Practice, under the Chairmanship of O. Sandvik.

Considerable difficulty was experienced at first in outlining the scopes of the Sub-Committees so that they would cover the necessary phases of the art and permit a coördinated course of action, without overlapping and duplication of work. It is impracticable at the present time to report specifically on a number of the items falling within these scopes, due to the fact that the technic of television is in a state of flux and many phases of the art are really in the experimental stage.

The characteristics and sensitivity of Iconoscopes (pick-up image tubes) have been changing as new and better models were produced. These changes affected the lighting set-ups, the lenses, the treatment of the sets, and other phases of production technic, and any report that might be made at the present moment might be obsolete and misleading by the time it reaches the members of the Society.

The Iconoscopes used for the transmission of images originating from motion picture film have somewhat different characteristics from those used in the studio. Due to the rapid changes occurring in the development of these Iconoscopes, the density and gamma of the films used could not be determined under these circumstances, but it was generally felt that, rather than have prints made with special characteristics for television requirements, it would be better at this stage of the art to endeavor to attempt to accept the standards of the motion picture industry at least until such time as the limits of the television system could be finally determined and stabilized—which limits might subsequently lead to specifications for specially processed film.

As a basis of a temporarily acceptable policy for the industry, the opinion appears to be that the present motion picture standards are acceptable for television and that television will try to work toward those standards. Motion picture standards should not be degraded to meet television requirements. There are differences, however, between the requirements of the television art and those of the motion picture art. For that reason, much of the early work of the Committee is to be of an educational nature—that is, the collection of pertinent information of interest to the motion picture industry. There are differences as to set construction, scenery, and limits as to detail, size, and coloring. There are also limitations of systems in relation to the sensitivity of the Iconoscope, types of light-sources, floor and overhead lighting, long shots and close-ups, modeling, and air-conditioning. The subject of lenses is closely connected with those of film and lighting. Some of the concepts are different in the two arts, for example, what is called a "dissolve" in television, is really what is known in motion pictures as a "fade-in" and "fade-out." Very little is known at the present time in a final sense with regard to mobile equipment and further developments must be awaited. Problems of background projection are similar to those for the motion picture except with regard to the light required. The Iconoscope screen size is not yet definitely standardized, and although projectors use standard sizes of film, they are modified to accommodate the different rates and methods of projection.

To be more specific, the proposed projects of the two Sub-Committes have been more or less definitely divided into the following groups:

SUB-COMMITTEE A

Production and Reproduction Technic

(*a*) *Glossary.*—Material for the glossary will be obtained from all sources including the publications of the Institute of Radio Engineers, Radio Manufacturers Association, Society of Motion Picture Engineers, Acoustical Society of America, Optical Society of America, and the like.

(*b*) *Bibliography.*—A list of articles and books dealing with television will be prepared so far as motion pictures, film, film photography for television, and film projection and transmission for television are concerned. It may prove advisable in some instances to include abstracts of the articles or summaries of books.

(*c*) *Tutorial.*—General descriptions of television equipment, methods and use of films, with respect to their present status and probable trends.

(*d*) *Dimensional practices.*

(*e*) *Normal equipment and procedure practices.*

(*f*) *Special problems* (inter-industry coördination, future equipment needs and specifications, and the like.)

With respect to the available data, items (*a*), (*b*), and (*c*) will be given preferred attention with early stress on (*a*). It is hoped, however, that eventually the entire work of the Committee will be expanded to include all the items listed above.

SUB-COMMITTEE B

Film Properties and Laboratory Practice

(*a*) *Glossary* (as before).

(*b*) *Bibliography* (as before).

(*c*) *Tutorial.*—A general description of television film equipment in relation to photographic requirements, desirable film characteristics, and exposure and processing conditions of negatives and prints.

(*d*) *Standards.*—Dimensional practices as related to the use of motion picture films and film handling equipment.

(*e*) *Normal equipment and procedure practices.*

It is recognized that a considerable amount of work will be required by the Sub-Committees to gather the material for the survey and prepare the glossary, as well as to undertake work on the other phases outlined above. It is felt that nomenclature and the glossary provide the logical starting point for the work, which should be followed immediately by the bibliography. Accordingly, it is hoped that at the Fall Convention of the Society, the Committee may report on these subjects, and, in addition, it is felt that sufficient experience may have been gained by that time to report on some of the other projects. For example, a limited television service will be available this season in the New York metropolitan area from one or more of the television broadcasters. The experience gained in actual operation during 1939 may assist materially to stabilize production technic, or at least permit the preparation of a report covering some of the phases of production. Some time will probably pass before production and reproduction technic of television will reach a stage of stability such as to permit a determination of standards of production.

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PROPERTIES OF LAMPS AND OPTICAL SYSTEMS FOR SOUND REPRODUCTION*

F. E. CARLSON**

Summary.—*Sound reproduction systems are designed on the premise that the sound-track will be illuminated by a scanning-beam of substantially uniform flux density. This paper presents results of extensive studies of the actual beam characteristics for all types of optical systems and lamps employed in the reproduction of sound from film. They were made possible by a unique microphotometer, designed by the author, with which the scanning beam can be analyzed in minute elements.*

The studies cover: relative levels of scanning beam illumination; effect of source displacement from design position on total flux at the sound-track; microphotometer recordings of distribution of flux density across the beam as affected by optical systems and source forms and by displacements of the source.

In reproducing sound from film the uniformity of sound-track illumination is becoming more and more a subject of interest to equipment, lens, and lamp manufacturers alike. Uneven illumination distorts tone quality and may cause volume attenuation.[1] Substantially uniform illumination is possible with any of the three characteristic types of optical systems currently in use. Failure to achieve such uniformity may be due to the design or lack of precision of the optical system, the use of a lamp of wrong design for the purpose, lack of precision in the source, or inaccurate adjustment of lamp position. This paper summarizes the results of extensive studies of the effects of source form and positioning on uniformity of illumination of the sound-track.

Test Equipment.—All the data presented in this paper were obtained by a recording microphotometer designed by the author. There had not previously been available facilities of a kind which made it convenient to carry out such studies of adequate extent. The instrument is, in effect, direct reading, measuring scanning beam brightness in terms of the response of a typical caesium cell. Thus

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the complications attendant upon the use of standard test-films are obviated.

The microphotometer is shown in Fig. 1 and schematically illustrated in Fig. 2. The essential elements include:

(*1*) A mounting for the exciter lamp permitting adjustment of source position in three dimensions in steps of 0.001 inch, and means for tilting the source by known amounts in the vertical plane.

(*2*) A mounting for the sound-reproducing optical system permitting the scanning beam to be focused in the plane of the film.

(*3*) A slit in this plane less than 0.001 inch wide in the direction of the long dimension of the scanning beam. Thus, with the slit in place, the flux in each element of less than 0.001 inch of the scanning beam may be measured or, by removing the slit from the beam, the total flux. An additional adjustable slit may be substituted and set for a band of any desired width.

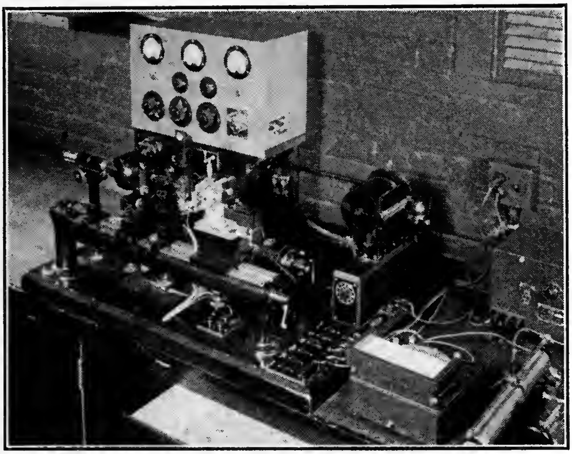

FIG. 1. The recording microphotometer.

(*4*) A small integrating sphere and caesium photoelectric cell to receive the flux from the scanning beam. The integrating sphere is used to eliminate errors due to differences in sensitivity over the cell surface.

(*5*) A direct-current amplifier[2] for the photocell current, the output of which may be read on a microammeter or by the deflection of a high-sensitivity galvanometer when the scanning beam is being explored with a narrow slit.

(*6*) A galvanometer lamp to project a beam of light onto the galvanometer mirror and a film drum to record the galvanometer deflections as a trace of the reflected beam on a moving film.

(*7*) A mechanical linkage between the slit and the film drum so that the abscissas of the exposed traces bear a direct relation to the movement of the slit, and suitable motive power to provide synchronized automatic movement of slit and drum.

Types of Optical Systems.—The optical systems tested are of the types shown in Figs. 3*a*, 3*b*, and 3*c*. They are in use in both 16-mm. and 35-mm. sound-reproducing equipment. The system illustrated in Fig. 3*a* closely resembles that employed for motion picture projection. The light-source is imaged substantially in the plane of a mechanical slit (corresponding to the aperture), which is, in turn, imaged on the film plane (corresponding to the screen) by an objective lens. The light-source is of the same general proportions as the slit, long in relation to diameter. Usually about 0.0015 inch of the filament coil diameter and about 0.126 inch of the coil length are effective.

The system illustrated in Fig. 3*b* closely resembles that of a stereopticon. Here the condenser forms an image of the light-source in the objective lens and the mechanical slit is placed close to the condensing lens. Since the aperture of the objective lens is circular, the useful portion of the light-source must lie within a circle of appropriate diameter (usually between 0.070 inch and 0.100 inch). This calls for a source relatively much shorter in length and much larger in diameter than those used with the "motion picture" type of system of Fig. 3*a*.

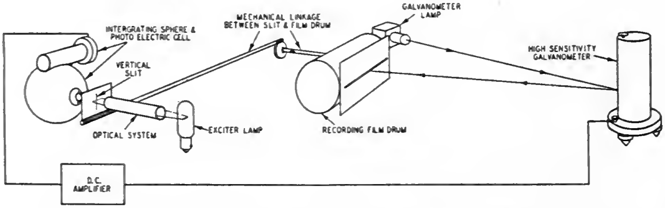

FIG. 2. Schematic diagram of recording microphotometer.

The system illustrated in Fig. 3*c* usually consists entirely of cylindrical lenses, although spherical surfaces are sometimes included. In this type of system the smaller dimension of the source is imaged directly on the film, and reduced in size to one-tenth or less, by the lens or lenses nearest the film plane, thus determining the short dimension (width) of the scanning beam. Since it is not confined by a limiting aperture, a change in the diameter of the coil produces a corresponding change in the width of the scanning beam and a variation in the resulting sound volume at different frequencies.[3,4] Similarly, tilt or distortion in the coil changes its width* and is reflected in a corresponding change in the width of the scanning beam and in the amount of amplitude distortion. Lamps with coils of comparatively small diameter are therefore used, selected within defined limits for source width (usually 0.013 inch).

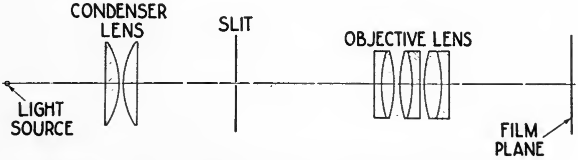

FIG. 3*a*. The "motion picture" type of optical system.

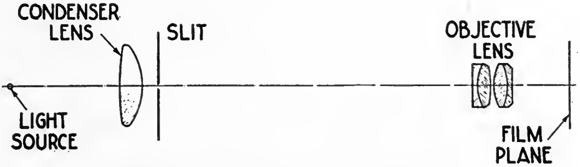

FIG. 3*b*. The "stereopticon" type of optical system.

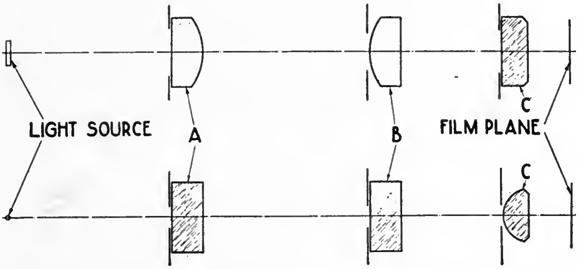

FIG. 3*c*. A "cylindrical lens" type of optical system.

In the plane of the coil axis, the cylindrical system is usually essentially of the "stereopticon" type. The condensing lens A (Fig. 3*c*) forms an image of the coil length in the objective lens B and an aperture is placed close to the condensing lens whose image defines the length of the scanning beam. Coil length is important only to the extent that it must be sufficient to cover the intermediate lens as in

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* Source width as used here is measured in a plane parallel to the film plane and is the separation between lines through the highest and lowest points of the source, both lines being parallel to the designed position of the coil axis.

TABLE I

		Source Dimensions (Inches)							Sound-Track Illumination			
										Scanning Beam Dimensions (Inches)		
Lamp Volts	Rating Amps.	Av. Length	Coil Diam.	Max. Width	Rated Initial Lumens	Rated Av. Lab. Life (Hrs)	Approx. Color Temp. (°K.) at Rated Amperes	Per Cent Modulation of Light on 60-Cycle Alternating Current	Type of System	Width	Length	Relative Level* (Db) at Rated Amperes
7	0.2	0.103	0.006	0.013	15	50	2685	22	Cyl.	0.0011	0.065	−20.0
										0.0011	0.084	−18.5
4	0.75	0.083	0.008	0.0125	30	50	2920	21	Cyl.	0.0011	0.065	−17.0
										0.0011	0.084	−15.0
6	1.0	0.177	0.009	0.013	75	100	2950	18	Cyl.	0.0011	0.065	−10.5
										0.0011	0.084	− 9.0
8.5	4.0	0.300	0.022	0.033	680	100	3115	5.1	Motion Picture	0.001	0.084	2.8 (−7 @ 3.2 A.)
8.0	2.0	0.243	0.024	0.033	160	150 @ 2.35 A.	2680	5.3	Motion Picture	0.001	0.084	−7.4 (1 @ 2.35 A.)
9.0	4.0	0.185	0.049	0.070	580	500	2960	4.5	Stereo.	0.0012	0.084	− 0.5
10.0	5.0	0.190	0.059	0.074	1000	100	3085	4.3	Stereo.	0.0012	0.084	3.5
10.0	7.5	0.200	0.077	0.090	1600	100	3110	3.7	Stereo.	0.0012	0.084	6.0
15.0	1.0	0.118	0.032	0.040	250	100	2985	12.8	Stereo.	0.0012	0.084	− 4.0
27.0	1.0	0.185	0.036	0.053	500	100	3025	12.6	Stereo.	0.0012	0.084	− 2.5

* Arbitrary reference level.

Fig. 3*c*, or sufficient to provide the requisite length of scanning beam, if imaged directly on the film.

Types of Lamps and Their Characteristics.—The data included in this paper are based on tests with the lamps listed in Table I, except in a few instances where great extremes in coil diameter or coil length were needed to indicate more clearly the effect of these factors.

Sound-track illumination varies with optical systems of different manufacture, as well as with the form of source employed and the current at which the lamp is operated. Table I gives the total light flux found for the optical systems of one manufacturer. In obtaining these data three systems of each type were tested and the scanning beam length was masked as indicated.

Where in subsequent charts uniformity of sound-track illumination is shown, the recordings apply for the individual system of each group of three which was most perfect in this respect. This is done in order to concentrate attention on source rather than on lenses. Some of the variation exhibited in the curves is, however, still ascribable to defects in the optical system.

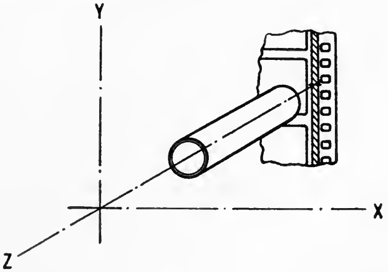

FIG. 4. The X, Y, and Z axes indicate the directions of source displacement in the tests covered in the text and charts.

The hum resulting from the light modulation of the exciter lamp operating on alternating current is a familiar phenomenon. The extent of this modulation is roughly proportional to the thermal inertia of the tungsten wire and is reduced as filament diameter is increased. It is also reduced when the frequency is increased. In Table I are also included data on the per cent modulation of the light when the lamps are operated at their respective rated currents on 60-cycle alternating current.

Some of the listed lamps are fitted with the bayonet-candelabra base, others with the newer bayonet-prefocus base. With the former, the accuracy of filament positioning with respect to the reference planes of the base is usually $\pm {}^{3}/_{64}$ inch (0.046 inch). When the bayonet-prefocus base is used these tolerances are reduced to ± 0.010 inch. Any of the lamps may be ordered so equipped. The significance of this more accurate base will be evident from the data to be presented

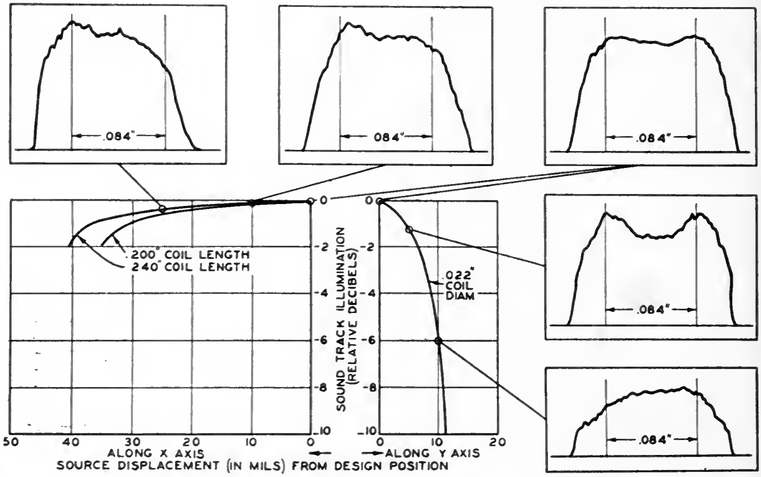

FIG. 5. The effect of source displacement along the *X* and *Y* axes on flux through aperture and uniformity of sound-track illumination—"motion picture" system.

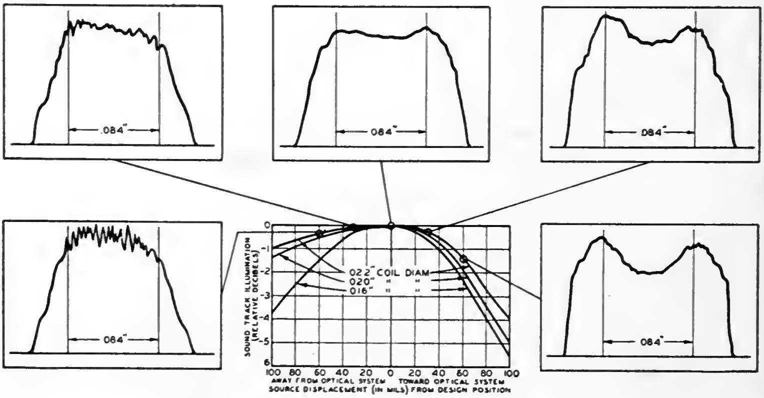

FIG. 6. The effect of source displacement along the optical (or *Z*) axis on flux through aperture and uniformity of sound-track illumination—"motion picture" system.

on the effect of source displacement on sound-track illumination.

For convenience in referring to source displacements they will be referred to as the *X* axis, *Y* axis, or *Z* axis, as shown in Fig. 4. The *X* and *Y* axes are parallel to the plane of the film. The *X* axis is parallel to, and the *Y* axis is perpendicular to the long dimension of the scanning beam. The optical axis is designated as *Z*. Except where stated otherwise, it may be assumed that the axis of the coiled filament coincides with *X*.

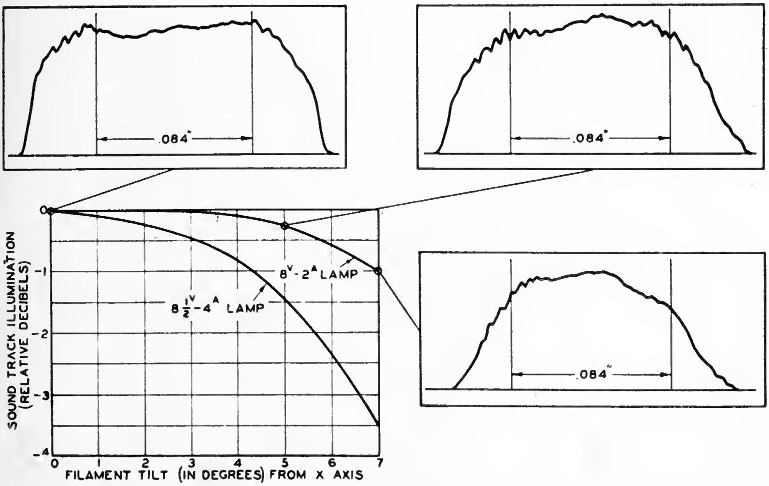

FIG. 7. The effect of filament tilt in the *X*-*Y* plane on flux through aperture and uniformity of sound-track illumination—"motion picture" system.

"Motion Picture" Systems.—The two lamps most frequently used with the "motion picture" system (Fig. 3*a*) are the familiar $8^1/_2$-volt, 4-ampere and the newer 8-volt, 2-ampere. In most 35-mm. reproducers, it has been the practice to operate the former at 3.2 amperes, since at this value photocells currently available provide ample response. Between 4-ampere and 3.2-ampere operation there is a difference in sound level of about 10 db. The newer 8-volt, 2-ampere lamp produces at rated current substantially the same sound-track illumination as does the $8^1/_2$-volt, 4-ampere lamp at 3.2 amperes. At its rated current of 2.0 amperes the service life of the lamp is comparable with that of the $8^1/_2$-volt, 4-ampere lamp at 3.2 amperes.

The scanning beam produced with this type of system is invariably considerably longer than the required 0.084 inch and therefore all measurements of sound-track illumination which follow are limited to the cell response from the middle 0.084 inch of the scanning beam length.

The curves of Figs. 5 and 6 show the effect on sound-track illumination of displacing filaments from the design source position along the *X*, *Y*, and *Z* axes. Due to the steepness of the curves for displacement along the *Y* axis the data for only one coil diameter are shown. The effect on uniformity of illumination is shown by the recordings. In Fig. 7 is shown the effect of filament tilt in the *X*-*Y* plane. The 8-volt, 2-ampere lamp has been used for these recordings because of the more uniform illumination it produces, as shown in Fig. 8.

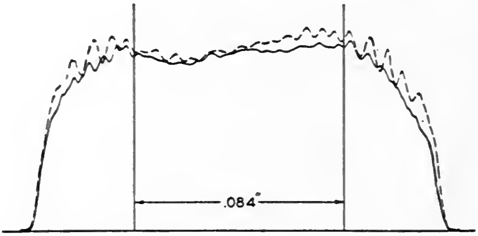

FIG. 8. Recordings of sound-track illumination using (*a*) 8-volt, 2-ampere lamp (solid curve) and (*b*) 8½-volt, 4-ampere lamp (dotted curve)—"motion picture" system.

Since, with this type of system, the source is imaged substantially in the plane of the slit, it is reasonable to expect that some non-uniformity in sound-track illumination is inevitable due to differences in brightness from turn to turn in the coiled filament. Actually, such non-uniformity is considerably influenced by the design of the coiled filament as shown in Fig. 8 and also by the fact that the mechanical slit in the systems submittted for these tests is curved to correct for curvature of field by the objective lens. Probably the presence of spherical aberration in the condenser lens is also helpful. It will be noted that, with the $8^1/_2$-volt, 4-ampere lamp, there is evidence of periodic changes in intensity due to individual turns of the coil but that it occurs only where, apparently, the filament image is critically focused on the curved slit. Such periodic changes in brightness along

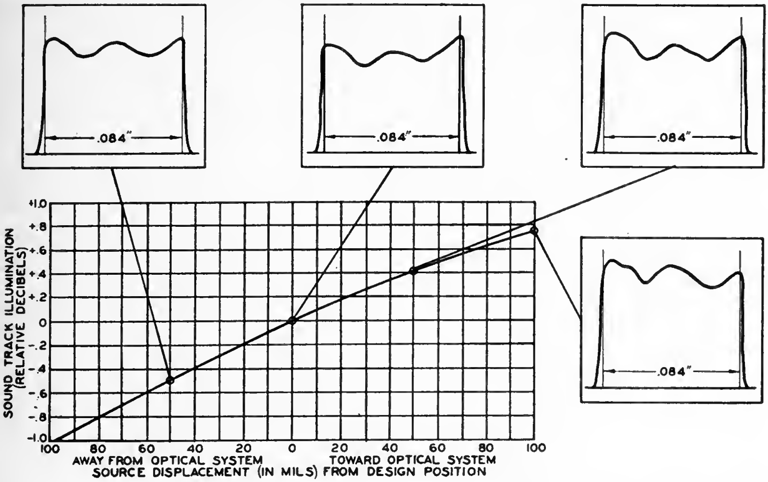

FIG. 9. The effect of source displacement along the optical or Z axis on flux through aperture and uniformity of sound-track illumination with "stereopticon" systems. Curve is typical for several sources listed in Table I and for optical systems having effective source areas of 0.070" and 0.100" diameter.

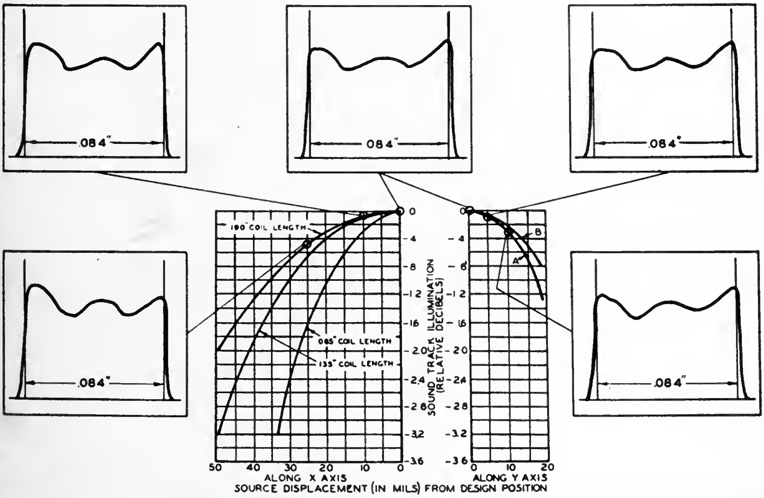

FIG. 10. The effect of source displacement from design position along the X and Y axes on flux through aperture and uniformity of sound-track illumination—"stereopticon" systems. Curves for displacements along X axis are typical for systems having effective source areas of 0.070" and 0.100" diameter. Curves for displacements along the Y axis show average values for several sources listed in Table I. Curve A applies to a system having an effective source area of 0.070" diameter; curve B, to one of 0.100" diameter.

the entire length of the scanning beam have been noted in previous tests with other systems of this type.

The use of ribbon-filament sources for this type of system has been proposed from time to time. Such a source does eliminate many of the minor irregularities evident in the recordings, but because of its lower luminous efficiency, it provides a much lower level of scanning beam illumination per watt consumed, and invariably must be of much higher wattage than desired by the designer of the power supply.

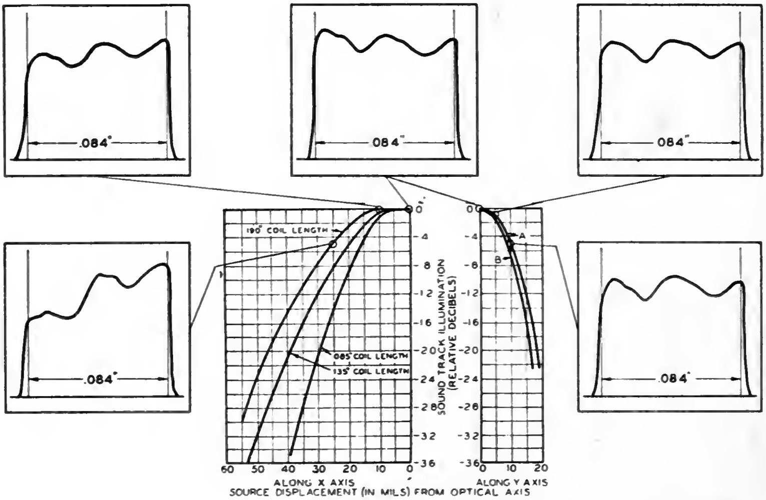

FIG. 11. The effect of source displacement, from position for maximum illumination, along *X* and *Y* axes on flux through aperture and uniformity of sound-track illumination—"stereopticon" system.

Curves for displacements along *X* axis are typical for systems having effective source areas of 0.070" and 0.100" diameter. Curves for displacements along *Y* axis show average values for several sources listed in Table I. Curve *A* applies to a system having an effective source area of 0.070" diameter; curve *B*, to one of 0.100" diameter.

Referring again to Figs. 5 and 6, it is apparent that the bayonet-prefocus base for lamps used with this type of system obviates all the usual lamp adjustments except for positioning the source along the *Y* axis. This adjustment could also be eliminated through the use of light-sources of considerably larger coil diameter, but only if coil length were at the same time reduced. Such reduction is, unfortunately, accompanied by some sacrifice in uniformity of sound-track illumination because of the lower temperature of the ends of the coil.

The "Stereopticon" Systems.—The relative levels of illumination from the various sources used with the "stereopticon" type of system, Table I, necessarily depend upon the aperture of the objective lens and the magnification of the source image. Rarely is this combination such that the objective is completely filled by the diameter of the coil image, although it is always filled by the length of the coil image.

It is interesting to note that, unlike the "motion picture" type of system, maximum illumination is not obtained at the design position for the source (Fig. 9). As shown by the recordings in Fig. 9, uniformity suffers when the source position is adjusted for maximum illumination. This is particularly true if the source is displaced from the optical axis as shown by comparing the recordings of Figs. 10 and 11.

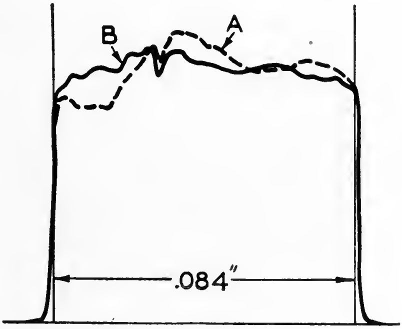

FIG. 12. Recordings of sound-track illumination using: (*A*) straight filament coil on *X* axis, and (*B*) curved filament coil in *X-Z* plane—"stereopticon" system.

Here again, the advantage of using filament coils longer than required merely to fill the system is evident. Moderate displacement of the recommended sources along the axis of the coil has relatively little effect on illumination. Positioning of the source in the direction perpendicular to the axis of the optical system continues to be the most critical adjustment, but less so than with the "motion picture" type of system. It becomes still less critical when coil diameter is increased materially beyond the value required to fill the objective lens or when coil diameter is drastically reduced so that the lens is only fractionally filled.

With this type of system, the effect of filament tilt at the design position for the source is negligible and therefore no curve is shown. This is due to the fact that, since the source is imaged in the objective lens, only that part of the source lying inside a circle of appropriate size can be utilized. This remains a constant, even when the coil axis is tilted 90 degrees from its usual position on the X axis.

The non-uniformity in the recordings shown in Figs. 9 and 10 is due primarily to variations in brightness of the source within the angle intercepted by the condenser lens. These variations are characteristic of coiled filaments in a plane through the coil axis. Referring to the diagram of this type of optical system, Fig. 3*b*, it will be observed that the brightness of any point in the slit is actually the brightness of a limited zone of the condenser lens as viewed by the objective lens, which is, in turn, proportional to the light intercepted by that small zone of the condenser.

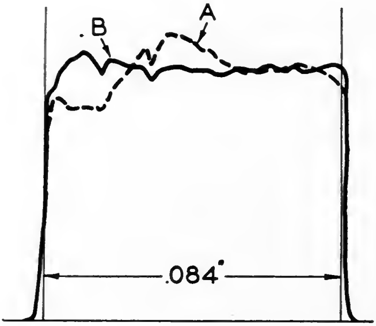

FIG. 13. Recordings of sound-track illumination using straight filament coil (*a*) on the X axis and (*B*) on the Y axis—"stereopticon" system.

With the source at the design position, uniformity of sound-track illumination can be improved by either of two methods. One involves curving the coil slightly and viewing it from the convex side with the curve in the X-Z plane (Fig. 12). The other makes use of the fact that the light output is relatively uniform in a plane perpendicular to the coil axis, and places the coil on the Y axis (Fig. 13) instead of on the customary X axis. The curved filament has been used for some time in recording equipment[5] where brightness uniformity is needed on the condenser side in all planes through the optical axis. For the stereopticon type of reproducing system, brightness uniformity in only the *X*-*Z* plane is effective and therefore the use of the straight coil in the *Y* axis is recommended.

Cylindrical Lens Systems.—Most of the cylindrical lens systems currently in use are in 16-mm. sound reproducers, although they have been, and still are being used in 35-mm. reproducers. They have the advantage of being relatively much less sensitive to source displacement. Displacements of as much as 0.020 inch along the *Y* axis result in practically no diminution of total flux to the sound-track. This is shown by the curves of Fig. 14.

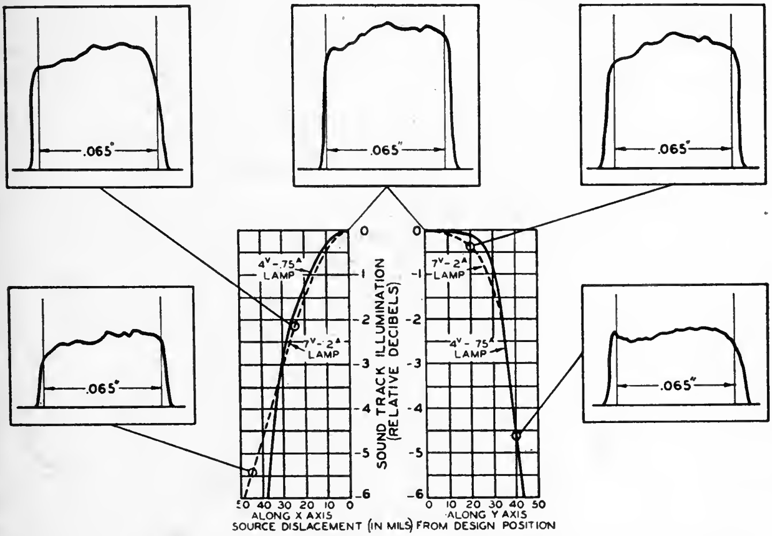

FIG. 14. The effect of source displacement along the *X* and *Y* axes on flux through aperture and uniformity of sound-track illumination—cylindrical lens system.

The curves for Fig. 14 were obtained from tests of a system in which, as in Fig. 3*c*, an aperture is provided at the lens nearest the light-source whose width along the *X* axis is imaged at the film plane by the intermediate lens to define the length of the scanning beam. It is the vignetting effect of this same aperture in the *Y* axis that finally causes the abrupt loss in sound-track illumination when the source is displaced more than 0.025 inch along the *Y* axis. The effect of displacement along the *X* axis on total flux is very similar to that with the "stereopticon" type of system because, in this meridian, the cylindrical system is essentially the same. As would be expected, displacements along either the X or Y axis do not materially affect uniformity of illumination. Since this particular system is of the "stereopticon" type in the X-Z plane, one would expect, as in Figs. 9 and 10, some non-uniformity in the scanning beam due to variations in brightness of the source in this plane. The absence of such non-uniformity is attributable to the much smaller effective angle of light collection of the first lens in this plane.

No data are included on the effect of source displacement along the Z axis because the effect is small within the permissible limit for this type of system. This limit is determined by the reduction of the lens system in the Y-Z plane and on its aperture. These factors determine the rate of change in the width of the scanning beam as the image of the width of the source moves in and out of the plane of the film.

Conclusion.—The data presented in this paper indicate the feasibility of a closer standard of uniformity of sound-track illumination than that covered in the 1938 recommendations of the Research Council of the Academy of Motion Picture Arts and Sciences. The results emphasize the importance of precision in optical systems and of accurate adjustment of lamp position. Fortunately, the need for service adjustment is obviated in most, if not all directions if correctly positioned sockets for the bayonet-prefocus bases are incorporated in the equipment. The data clearly show that the order of precision of this base is within the limits of negligible effect on sound reproduction —limits to which many operators find it difficult to work by manual adjustment.

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DISCUSSION

MR. SKINNER: With regard to the position of the lamp, the vertical arrangement is contrary to the usual practice.

MR. CARLSON: The vertical position for the filament is suggested only when used with the "stereopticon" type of system. Its purpose is to improve the uniformity of sound-track illumination.

MR. SKINNER: What about the life of the lamp?

MR. CARLSON: The life is not seriously affected.

MR. SKINNER: In most 16-mm reproducers the practice is to control the volume of the machine by adjusting lamp current. I think there is a good chance of exceeding the limits set by the design of these lamps, and there certainly are more replacements than with most lamps. This is one of our problems and I was wondering whether the lamps were designed so that we could get more volume out of them.

MR. CARLSON: There are several factors which must be considered in designing lamps for portable 16-mm reproducers.

First of all, the design of portable equipments usually dictates low lamp wattage and current which means that the filament's diameter is small and much more fragile than the thicker, more rugged filaments used in lamps designed for the larger reproducers.

The level of sound-track illumination, as shown in Table I, is much lower because of the low lamp wattage. The illumination would be even lower and the amplifier gain would have to be increased if service lives typical of lamps for 35-mm reproducers are desired. In the interest of sound quality, the shorter life of the order of 50 hours is preferable.

Your problem can best be solved through the use of a power supply and lamp of higher wattage and current, such as are used in larger reproducers.

DR. FRAYNE: Which of the two systems, the motion picture system or the projection slide system, is to be preferred in case of standardization?

MR. CARLSON: I feel that the "stereopticon" type is to be preferred. The system does not require so precise an adjustment of filament position as does the "motion picture" type to maintain level and uniformity of illumination. If the more accurate bayonet-prefocus base and a properly positioned socket are used all the manual adjustments for filament positioning can be eliminated. As pointed out in the paper, substantially uniform illumination is possible with any of the three characteristic types of systems. Achievement of such uniformity is more difficult with the "motion picture" type. In most other respects, the two systems are about equally effective.

MR. KELLOGG: I should like to bring out one point in regard to the history of the curved filament lamp. The number two type, or stereopticon type, as Mr. Carlson has pointed out, has proved to permit very large tolerances in the positioning of the lamp as well as in the shape of the filament or source. As shown by Mr. Carlson's curves, even turning the filament axis from horizontal to vertical had very little effect on the distribution of light. In fact, those who have been working with that system had come to rely on these tolerances so far that we gave very little consideration to the lamp itself in trying to get uniformity of light. Our first efforts were concerned more with improving the lens system.

One of the men with whom I have been associated, Mr. L. T. Sachtleben, began several years ago to make some studies closely similar to those Mr. Carlson has been describing. He found that although the position of the lamp and the shape of the source did not make much difference, the system is sensitive to changes in the intensity with the direction from which the lamp is viewed. He found that the lamps would measure brighter and dimmer as the direction of viewing was changed. This was because the inside of the filament helix looks brighter than the outside. In some positions the inside is hidden by the outside, and in other positions both are in view. Mr. Sachtleben found that this was quite pronounced; the irregularities were made much worse by the fact that the hiding of the inside turns occurred almost simultaneously, due to the uniformity of spacing of the turns. He suggested that by curving the filament we could break up that uniformity of spacing and get greater uniformity of illumination. That was tried out and it proved to be so satisfactory that it has become standard with us.

I think Mr. Carlson would have mentioned this point himself except for the fact that it originated before his immediate contact with that phase of the problem, and, therefore, he would have had to state it on hearsay.

MR. CARLSON: The curved filament construction is of definite value in improving uniformity of illumination with both the recording type of optical system to which Mr. Kellogg refers and the "stereopticon" type of reproducing system. It is the only construction in use which provides the desired uniformity of illumination from the recording system in question. For reproducing systems of the "stereopticon" type, comparable uniformity is obtainable with the straight coiled filament and it is recommended because of its inherently lower cost and performance characteristics.

REPORT OF THE STUDIO LIGHTING COMMITTEE*

***Summary.**—An explanation is given of lighting problems from the viewpoint of the cinematographer. Certain advances in equipment and working tools remain in obscurity for a long period before they find their rightful places in motion picture set lighting because they seem to interfere with dramatic effect. If they possess merit, however, they are gradually adapted to general use. A typical example is the light-meter, which is now going through the final stages of assimilation to studio lighting technic. New fast films have been brought into use and the resulting changes in lighting technic are now in the process of perfection. Recent changes in lighting equipment are described. Three new higher-speed negative films for the Technicolor process are being used. The effect of the new films on Technicolor set lighting is explained.*

The mechanics of motion picture studio lighting consist largely in placing illuminants around and above a set in such a manner as to obtain an overall light of sufficient intensity for desired exposure; to increase intensity on points of interest in order to relieve flatness and make interesting areas stand out; and with the aid of diffusers and black screens to diffuse and block out undesired light.

With requirements that may be stated in one paragraph it would seem that knowledge of the latitude and speed of the film coupled with the use of a suitable light-meter should make studio set lighting a comparatively simple procedure. However, the mechanics of studio lighting, important as they are, sink into insignificance when compared to the main problem, which consists in using light as an aid to the dramatic effect of the photoplay.

The dramatic effect in motion picture photography is a mysterious, intangible thing. Imagine the heroine of a photoplay on a set built to represent the interior of a haunted house. A circular staircase winds upward toward a cobweb-covered door. The lighting is arranged to create a chilly, ghostly atmosphere, yet the heroine must roam at will through the set without moving into an area where the light will make her appear other than attractive.

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 17, 1939.

The successful director of cinematography is a combination of engineer, artist, writer, director, and salesman. With his knowledge of story value and his ability as a psychologist he is telling his story with light just as the writer is with words.

The director of cinematography must at once satisfy the director, producer, and often the star or stars of the picture. His prime interests are camera angles, mood, sweep, and many other problems serving to make the total dramatic effect. New types of motion picture film, cameras, lenses, lighting equipment, and light-meters are the tools that may make it possible to enhance this dramatic effect, but if they seem to interfere with the technic that has been developed through years of experience they sometimes go through a long period of testing before they are accepted.

The laboratory technician may desire a negative showing some detail in all shadow and highlight areas with most of the density range on the straight-line portion of the gamma curve. The producer and art director may desire sufficient overall density to insure an appreciation of set values. Yet the cinematographer, director, or both, may desire a dramatic effect that fails to meet the requirements of either laboratory technician or art director, but does achieve the end result of affecting the senses of the theater patron in a manner which forwards the total desired effect of the story.

If the cinematographer is able to expose the film in a technically correct manner, to show the cost value of the set, and still achieve the desired dramatic effect, he has accomplished the ideal.

Mathematically two and two are always four; but the enemy of successful drama is strict formula. Thousands upon thousands of dollars are spent in an effort to twist the dramatic formulas to make them appear new and different to the viewing public. It is for these reasons that certain technical improvements sometimes find slow acceptance.

At this writing the studio lighting situation is in a somewhat unsettled condition. New and faster films have brought about a cycle wherein a great deal of interest is shown in learning just how low the set levels may be held, or as to just what photographic improvement may be obtained by maintaining the higher levels and greatly improving definition by reduced lens apertures.

A continued trend toward the increased use of spotlighting equipment and away from floodlighting units has resulted in a technic in which points of interest are maintained at a level suiting the requirements of the cinematographer, and shadow areas are allowed to go dark. This has resulted in an increased use of small spotlighting units.

In summing up the experiences of a number of cinematographers with the new films, it may be said that as many units are used as before to obtain the same general type of photography, but the intensity of the units has been decreased by the use of bulbs of lower wattage, smaller carbon arc units, by moving the lamps farther back, or by adding diffuser mediums.

The exact amount of light reduction depends upon whether the cinematographer wants a sharp, crisp negative with translucent shadow areas, or a soft, "effect" type of lighting. Considerable light reduction has been accomplished in some cases, but the present trend seems to be toward higher levels.

Past changes in film speeds have shown that a new technic of set lighting is developed only after the cinematographers have had sufficient time to test the practical application of the new emulsions by gradual exploration. Some portion of the additional film speed will probably be used to maintain reduced light levels, but continued experimenting will be carried on to determine how the additional speed may be properly used to improve photographic quality by the use of reduced lens apertures for increased definition. A proper light balance at a reasonably high level will simplify the problem of obtaining adequate screen light to satisfy the viewing public.

Arc Lamps on Black-and-White Sets.—The general use of arc lamps mixed with incandescents on black-and-white sets is well established. The proportion of arc lamps to incandescent units depends upon the desires of the cinematographer and the size of the set. In cases where the general level from incandescents has been reduced by using bulbs of lesser wattage, a light reduction from the arcs has been accomplished by using smaller units, moving the lamps farther back or by adding diffusers.

Fluorescent Tube Lighting.—White fluorescent tubes are being used in some close-ups to give soft front lighting and to "iron out" wrinkles. The new emulsions have made the use of this type of illuminant possible.

Light-Meters.—The increased use of the photoelectric exposure meter on interior sets since the advent of the new films has been phenomenal. A paper published in December of 1938 forecast the possible use of a direct-reading, rather than a reflection-reading meter for use under artificial illumination. Several companies have produced such meters and they are being used generally.

There is still some reluctance to the acceptance of light-meters, on the grounds that their use will restrict the cinematographer from using individuality in his work. This has not been found to be the case where light-meters have been used extensively.

The most successful use of light-meters seems to be where the meter reading is taken from the plane in which the principal actor's face will be, with the meter pointed directly at the source of key light. After the key light has been established at the proper level the rest of the illumination is balanced visually. Sometimes the highlight and shadow areas are checked as an added precaution. The light-meter is particularly valuable when exploring the possibilities of a new film emulsion, or new types or arrangements of lighting units.

Lighting for Technicolor.—Technicolor has also introduced faster films, and what applies to black-and-white photography will likewise probably apply to the technicolor process. As this report is written there has not been sufficient footage of the new technicolor film exposed to establish a technic.

C. W. HANDLEY, *Chairman*

R. E. FARNHAM
E. HUSE

G. F. RACKETT
V E. MILLER

E. C. RICHARDSON
J. H. KURLANDER

REPORT OF THE PROJECTION PRACTICE COMMITTEE*

Summary.—*A report of the work of the Committee since the last Convention. Work on the proposed revision of the NFPA Regulations for Handling Nitrocellulose Motion Picture Film has been completed and the revision will be placed before the NFPA at the Chicago meeting in May. The present report discusses also the Committee's search for practicable and inexpensive light-measuring instruments for use in theaters, in addition to other subjects engaging the attention of the several sub-committees.*

A number of important matters are actually before the Committee at this time. As detailed information on these matters is not yet complete, they will be reported on more fully at a later date. Among these projects are:

(*1*) Study of screen brightness and methods of measuring it.
(*2*) Problem of obtaining simple and practicable meters for measuring screen illumination and brightness.
(*3*) Study of screen sizes and placement, and seating arrangement.
(*4*) Study of tolerances and tensions permissible in motion picture projection equipment and means of measuring and checking the values.
(*5*) Revision of the NFPA Regulations for Handling Nitrocellulose Motion Picture Film.
(*6*) Survey of the power requirements of motion picture theaters.

SCREEN BRIGHTNESS AND INSTRUMENTS

The Committee has had under consideration for quite some time the subject of measuring reflected light and while it is relatively easy to obtain meters which are calibrated correctly on diffused light, the readings obtained from motion picture screens are greatly influenced by the fact that all commercial screens are in some degree specular, that is, not completely diffusing. This fact precludes the possibility of easily making absolute brightness measurements and for this reason the Committee is having tests made on various types of screens to determine whether an empirical method of testing can be established and whether thereafter it can be systematically correlated to a primary and precision method yet to be devised.

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 5, 1939.

REVISION OF THE NFPA REGULATIONS FOR HANDLING NITROCELLULOSE MOTION PICTURE FILM

The report of the Committee, published in the November, 1938, Journal, contained the complete recommendations of the Committee with regard to the revision of the Regulations. These proposals were submitted to the National Fire Protection Association and are now being considered by the NFPA Committee on Hazardous Chemicals and Explosives. It is expected that final action on this revision will be taken at the May convention of the NFPA at Chicago. The Committee feels gratified that a great number of its proposals have been accepted by the NFPA Committee without modification. As it has been many years since the last issue of the "Regulations," this revision fulfills an important need of the industry in bringing theaters up-to-date as regards equipment and installation.

SURVEY OF POWER REQUIREMENTS OF MOTION PICTURE THEATERS

A great deal has been written in various non-technical trade publications on the subject of theater lighting and power equipment operating characteristics. Also many attempts have been made to relate the lighting and power equipment installations to total energy costs. Developments in the motion picture field have reached the stage where every important operation is related in some manner to electrical apparatus of widely varying types. Some exhibitors and projectionists do not have reliable sources of information to determine whether or not their equipment and their methods of operation conform to present-day trends. There has long been a need for a comprehensive report showing the various types of electrical equipment, their load characteristics, and their use and cost of operation. The Committee now has in progress the preparation of such a report.

Harry Rubin, *Chairman*

T. C. Barrows
A. A. Cook
C. C. Dash
J. K. Elderkin
R. R. French
E. R. Geib
P. J. Larsen
A. N. Goldsmith
A. Goodman
H. Griffin
S. Harris
J. J. Hopkins
D. E. Hyndman
E. R. Morin
M. D. O'Brien
J. J. Kohler
F. H. Richardson
B. Schlanger
C. Tuttle
V. A. Welman
A. T. Williams

REPORT OF THE COMMITTEE ON EXCHANGE PRACTICE*

Summary.—*A brief account of the work of the Committee during the past year, including handling of shipping cases, direction of rewinding film returned from theaters, disposition of scrap film, use of lacquer in splicing, etc.*

During the past year meetings of the Committee were held regularly each month at the Firenze Restaurant in New York, and although there is little material of a specific nature to be reported at this time, nevertheless these meetings have proved of great value in providing periodic contacts among the heads of the exchanges of the various companies, and to permit interchange of ideas and discussions of technic, administration, and conduct, to the general betterment of exchange operation.

Some of the studies initiated last year have not yet been completed. For example, the Committee is awaiting further reports from its members and from other Committees of the Society and the Academy of Motion Picture Arts & Sciences on the relative merits of various modes of processing release prints, and as soon as all the material is available the Committee will be able to report further on the subject.

The problem of mutilation and mishandling of release prints has received very close attention by the Committee. Although the 2000-ft reel has received complete acceptance by the industry and has proved very successful, a number of minor problems have arisen during the period of adjustment of the industry to the new size. The weight of cases, for example, has met objection in some quarters and seems to have aroused a feeling that rough handling of the cases must be expected and tolerated as something inherent in the business. The Committee is trying to discourage this idea, and to show that what is now regarded as "ordinary" wear and tear should no longer be regarded as ordinary. Contacts have been made with the various carriers of film and good coöperation has been shown. It is expected, therefore, that some improvement may soon be evidenced in this direction.

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 21, 1939.

Recently the question has been revived as to which is the better way of shipping film from the exchanges to the theaters—"heads up" or "tails up." About two years ago, the Committee made an extensive study of the subject, principally in the interest of determining the best method of splicing. Drawings and data obtained from the film stock manufacturers showed that the most satisfactory splice was made when the film was wound in the "head-to-tail" direction, that is, leaving the tail out.

A survey indicated that almost 88 per cent of the films returned to the exchanges had the tails out. This meant one of two things, *viz.*, either the majority of the theaters of the country were not equipped with special reels, or they could (or would) not spare the additional time required for rewinding in order to return the film to the exchanges "heads up."

The representatives of the various companies on the Committee felt that some expense might be involved if it were decided to adopt the "tails up" system, which involved an additional rewinding at the exchange. Nevertheless, they were willing to go to this expense if, as a result, the quality of the films delivered to the theaters and the resulting projection should prove much better. However, in view of the overwhelming figures indicating that projection in general was definitely on a "tails-out-return-to-branch" basis, the project was abandoned, and since that time it has not been brought before the Committee again.

With regard to the use of lacquer in splicing film, investigation showed that there was no uniformity of practice among the exchanges, some of them not using lacquer at all and others for first-run films only. The efficacy and necessity of using the lacquer are now being studied further by the Committee.

The problem of disposing of scrap film was also under consideration, and a canvass of the companies was made to determine what the current practices were. It was found that general procedure in the exchanges was satisfactory and according to regulations, although differing somewhat in details. This brought up the question also of fire regulations in exchanges, and as it was reported that the National Fire Protection Association was engaged in revising its "Regulations for Handling Nitrocellulose Motion Picture Film," a Sub-Committee appointed for the purpose drew up a set of suggestions, relating to exchanges, for the consideration of the NFPA.

Other subjects under consideration by the Committee include methods of blooping, dryness and brittleness of film, cleaning films in exchanges (several of the companies are now cleaning their films, with gratifying results), and handling and storing film cement. In addition, the Committee has investigated a number of new devices, such as film cleaners, metal and fiber reel bands, new designs of shipping cases and reels, etc.

A. W. SCHWALBERG, *Chairman*

O. C. BINDER
A. S. DICKINSON
S. HARRIS

J. S. MACLEOD
H. A. MERSAY
H. C. KAUFMAN
G. K. HADDOW

N. F. OAKLEY
H. RUBIN
J. H. SPRAY

REPORT OF THE MEMBERSHIP COMMITTEE*

Summary.—*A brief announcement of the present membership of the Society, and the growth during the past year.*

During the past year, the increase of membership has been somewhat slower than the increase during the previous several years, although we are gratified to know that the membership is increasing, however, slowly. The total of the new members acquired is 59, and 12 old members were reinstated. Unfortunately, there were losses due to resignations and deaths totalling 48, which make a net total increase for the year of 23. At present the total membership consists of 6 Honorary members, 140 Fellows, 356 Active members, and 840 Associates, totalling 1342. Pending action by the Admissions Committee are 14 Actives and 11 Associates, upon admission of which the total will rise to 1367.

The growth of membership during the past several years is very striking when compared with the membership in 1933. In 1931, the membership was 760, whereupon it dropped preciptantly to 560 in 1933. However, from that time on, the growth has been very steady and almost linear, so that the present membership is two and one-half times what it was in 1933.

Although during the several past years the subscriptions have been increasing steadily, 1938 showed a slight drop, the net decrease being 61. The present total number of subscriptions is 328.

E. R. Geib, *Chairman*

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 7, 1939.

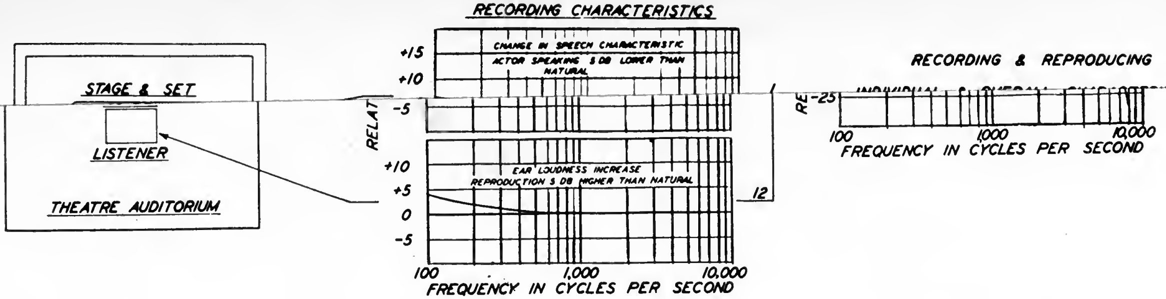

Fig. 8. Recording and reproducing individual and overall characteristics.

SOUND PICTURE RECORDING AND REPRODUCING CHARACTERISTICS

D. P. LOYE AND K. F. MORGAN

Due to the fact that this illustration, as published with the above-entitled paper in the June, 1939, issue of the JOURNAL (p. 643), was not sufficiently large to make the legends legible, the figure is reproduced here on a larger scale. This illustration depicts all the factors to be considered as affecting the quality of dialog, from the vocal organs of the speaker to the subjective aural effect upon the listener. Details of the diagram are discussed in the original paper in the June issue.

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, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C.

Acoustical Society of America, Journal

10 (Apr., 1939), No. 4

Mechanism of Hearing by Electrical Stimulation (pp. 261–269)	S. S. Stevens and R. Clark Jones
On Sound Localization (pp. 270–274)	H. Wallach
Multitone (pp. 275–279)	W. L. Barrow
Absorption of Sound by Vibrating Plates Backed with an Air Space (pp. 280–287)	R. Rogers
Theoretical Determination of Sound Absorptivities by the Impedance Method with Experimental Verification (pp. 288–292)	H. A. Leedy
Comparison of Sound Absorption Coefficients Obtained by Different Methods (pp. 293–299)	F. J. Willig
Reverberation-Time Scale for High Speed Level Recorders (pp. 300–301)	K. C. Morrical
Reverberation-Time Meter (pp. 302–304)	W. M. Hall
Multiple Coil, Multiple Cone Loudspeakers (pp. 305–312)	H. F. Olson
Velocity of Sound in Air (pp. 313–317)	W. H. Peilemeier
Mechanical and Electrical Analogies of the Acoustical Path (pp. 318–323)	H. L. Saxton
Reversed Speech (pp. 324–326)	E. W. Kellogg

American Cinematographer

20 (May, 1939), No. 5

Hollywood Engineer Designs New Type Meter (pp. 200–201, 230)	W. Stull
To Use Blood in Color Photography (pp. 202–203)	I. B. Hoke
Making Stereoscopic 8-Mm. Pictures in Color (pp. 210–211)	J. V. Wood
Fast Films and Color Have Made Big Light Changes (pp. 213–214)	G. Kornmann
Practical Gadgets Expedite Camera Work (pp. 215–218)	G. Toland
Shooting from Air Uncovers Camera Marvels (pp. 223–224)	R. B. Stith

British Journal of Photography

86 (Mar. 31, 1939), No. 4117	
Progress in Colour (pp. 198–200)	
86 (Apr. 7, 1939), No. 4118	
Progress in Colour (pp. 211–213)	
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1939 FALL CONVENTION

SOCIETY OF MOTION PICTURE ENGINEERS

HOTEL PENNSYLVANIA, NEW YORK, N. Y.
OCTOBER 16th–19th, INCLUSIVE

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Headquarters

Headquarters.—The headquarters of the Convention will be the Hotel Pennsylvania, where excellent accommodations have been assured, and a reception suite will be provided for the Ladies' Committee.

Reservations.—Early in September room reservation cards will be mailed to members of the Society. These cards should be returned as promptly as possible in order to be assured of satisfactory accommodations. The great influx of visitors to New York, because of the New York World's Fair, makes it necessary to act promptly.

Hotel rates.—Special *per diem* rates have been guaranteed by the Hotel Pennsylvania to SMPE delegates and their guests. These rates, European plan, will be as follows:

Room for one person	$ 3.50 to $ 8.00
Room for two persons, double bed	$ 5.00 to $ 8.00
Room for two persons, twin beds	$ 6.00 to $10.00
Parlor suites: living room, bedroom, and bath for one or two persons	$12.00, $14.00, and $15.00

Parking.—Parking accommodations will be available to those who motor to the Convention at the Hotel Fire Proof Garage, at the rate of $1.25 for 24 hours, and $1.00 for 12 hours, including pick-up and delivery at the door of the Hotel.

Registration.—The registration desk will be located on the 18th floor of the Hotel at the entrance of the *Salle Moderne*, where the technical sessions will be held. Express elevators from the roof will be reserved for the Convention. All members and guests attending the Convention are expected to register and receive their badges and identification cards required for admission to all the sessions of the Convention, as well as to several *de luxe* motion picture theaters in the vicinity of the Hotel.

Technical Sessions

The technical sessions of the Convention will be held in the *Salle Moderne* of the Hotel Pennsylvania. The Papers Committee plans to have a very attractive program of papers and presentations, the details of which will be published in a later issue of the JOURNAL.

Luncheon and Banquet

The usual informal get-together luncheon will be held in the Roof Garden of the Hotel on Monday, October 16th.

On Wednesday evening, October 18th, will be held the Semi-Annual Banquet and Dance, also in the Roof Garden of the Hotel. At the banquet the annual presentation of the SMPE Progress Medal and the Journal Award will be made, and the officers-elect for 1940 will be introduced.

Entertainment

Motion Pictures.—At the time of registering, passes will be issued to the delegates of the Convention admitting them to several *de luxe* motion picture theaters in the vicinity of the Hotel. The names of the theaters will be announced later.

Golf.—Golfing privileges at country clubs in the New York area may be arranged at the Convention headquarters. In the Lobby of the Hotel Pennsylvania will be a General Information Desk where information may be obtained regarding transportation to various points of interest.

Miscellaneous.—Many entertainment attractions are available in New York to the out-of-town visitor, information concerning which may be obtained at the General Information Desk in the Lobby of the Hotel. Other details of the entertainment program of the Convention will be announced in a later issue of the JOURNAL.

Ladies' Program

A specially attractive program for the ladies attending the Convention is being arranged by Mrs. O. F. NEU, *Hostess*, and the Ladies' Committee. A suite will be provided in the Hotel where the ladies will register and meet for the various events upon their program. Further details will be published in a succeeding issue of the JOURNAL.

New York World's Fair

Members are urged to take advantage of the opportunity of combining the Society's Convention and the New York World's Fair on a single trip. Information on special round-trip railroad rates may be obtained at local railroad ticket

offices. Trains directly to the Fair may be taken from the Pennsylvania Station, opposite the Hotel: time, 10 minutes; fare, 10¢. Among the exhibits at the Fair are a great many technical features of interest to motion picture engineers.

Points of Interest

Headquarters and branch offices of practically all the important firms engaged in producing, processing, and exhibiting motion pictures and in manufacturing equipment therefor, are located in metropolitan New York. Although no special trips or tours have been arranged to any of these plants, the Convention provides opportunity for delegates to visit those establishments to which they have entree. Among the points of interest to the general sightseer in New York may be listed the following:

Metropolitan Museum of Art.—Fifth Ave. at 82nd St.; open 10 A.M. to 5 P.M. One of the finest museums in the world, embracing practically all the arts.

New York Museum of Science and Industry.—RCA Building, Rockefeller Center; 10 A.M. to 5 P.M. Exhibits illustrate the development of basic industries, arranged in divisions under the headings food, industries, clothing, transportation, communications, *etc.*

Hayden Planetarium.—Central Park West at 77th St. Performances at 11 A.M., 2 P.M., 3 P.M., 4 P.M., 8 P.M., and 9 P.M. Each presentation lasts about 45 minutes and is accompanied by a lecture on astronomy.

Rockefeller Center.—49th to 51st Sts., between 5th and 6th Aves. A group of buildings including Radio City Music Hall, the Center Theater, the RCA Building, and the headquarters of the National Broadcasting Company, in addition to other interesting general and architectural features.

Empire State Building.—The tallest building in the world, 102 stories or 1250 feet high. Fifth Ave. at 34th St. A visit to the tower at the top of the building affords a magnificent view of the entire metropolitan area.

Greenwich Village.—New York's Bohemia; a study in contrasts. Here are located artists and artisans, some of the finest homes and apartments, and some of the poorest tenements.

Foreign Districts.—Certain sections of the city are inhabited by large groups of foreign-born peoples. There is the Spanish section, north of Central Park; the Italian district near Greenwich Village; Harlem, practically a city in itself, numbering 300,000 negroes; Chinatown, in downtown Manhattan; the Ghetto, the Jewish district; and several other such sections.

Miscellaneous.—Many other points of interest might be cited, but space permits only mentioning their names. Directions for visiting these places may be obtained at the Convention registration desk: Pennsylvania Station, Madison Square, Union Square, City Hall, Aquarium and Bowling Green, Battery Park, Washington Square, Riverside Drive, Park Avenue, Fifth Avenue shopping district, Grand Central Station, Bronx Zoo, St. Patrick's Cathedral, St. Paul's Chapel, Cathedral of St. John the Divine, Trinity Church, Little Church Around the Corner, Wall St. and the financial district, Museum of Natural History, Columbia University, New York University, George Washington Bridge, Brooklyn Bridge, Triborough Bridge, Statue of Liberty, American Museum of Natural History, Central Park, Metropolitan Museum of Art, and Holland Tunnel.

S. M. P. E. 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 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. 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.

16-Mm. Sound-Film

Approximately 400 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 6000 cps.; the constant-amplitude frequencies are in 11 steps from 50 cps. to 6000 cps.

Price $25.00 each.

16-Mm. Visual Film

An optical reduction of the 35-mm. visual test-film, identical as to contents and approximately 225 feet long.

Price $25.00 each.

* * *

SOCIETY OF MOTION PICTURE ENGINEERS
HOTEL PENNSYLVANIA
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PROGRESS IN THE MOTION PICTURE INDUSTRY

REPORT OF THE PROGRESS COMMITTEE FOR THE YEAR 1938

Summary.—*This report of the Progress Commitee covers the period June, 1938, to April, 1939. The advances in the cinematographic art are classified as follows: (I) Cinematography: (A) Professional, (B) Substandard; (II) Sound Recording; (III) Sound Reproducing Equipment; (IV) Television at the Close of 1938; (V) Publications and New Books; (VI) Appendix A: The Motion Picture Industry in Japan.*

Motion picture history for 1938 has repeated itself in that the most notable advances recorded during the year have, as in the previous year, been in the production of new panchromatic emulsions for professional cinematography. Of special interest is the new background fine-grain negative which permits considerable improvement in cinematographic quality of background projection scenes. Outside this development, there is nothing of outstanding importance in either professional or amateur cinematography for the year 1938.

In the field of sound recording and reproduction, progress during the year has been confined to improvement and modernization of equipment and technics rather than the introduction of any novel schemes. Considerable effort has been expended in bringing about a more uniform quality of sound projection in the theaters throughout the country by providing various test-films and making them available to theater operating personnel.

The Progress Report contains for the first time a complete section on television, and it seems quite probable that this section will become of more importance in future reports of the Progress Committee than it is at the present time.

The committee wishes to thank the following companies for supplying materials and photographs for the report: Agfa Ansco Corp.; Bell & Howell Co.; Warner Bros. Studio; Electrical Research Products, Inc.; Eastman Kodak Co.; Ampro Corp.; General Electric Co.; Bell Telephone Laboratories; General Radio Corp.; Metro-Goldwyn-Mayer Studio; RCA Victor Corp.; and Twentieth Century-Fox Studio.

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SUBJECT CLASSIFICATION

- **(I) Cinematography**
  - (*A*) *Professional*
    - (1) Emulsions
    - (2) Cameras and Accessories
    - (2) Stage Illumination
    - (4) Color
    - (5) Film Processing
    - (6) Miscellaneous
  - (*B*) *Substandard*
    - (1) Films
    - (2) Cameras
    - (3) 16-Mm Sound Cameras
    - (4) Projectors
    - (5) Miscellaneous
- **(II) Sound Recording**
  - (1) General
  - (2) Equipment
  - (3) Accessories
  - (4) Recording Methods
- **(III) Sound Reproducing Equipment**
- **(IV) Television at the Close of 1938**
  - (1) Studio Pick-Up Equipment
  - (2) Mobile Pick-Up Equipment
  - (3) Transmitters
  - (4) Signal Propagation
  - (5) Receivers
  - (6) Large Screen Pictures
- **(V) Publications and New Books**
- **(VI) Appendix A**
  - The Motion Picture Industry in Japan—1938

(I) CINEMATOGRAPHY

(*A*) *Professional*

History of motion picture progress for 1938 has repeated itself, for again the outstanding advance has been in the improvement of panchromatic negative emulsions.

(*1*) *Emulsions.*—The negative photographic motion picture emulsion has undergone a tremendous change since the introduction of the first panchromatic film in 1913. The major portion of this advance in emulsion manufacture technic has occurred during the past seven years because these films did not vary much in their characteristics until 1931. In no year of the quarter century, however, have so many new films appeared as in 1938.

Another interesting trend of the times has been the ever-growing demand of the trade for more technical information with regard to film emulsions. This trend has been especially noteworthy throughout the past decade since the event of sound motion pictures. Each manufacturer has supplied the trade with detailed information when a new film was announced.

In conformity with this established custom, the Eastman Kodak Company prepared a special technical pamphlet giving full data on their three new products, Plus-X Panchromatic Negative, Background-X Negative, and Super-XX Negative, when these films were announced in October, 1938. Plus-X was shown to be definitely finer-grained and double the speed of standard panchromatic negative emulsions in use the previous year. The use of smaller stops with resulting improvement in image definition and a reduction in set illumination were recommended with this film, which was stated to be especially suitable for all types of interior photography.

Background-X was described as a faster emulsion than earlier films which were used for background work, and of equally as fine grain.

Besides its satisfactory properties for use as a negative for projection backgrounds, the film was claimed to be well suited as a panchromatic negative exclusively for exterior photography.

The third film, Super-XX, was stated to represent a film which had four times the speed of standard fast panchromatic emulsions in use the previous year. The increased speed was obtained without any appreciable graininess increase. This film was recommended for all types of photography under extremely poor lighting conditions.[1]

The Belgian firm Gevaert, Ltd., was stated to be planning to re-enter the professional 35-mm film field. A duplicating emulsion and a new positive film were said to be in production at the Antwerp, Belgium, plant of this company.[2] The Gevaert Panchromosa film was described technically in a French publication. It was said to possess greater red sensitivity and white-light speed than a previous product.[3]

A comprehensive account of the manufacture of motion picture film support and emulsions, coating of emulsions, and the operations of slitting, perforating, testing, and packing of finished film was given by Amor before the Royal Photographic Society and published in their Journal.[4]

A research program over the past 25 years to produce a suitable metallic film support was described by Carter. The resulting thin flexible non-ferrous metal with a chemically inert oxide surface was claimed to offer several advantages over cellulosic supports such as greater permanence, non-shrinkage, lighter weight, non-inflammability, different images on two sides, *etc.* Projection by reflection with a loss of only 7 per cent of the light from absorption was claimed.[5]

(*2*) *Cameras and Accessories.*—No outstanding improvement in professional camera design has been reported for 1938. The Mitchell *NC* type was somewhat improved and widely replaced many of the older types still in use in the studios. The one outstanding camera further improved but not yet on the market is the one built at 20th Century-Fox. That studio now has two in operation and others building, and is of such advanced design that its début is eagerly awaited.

The use of photoelectric exposure meters reached a new high during the year. They are gradually being adopted as a regular "tool" in most studios, as it has been proved their scientific application results in a more uniform product, more easily handled by the laboratories, without taking away any of the individuality of the various cameramen. Progress may be predicted for the coming year, as an intensive study is being made, not only by the cinematographers, but by the Weston, General Electric, and other manufacturers of such meters, and the best methods to be used in measuring both incident and reflected light.

(*3*) *Stage Illumination.*—The introduction of extremely fast emulsions has resulted in the reduction of wattages used in electrical units, thus effecting a saving of almost one-half in current consumption. Also, the technic of lighting is undergoing a slight change, inasmuch as superfluous or "leak light" must be controlled, as it registers on the walls and subjects more quickly, due to the faster film. Spots are becoming more prevalent, replacing gradually the more open lights, such as "broads," rifles, banks, *etc.;* the cinematographer has better control of his light with the more confined units. Mole-Richardson and Bardwell-McAllister have each brought out a new series of "baby" spots, Fresnel-lensed, more simply controlled and with a more uniform field; they have also made improvements in their Junior and Keglite series, respectively. Bardwell-McAllister's Type *T-5* Studio Spot, which substitutes a Fresnel lens for the spill-ring, should become very popular.

Mole-Richardson's new, silent "Arc-Broad," developed for color work, is a splendid example of what scientific research, properly applied, will do in solving the industry's peculiar problems. This lamp is silent; has a very even and intense field; is self-adjusting and will burn constantly for two hours, with practically no variation in intensity or color; all requisites of lighting for color.

(*4*) *Color.*—In the field of two-color photography, the Eastman Kodak Company brought out a new pair of bi-pack negatives which they designate by the term "Zelcras." The new negative has considerably increased speed, but its biggest improvement lies in the semitransparency of the front emulsion, permitting much sharper back negatives with a corresponding increase in print definition. All two-color prints now being made are done on duplitized (double coated) stock which is made as a standard product by both the larger film companies. Cinecolor, Inc., and Consolidated Film Industries both produce two-color prints, and they both report increased volume during the year. The former reported that they did a total of about eight million feet, representing the capacity output of their old plant. They announce construction of a new plant in Burbank, Calif., to handle between fifty and one hundred million feet per year.

Several different processes for two-color photography were announced throughout the year. Of these Telco is unique in method and has been described in the press.[6] Another using a special camera attachment to produce two half-size images was tested on a short by RKO. Prints from these negatives were made optically and processed by one of the standard methods described above.

In the field of three-color photography the increased speed of negative materials for black-and-white work was reflected in the Technicolor process. At the very close of the year this organization brought out a new set of negatives which were expected to show from two to four times the speed of their standard stock. The negatives have not been used enough as yet to permit inclusion of further details. All three-color prints made during the year were done by Technicolor. They report upward of one hundred million feet processed. They also report completion of an English plant having a capacity of twenty-five million feet and additions to their Hollywood facilities to the extent of one hundred and thirty million feet capacity per year.

The Dunning Process Company, Inc., announced a three-color camera employing three negatives in a special bipack combination and a processing method characterized by the fact that it is all photographic as distinguished from an imbibition process, such as Technicolor. They announced plans for increasing their facilities during the coming year.

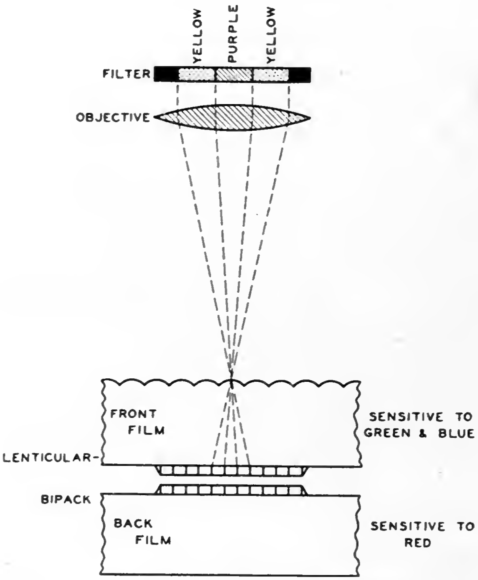

FIG. 1. Pantachrom subtractive lenticular bipack tricolor process.

In October, Eggert of the Agfa Research Department, read a paper at the Berlin meeting of the Deutsche Gesellschaft für photographische Forschung, on the Pantochrom subtractive lenticular bipack tricolor process. (Fig. 1.) The green and blue separation positive images are formed in a lenticular emulsion (nearest the lens) and the red separation image is formed in a single layer coating in contact with the emulsion side of the lenticular film. Positives are printed on double coated stock carrying on one side an ordinary silver bromide emulsion, and on the other a double coated emulsion having a purple pigment in the upper layer and a yellow pigment in the lower layer. Printing is effected by contact simultaneously from both camera films, the front one, which has gone through a reversal process, being printed on the double emulsioned side of the positive and the other camera film on the single emulsion side. The single emulsion of the projection print (carrying the sound-track) is processed by a catalytic bleach method to form a blue-green image, whereas the double emulsion side is processed similarly to yield the remaining two-color subtractive positive.[7]

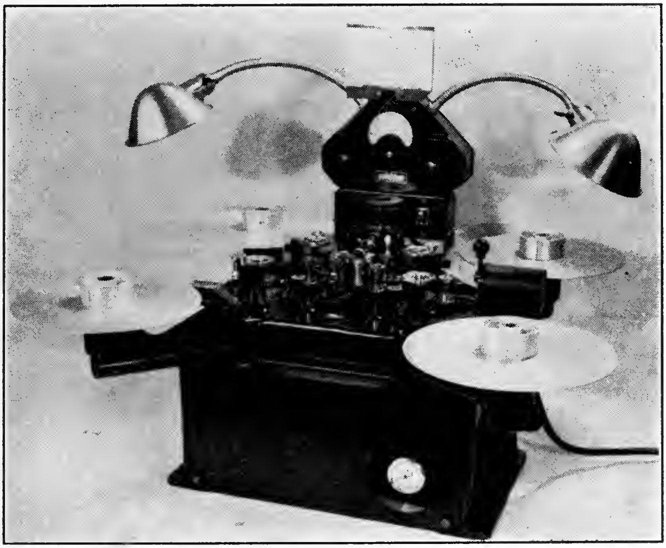

FIG. 2. Bell & Howell 35-mm non-slip sound printer.

(5) *Film Processing.*—In the professional field, the Bell & Howell Company has created a non-slip 35-mm sound printer which, though an outcome of the principles recognized by RCA in 1936, offers many novel features, every one and all of which assure fidelity of reproduction and full protection of the negative sound record. The B & H non-slip printer operates in a horizontal position (Fig. 2), thus relieving both negative and positive film from unnecessary stress and keeping them free from possible damage which may be caused by lubricant materials, as it is impossible for the film to be contaminated by them. The design of the film-driving parts permits accommodation with-

out slippage of two films whose length may differ from 0 to 1.2 per cent with respect to each other. The driving energy is supplied by a $^1/_8$-hp, 220-volt a-c, 3-phase, 60-cycle, 1725-rpm, ball-bearing, squirrel-cage induction motor, with heavy-duty worm-gear reducer to operate it at the recommended speed of 75 feet per minute, a mechanical filter insuring uniformity of motion.

The printing aperture consists of an optical slit 0.005 inch in width produced by an optical system consisting of a prefocused 10-volt, $7^1/_2$-ampere, vertical-filament exciter-lamp operating at approximately 8 volts as a light-source, a short-focus condenser, an ultraviolet filter (with provision of rapid replacement so that any desired type of filters can be used); a mechanical slit 0.010 inch wide, and a fully corrected lens to focus the slit at the printing point at a reduction of 2 to 1 in the form of a sharp optical slit 0.005 inch in width.

FIG. 3. Sizes of fluorescent lamps commercially available.

(6) *Miscellaneous.*—Byron Haskin, of Warner Bros. Studios, has developed and applied for patents on a triple-head background projector. The method utilizes three projectors mounted on one center base, operating as a single unit and superimposing three identical pictures upon a single screen.

This triple head projector provides greater illumination on present size screens, and permits the use of much larger screens in background projection, thereby greatly increasing the possibilities of process photography in color as well as in black and white.

In the process background field, a twin-camera unit, properly coördinated, simultaneously makes a "plate" of double the ordinary width; when projected similarly with coördinated projection, the screen size is of double width, permitting a scope of action more in keeping with actual wide-angle non-process set-ups.

The Fluorescent Lamp (*Fig. 3*).—While the phenomenon of fluorescence with ultraviolet light is not a new one, it was only during the past year that lamps involving this principle were made commercially available. They are all of tubular form, either one or one and a half inches, and available in 18, 24, 36, and 48-inch lengths. The exciting ultraviolet energy is obtained from a low-pressure mercury arc and by the use of phosphors of different composition, seven different colors including a good quality of daylight (color temperature, 6500°K) are available. Daylight fluorescent lamps found immediate application in the motion picture studios for make-up room lighting, in the mixing of paints, and in set painting, particularly where it was necessary to secure correct colors for color photography. A paper discussing the use of these lamps in studio applications is being given at this convention.[8]

(*B*) *Substandard*

It is during only comparatively recent years that the tremendous possibilities offered by the motion picture have become fully realized. The realization of its possibilities and importance has created new and interesting uses for the motion picture, and has extended its scope into many new fields. This has stimulated the interest of the older, well established organizations and manufacturers to adapt their products to meet the changing requirements and to create new products to satisfy the new demands. It has also proved an incentive for new manufacturers to enter the field with a great variety of products and equipment, some of which have shown real merit. For the most part, however, these products could not be called new in the sense that the product is recently invented, novel, or progressive in contributing to the art of amateur cinematography.

Mechanical equipment and adaptations in 1938 have far exceeded, in number, the introduction of chemical products intended for substandard cinematographic use, such as films. This is undoubtedly due to the fact that the manufacture of sensitized products in general requires knowledge, skill, and a capital investment that but few can, or would, care to bring together.

Although many new films have appeared in 1938, most of them have been introduced by marketing organizations and the products represent the well known varieties of positive or negative film introduced to the public under new appellations.

Abroad, as in immediately preceding years, 1938 has seen an increase in the popularity of American made equipment. Sixteen-mm projection equipment, especially, is in great demand. Sturdiness of mechanical design, high-powered illumination, together with adequate sound mechanisms, have made much of the better-grade 16-mm domestic equipment especially suited for hard, continuous use in theaters. For these reasons much of this type of equipment was exported to those countries where 16-mm films are regularly exhibited in theaters for entertainment purposes.

(*1*) *Films.*—Super XX, a new, high-speed, reversible 16-mm film, manufactured by the Eastman Kodak Company, was introduced during the latter part of 1938.[9] This new reversible film possesses four times the speed of regular panchromatic reversible material, and is about twice as fast as supersensitive panchromatic reversible films. This film greatly broadens picture-taking possibilities. Movies of stage performances, street scenes, and night indoor movies are now easily made.

Agfa Supreme Negative, manufactured by the Agfa Ansco Corporation, was made available in 16-mm width. This film fills the need of an extremely high-speed negative 16-mm material, and places in the hands of the 16-mm trade a film having properties identical to those of the films used by the professional 35-mm industry. Fine grain combined with brilliant gradation makes this new film a suitable recording medium for use wherever difficult lighting conditions are encountered, such as indoor sports, athletic events, and the like.

Dupont Regular Panchromatic, a product of the Dupont Film Manufacturing Corporation, was announced. This film has a color-sensitivity closely approaching that of the human eye, and will give excellent results outdoors and is also suitable for use indoors with artificial illumination. Because of its complete color-sensitivity, a wide range of filters may be used. This film is of the reversible type, and is processed by the manufacturer using the Dupont reversal method.

Agfa Hypan reversible film was made available in 50-foot cassettes for the Siemens-Halske camera.

Service for duplicating 16-mm sound-film was announced by the Agfa Ansco Corporation through their New York City laboratory. Special equipment is used to provide sound duplicates of continuous length and uniform quality.

An outstanding contribution to 16-mm color was made during the past year by an announcement by the Eastman Kodak Company of

Kodachrome duplicates.[10] Amateurs, advertisers, and scientists have looked forward to the time when duplicates could be made from their Kodachrome films. Although this service was announced late in 1938, it is already finding wide application. Technicolor is now prepared to make 16-mm Kodachrome copies of any of its 35-mm material. The Dunning Process Company makes copies of both 35-mm two-and three-color originals and 16-mm Kodachrome originals, both sound and silent; and the Stith-Noble Company also copies Kodachrome. The number of processing organizations in this field is increasing from time to time.

FIG. 4. Filmo *141-B* camera.

(*2*) *Cameras.*—Filmo *141*, a 16-mm magazine camera, was announced by Bell & Howell of Chicago. (Fig. 4.) This camera uses 50-ft 16-mm film magazines. A new type of view-finder gives a magnified, sharply defined field. The front element of the view-finder unscrews for quicker interchange with others to match seven lens focal lengths from 15 mm to six inches. This camera is also equipped with a soft rubber cup over the eyepiece to prevent side glare, and makes the finder easier for wearers of glasses to use. The Filmo *141* is available in either of two types, being identical except for speed range. The Filmo *141-A* has speeds of 8, 16, 24, and 32 frames per second, while the Filmo *141-B* has speeds of 16, 32, 48, and 64 frames per second. Either of these cameras may be operated at speeds intermediate between those calibrated speeds merely by setting the dial accordingly. In addition, the camera is also provided with a single-exposure device.

A new Filmo 8-mm camera with turret lens mounting accommodating three lenses was introduced. (Fig. 5.) This new camera combines economy with features which heretofore have been available only to users of 16-mm and 35-mm film. A novel feature of this camera is in the view-finder objectives, which are mounted on the turret. When a lens is in the photographing position, its matched finder objective is always in view-finder position. This is the first 8-mm camera to be equipped with the positive type view-finder providing a real image in the position of the view-finder mask rather than a virtual image in front of the camera. Since the image and the mask coincide with one another in position, the image never shifts. It always shows exactly as much of the subject as will appear on the screen, no matter at what angle the eye looks into the eyepiece. The image is full size—without masking for telephoto lenses. The camera is equipped with a Taylor, Hobson 12$^1/_2$-mm, $f/2.4$ lens.

FIG. 5. Filmo turret-8 camera: the "Aristocrat."

A new 8-mm camera manufactured by Ditmar abroad and offered in this country by Hans Unfried of Buffalo, N. Y., made its appearance in 1938. This new camera employs a built-in, photoelectric exposure meter. The scale of the exposure meter is viewed through the regular image view-finder. Beside the scale is an indicator showing the lens stop values. This is the first 8-mm camera making its appearance in the United States having a built-in exposure meter. The camera has two speeds, 16 frames per second and 32 frames a second. A change to either speed may be made instantly by pressing the proper button conveniently located on the camera. The camera is regularly equipped with an *f*/2.8 lens. Higher-speed lenses and lenses of different focal lengths are also available. Models of this manufacturer were introduced last year, but did not have the built-in exposure meter.

An 8-mm-camera, under the name of Eumig *C-4*, recently appeared on the American market. This camera is driven by a midget electric motor, power for which is supplied by flashlight batteries. The camera is box-like in appearance and weighs, complete with battery, about one and one-half pounds. The camera is equipped with an *f*/2.5, $12^1/_2$-mm lens of the universal focus type. It operates at a film speed of 16 frames per second.

Emel, an 8-mm cine camera, was introduced in France during the past year. This camera is one of the first 8-mm cameras to incorporate professional features such as provision for lap dissolves and double exposures. The Model *C-61* is equipped with a fixed focus *f*/2.5 lens. The Model *C-82* is equipped with a turret head for accommodating three lenses. The camera has provisions for exposing single frames. It has five speeds: 8, 16, 24, 48, and 64.

A new Movikon 16-mm camera was introduced abroad by Zeiss-Ikon. The camera is of very compact design and is of the magazine type. It is equipped with a 20-mm, *f*/2.7 Tessar lens. Provisions are made for interchanging lenses of various focal lengths. The camera has film speeds of from 8 to 64 frames per second.

Siemens-Halske introduced a new 16-mm camera abroad having the range-finder and the view-finder combined in one unit.

(*3*) *16-Mm Sound Cameras.*—To meet the demands of the industry for better 16-mm sound, Electrical Research Products, Inc., has designed a film-recording machine for recording directly on 16-mm film. The machine is intended primarily for studio use and its design is such as to permit recording 16-mm variable-density negatives from direct pick-up or by re-recording from 35-mm film. Release prints are then obtained by contact printing the sound-track in combination with optical reduction printing of the picture from the 35-mm negative.

The sound-track is recorded by a recently developed variable-intensity light-valve modulator shown in the right-hand compartment of Fig. 6. The film is exposed at the periphery of a film-driven oil-damped kinetic scanner resulting in uniformity of film motion comparable to that of the latest 35-mm film-recording machines. The film-propelling mechanism is shown in the left-hand compartment of Fig. 6. A transparent deflector diverts part of the modulated light to the photoelectric cell and monitor amplifier located in a rear compartment.

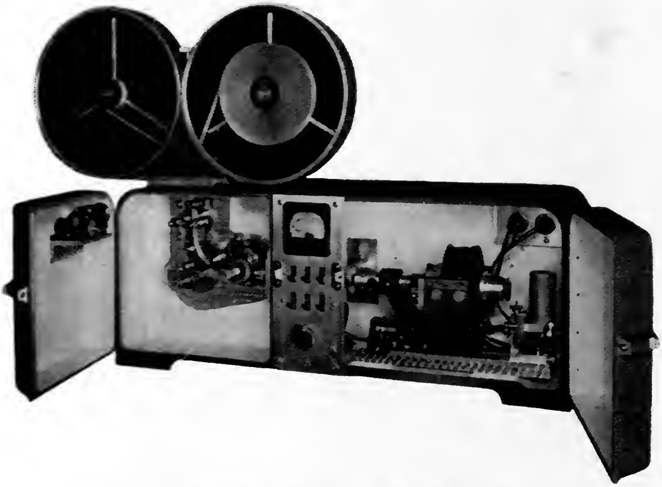

FIG. 6. Variable-intensity light-valve modulator.

With proper equalization to compensate for the known losses, positive prints obtained from negatives recorded on this machine show a frequency characteristic substantially flat up to 6000 cycles.

A new 16-mm sound-film camera was introduced by the Berndt-Maurer Corporation. The equipment is designed for single-system sound recording. The camera is motor-driven, and has a galvanometer and an optical system which produce the "bilateral" or symmetrical type of variable-area sound-track. The film motion of the camera is reported to be exceptionally steady, making the camera suitable for recording music as well as speech. Critical focusing is provided by a ground-glass viewer with an enlarging microscope. The camera is equipped with a built-in dissolving shutter mechanism. Controls for the camera are grouped on the back. Detachable magazines having either 400 or 1000-ft capacity are provided.

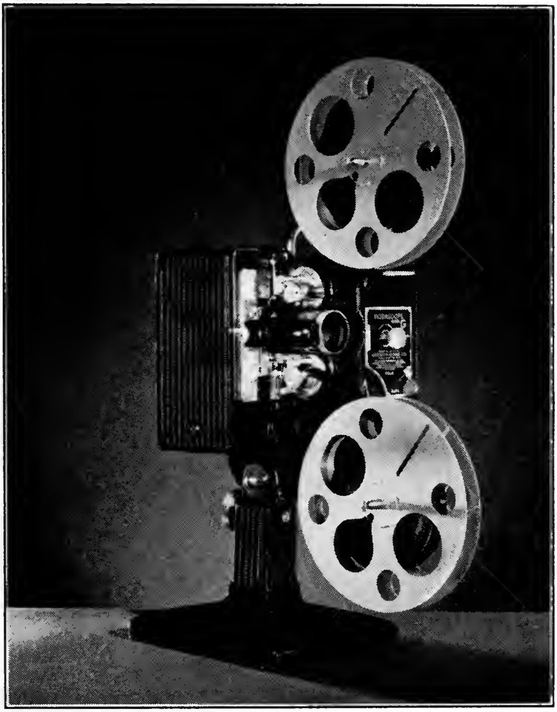

FIG. 7. Kodascope Model *G*.

Abroad, Zeiss Ikon have introduced the Ikophon, a 16-mm camera for single-system picture and sound recording.

(*4*) *Projectors.*—A new 16-mm projector was introduced by the Eastman Kodak Company. This projector is known as the Model *G*. (Fig. 7.) A special feature of this projector is the wide selection of lenses of various focal lengths which are available. It is readily adaptable to either 400, 500, or 750-watt lamps. This wide selection of lenses of various focal lengths and lamps of various intensities makes the equipment very flexible for meeting any projection conditions.

The Ampro Corporation introduced two new 16-mm sound projectors (Fig. 8), Model *X* and Model *Y*. Both models are adaptable to either 750 or 1000-watt lamps. These new projectors are of compact design. Operation has been simplified to the extent that they are especially suitable for use by inexperienced operators, such as for classroom use, *etc.* The Model *Y* is suitable for either a-c or d-c operation, and will project at either silent or sound-film speed. Ampro also introduced the Ampro Arc. (Fig. 9.) This projector is especially suitable for displaying 16-mm motion picture films before large audiences, as in theaters. It is claimed that the high-intensity arc produces five times the screen brilliance of a 750-watt projector. This new projector has numerous special features, including a high-intensity type lamphouse, automatic carbon feeding, full-wave rectifier and collapsible type projection stand. The complete equip-

FIG. 8. Ampro Models *X* and *Y*.

ment includes the projector unit equipped with a 1600-ft reel capacity and two torpedo speakers with tripod stands.

Two new Filmo sound projectors were introduced by the Bell & Howell Company of Chicago. (Figs. 10 and 11.) The new models are known as the "Commercial," shown in Fig. 10, and the "Academy," shown in Fig. 11, models. The "Commercial" model is a single-case machine, designed for use by industrial firms requiring a low-priced, sturdy, durable sound projector. The machine is readily portable and has sufficient illumination and volume for effective sound projection with audiences up to five hundred people. The "Academy" model is a two-case projection equipment, with the projector operating in a "blimp." The projector has a governor-controlled silent speed as well as a sound speed. In the "Academy" model are incorporated all the elements that contribute to satisfactory projection on both sound and silent classroom films. Simplicity is the keynote of the "Academy" sound projector.

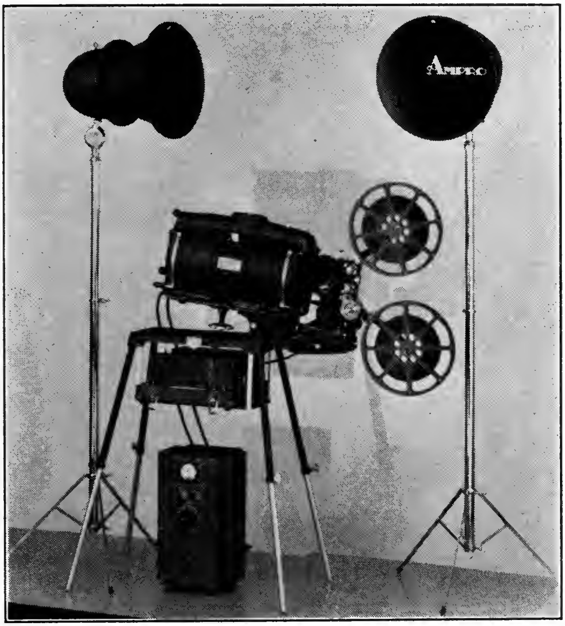

FIG. 9. Ampro Arc.

The Filmoarc, a high-powered 16-mm projector, was introduced by Bell & Howell. This projector presents to the 16-mm industry a high-powered, sturdy projector suitable for hard continuous use in displaying pictures before large audiences heretofore unable to be served with 16-mm projection equipment. The new projector is equipped with an automatic carbon arc and mirror reflectors.

Standard Projectors, Incorporated, introduced their Model *90-S*. This silent projector is equipped with a 750-watt lamp and is said to have an unusually efficient optical system. This, together with the $f/1.6$ projection lens, insures brilliant screen illumination. The projector is equipped with a removable film-gate, framing device, and pilot light. The entire projector is of die-cast construction. All electric controls are centralized. The projector is equipped with forward and reverse motion and has a rapid mechanical rewind.

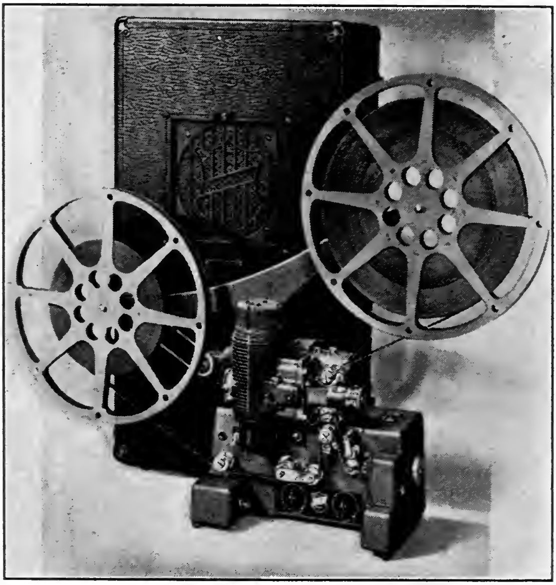

FIG. 10. Filmosound "Commercial" model.

American Bolex Company, Inc., introduced in the United States a new Bolex projector which has enjoyed much popularity abroad. A novel feature of this new machine is that it is interchangeable for projection of either 16-mm or 8-mm films.

Pathe, Limited, introduced the Pathescope Model *H*, a $9^1/_2$-mm projector. This projector is adaptable for a-c circuits only, and is equipped with low-voltage and a high-amperage light-source operating through a transformer. The projector will accommodate reels up to 300-ft size.

Siemens-Halske introduced a new Siemens 8-mm projector. The projector has a 200-watt lamp and an adjustable film speed, varying from ten to twenty frames per second. The machine is equipped for still-frame projection. The projector is equipped with either a 25-mm or 35-mm projection lens.

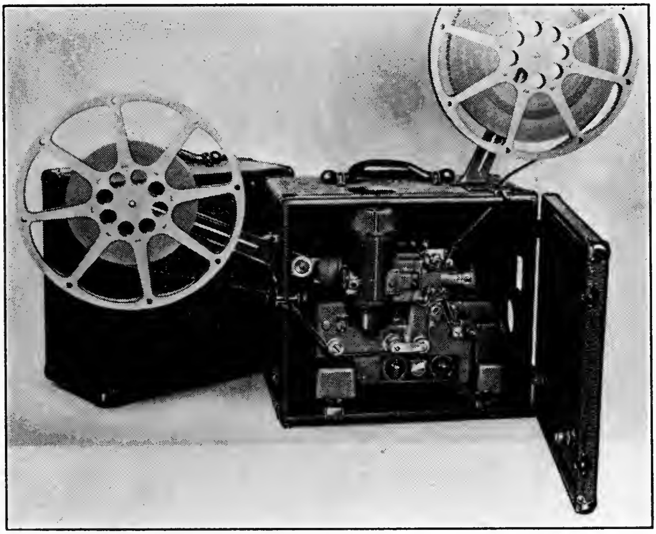

FIG. 11. Filmosound "Academy" model.

The firm of Heurtier, in France, introduced a new motion picture projector which will accommodate either 8-mm, $9^1/_2$-mm, or 16-mm film. The change from one gauge to another has been simplified to a great extent by the novel form of sprocket mounting used in the equipment. Both the feed and take-up sprockets are built on a rotating plate. A turn through 120 degrees brings one of the three (8-mm, $9^1/_2$-mm, or 16-mm) sprockets mounted onto the plate into position for carrying the film. The gate is easily interchangeable. In order to allow for the projection of old or very shrunken films, the pull-down mechanism is of the somewhat unusual triple-claw type. With 8-mm film, an extra short focal length lens is recommended;

however, for $9^1/_2$-mm and 16-mm projection, a longer focal length lens is recommended, but the same lens can be used for either $9^1/_2$-mm or 16-mm films.

(5) *Miscellaneous.*—General Electric Company introduced a newly designed photoelectric exposure meter adaptable for all photographic use, especially recommended for cine work. The new meter is said to give an unusually accurate indication of exposure with very low light intensity.

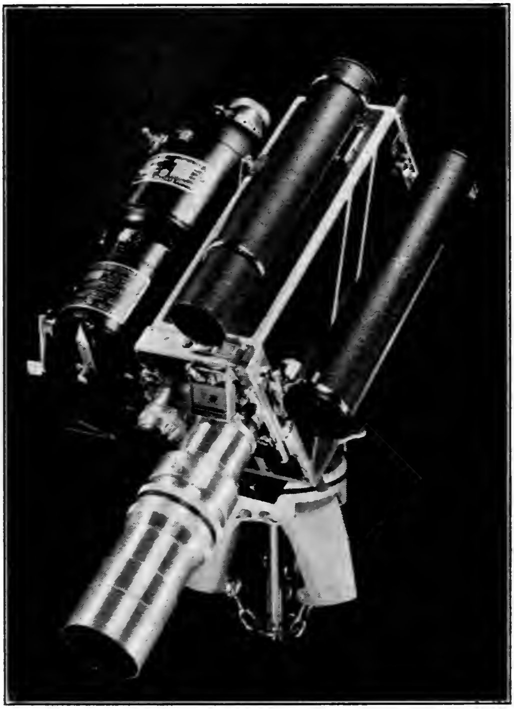

FIG. 12. Eastman reflex finder magnifier.

A new Kodak 16-mm enlarger was introduced by the Eastman Kodak Company during the past year. This device makes it possible to make black-and-white prints $2^1/_2$ by $3^3/_8$ inches from either 16-mm black-and-white films or from Kodachrome.

The Eastman Kodak Company also introduced a new Kodascope movie viewer. The movie viewer shows movies on a built-in screen as the film is drawn through. This device assists in simplifying the editing of 16-mm motion picture film.

A new Reflex Finder Magnifier for the Cine Kodak has been made available. (Fig. 12.) This finder shows on a ground-glass screen, working in conjunction with a built-in magnifying glass, the exact field of focus with whatever lens is being used. There is also available the optical finder which shows the field of any lens and corrects for parallax down to two feet.

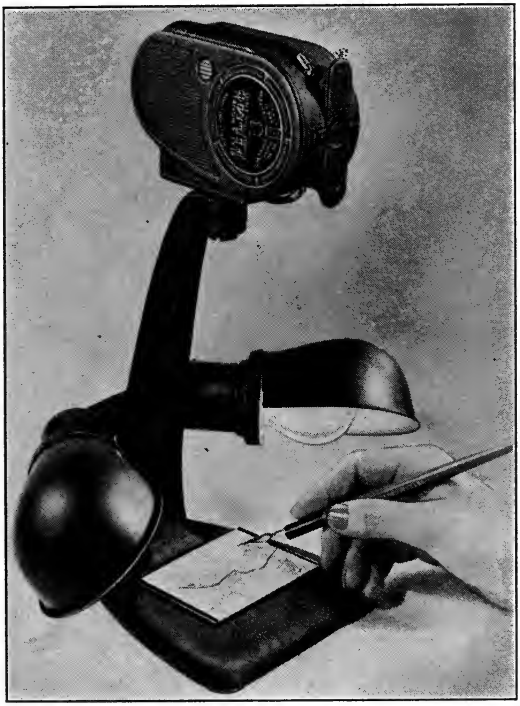

FIG. 13. Bell & Howell 8-mm titler, with Filmo *134* "Sportster" camera.

A new 8-mm titler for Filmo cameras has been introduced by Bell & Howell. (Fig. 13.) This unit, comprising the main titler assembly and a cross-arm bracket bearing two sockets and reflectors, is equipped with a special copying lens, making it unnecessary to use the camera lens for a titling lens. The copying lens is corrected for either color or black-and-white film, giving remarkable sharpness and flatness of field—very necessary in making 8-mm titles.

An 8-mm editor has been made available by Bell & Howell. The new editor (Fig. 14) comprises a splicer and film-viewing device. The entire equipment is based on the design of the well known Bell & Howell laboratory splicing equipment.

Projection Lamps (*Fig. 15*).—A new 1000-watt, 110–120-volt, *T-12* bulb projection lamp intended primarily for high-power 16-mm motion picture projection, was introduced by the two Mazda lamp manufacturers. This lamp incorporates several rather novel design features, with the result that it delivers 50 per cent more light to the screen than do lamps of the old design and the same wattage.

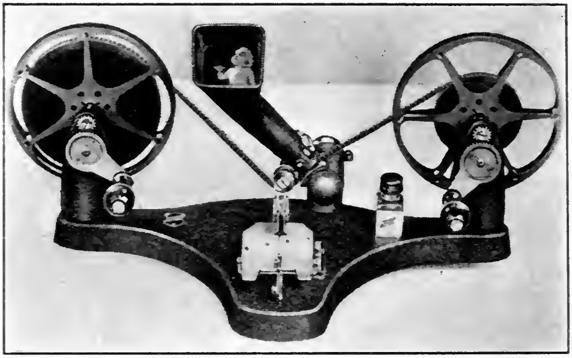

FIG. 14. Bell & Howell 8-mm editor.

The Reflector Photoflood Lamp (*Fig. 16*).—This very useful lamp for amateur motion picture photographers takes advantage of a recently developed process of depositing a layer of aluminum on the interior wall of a glass lamp bulb to form an efficient reflector. The base half of the bulb has been given a modified parabolic shape and aluminized to redirect the bulk of the light within an approximate angle of 60 degrees. The front half of the bulb is frosted inside to improve the uniformity of the illumination. The lamp is intended to be used in floor and table lamps and with a simple swiveling socket and clamp where separate reflectors are not feasible, for amateur still and movie photography, and as a supplementary light for professional photographers. It has a rating of 500 watts and six hours' life, the same as the number *2* Photoflood.

(II) SOUND RECORDING

(*1*) *General.*—Existing sound recording systems have been carefully examined during the past year for factors contributing to the impairment of sound quality and volume range. Special equipments[11] have been devised to investigate distortion of various forms occurring in recording and re-recording channels. The data obtained have exonorated certain parts of the system, but have suggested possible improvements, primarily in the link from the modulator to the reproducing machine PEC cell. Improvements in quality, and in overall volume range have been effected by push-pull modulators,[12,13] improved noise-reduction methods, pre- and post-equalization, track squeezing,[14] and volume compressors[15] and limiters.[16]

(*2*) *Equipment.*—In the recording channel field, Electrical Research Products, Inc., in coöperation with Metro-Goldwyn-Mayer Studio, has developed a new simplified channel for production dialog. It consists of two units—a combined amplifier-noise-reduction and a film recorder equipped with all necessary motor controls. Both units are compact, and weigh 40 and 100 pounds, respectively. Power is supplied from batteries or rectifiers.

FIG. 15. 1000-watt, *T12* bulb, 100–120-volt projection lamp.

RCA have converted some of their variable-area recorders by changes in the optical system to record variable-density track. In addition, an optical volume limiter is being incorporated in some of their modulators.

The use of various forms of volume compressors and volume limiters for dialog production is increasing. Advantages claimed are greater freedom from overload with corresponding improvement in quality and intelligibility.

The use of new optical and modulator systems, and new type of film have brought about a demand for an increase in light for exposure. The high-pressure mercury lamp[17] developed by General Electric fulfills this need.

With the increasing use of rectified a-c for power supply, several manufacturers have developed both low and high-voltage units incorporating a self-regulating feature. These provide a constant output voltage for a wide range of current demand, and also compensate to some extent for a-c line voltage variation.

An interesting method of introducing artificial reverberation into re-recording has been employed by M.-G.-M. An "echo pipe," a pipe some 300 feet long, is used. A moving-coil type of loud speaker furnishes acoustic energy to the pipe, and several microphone pick-up points are located at intervals along its length. Due to the finite time of transmission through the pipe, and the resulting reflections from its end, a condition simulating reverberation is produced.

(3) *Accessories.*—Two new microphones have been made available. The first, by Bell Telephone Laboratories, is the *639-A* cardioid directional microphone. (Fig. 17.) While intended primarily as a unidirectional device, each of its constituent elements may be used separately, thus providing bidirectional and essentially nondirectional response characteristics. The ribbon structure is of novel form and is relatively unsusceptible to mechanical vibration. The second microphone, announced by ERPI, employs a miniature condenser transmitter, vacuum tube, and transformer developed by Bell Telephone Laboratories. These components make possible a small unit of high quality. In size it is approximately seven inches long, two and a half inches in maximum diameter, and weighs one and a quarter pounds.

FIG. 16. Reflector photoflood lamp; 500-watt, 6 hours life.

Among new test equipment, General Radio Co. offers the *736-A* wave analyzer. (Fig. 18.) It is useful in determining harmonic distortion in recording systems, and offers the following advantages over previous equipment: It is a-c operated, has a band-pass characteristic, and is stable and easily operated. The *760-A* sound analyzer employs a novel method of securing a variable band-pass selection. It is obtained by placing a variable bridge circuit in the feedback path across a high-gain amplifier. In addition, the output meter operates from a logarithmic circuit and can be read directly over a 42-db volume range. Such an instrument, in conjunction with a sound-level meter,[18] is useful in evaluating the frequency spectrum of camera or projector noise.

The modulated-carrier oscillator, which was developed during 1937, has been reduced to a production design and a quantity have been manufactured. (Fig. 19.) This unit has become an excellent tool for the determination of optimum processing conditions for variable-area recording and for the maintenance of accurate control of film-processing laboratories.

FIG. 17. *639-A* cardioid directional microphone.

(*4*) *Recording Methods.*—Warner Bros. Studios have adopted push-pull variable-area recording for all original recording. Non-linear apertures were installed on all machines for original recordings. These apertures are linear for 80 per cent modulation, but beyond this level require an 8-db increase to reach 100 per cent modulation, affording 6-db volume compression, which is very desirable on shouting and extremely loud dialog. The same studios are using fine-grain duplicating stocks for re-recording prints and for the master prints from which the sound and picture negatives for foreign release are made. Great improvement in sound and picture quality has been realized as a result of the use of the new stock.

Twentieth Century-Fox Studios have replaced the RCA variable-area system with a variable-density system of recording, wherein the usual galvanometer is used to move the penumbra of light with respect to an aperture, thus passing light onto the film with intensity varying with the deflection of the galvanometer. The usual monitoring card is used for determination of noise-reduction adjustments, *etc.*

In order to improve the quality of variable-area dialog recording, the RCA-equipped studios are employing an electronic limiter, taking effect at a level of about 80 per cent modulation. In addition, a volume compressor is used both in original and dubbing recording. The compressor is likewise an electronic device, and may be adjusted to compress at different levels and different rates. The result is a reduction in objectionable overload for the same average level of speech. This device was initiated by J. O. Aalberg of RKO Studios, and has been universally accepted in all RCA variable-area installations.

FIG. 18. General Radio type *736A* sound analyzer.

The use of squeeze-track in release prints has grown considerably during the year, being in use now at Universal, Columbia, and Paramount, in addition to M-G-M, the originator of the method.

The intermodulation test has been introduced for control of variable-density recording, and has been used not only in studios, but in laboratories such as Paramount's. By means of this test, optimum negative and positive densities and gammas may be determined dynamically. The test consists of first recording a combination of low and high frequencies, such as 50 and 1000 cps, to be subsequently reproduced through a system which filters out the low-frequency component and measures the relative modulation of the remaining high-frequency at the low-frequency rate.

A recording optical system has been developed that makes orignal push-pull recordings of the direct positive type. Anticipation of the recorded sound-waves by the noise-reduction system is made possible by providing a separation between the modulation and noise-reduction light-beams. The optical system is being tested under commercial conditions and has the advantages of less clipping, lower noise, and freedom from possible printer distortion.

FIG. 19. Modulated carrier oscillator.

(III) SOUND REPRODUCING EQUIPMENT

During 1938 considerable time was spent by the suppliers of reproducing equipment with members of the Academy of Motion Picture Arts and Sciences participating in a coöperative program designed to improve the quality of sound in theaters. As a first step in its investigation, the Committee appointed by the Academy inaugurated a series of tests to determine upon a standard electrical characteristic for theaters which would present the recorded product of all the studios to the public to the best advantage and which, in addition, would fit the acoustic characteristic of a majority of the theaters. These tests were conducted employing the newer two-way type of loud speaker systems, typical of which is the RCA combined low and high-frequency units shown in Fig. 20.

The characteristics ultimately decided upon have already been published.[19] Obviously, this characteristic is not a "cure-all," and may have to be modified depending upon the particular theater involved.

As a result of the tests conducted jointly with the Academy, the RCA Manufacturing Co. took the necessary steps to have the *PG-90*

FIG. 20. Loud speaker combination for *PG141–142.*

series of equipments so modified in the factory that they could be shipped with the desired characteristic.

The above developments were a long step forward in the short but lively history of sound-on-film, but much still remained to be done in refining these developments and in bringing about other practical improvements, which, while probably not as revolutionary as a rotary stabilizer, were nevertheless important to the progress of sound projection in the theaters.

The requirement for a correct two-way speaker system with a true cellular horn in the above field brought about the production by RCA of the *PG-138* equipment. This equipment consists essentially of the *MI-1040* sound-head (Fig. 21), the *MI-9250* main amplifier, the *MI-9512* field supply, the *MI-1444* low-frequency speaker, *MI-9457* low-frequency baffle, and the *MI-1443* high-frequency speaker and *MI-9485–6* high-frequency horn.

All parts of the amplifier are conveniently arranged for ease in servicing. It is equipped with separate main system and monitor volume controls. The crossover network with standby switch is also contained in this cabinet.

In emergencies the low-frequency horn can reproduce the higher frequencies, in addition to the low frequencies. A minimum of back-stage space is required for installation. The high-frequency horn is a true cellular design and provides equal distribution of the sound throughout the auditorium. It has the added and very distinct advantage that it can easily be adjusted for phasing and distribution.

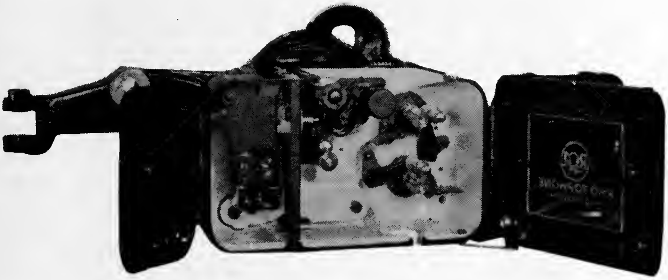

FIG. 21. *MI-1040* sound head for *PG-105–138*.

Realizing the necessity for a high-quality low-cost equipment for the medium size theater gave rise to the scheduling by RCA of the *PG-139* equipment. This equipment includes a complete line of reproducing equipment, including sound-head, main amplifier, speaker field and lamp supply, pre-amplifier and low and high-frequency units.

RCA have also introduced the *PG-140*, *-141*, and *-142* series of equipments representing an outstanding achievement in sound reproducing equipment. They meet the specifications of the Academy of Motion Picture Arts and Sciences and have incorporated in their design the refinements desired in earlier equipment of all makes. Thought was given in their planning to the requirements of the projectionists, and nothing was omitted to give the exhibitor the best possible performance.

A few of the features of these equipments are: Oil collection and mounting plate which makes the projector head easily adaptable to the sound-head and affords an effective oil seepage system. Isolated constant-speed sprocket drive reduces flutter. Micrometric optical system adjustment; double exciter lamp socket with prefocused lamps; optical system dowelled in position insuring positive azimuth adjustment. It will be observed in Fig. 22 that all units are in one rack, requiring minimum space and offering modern styling.

FIG. 22. *MI-9210* amplifier for *PG140.*

The H-6 Water Cooled Mercury Lamp (*Fig. 23*).—This lamp presents the interesting contrast of a large amount of light from a very small unit. The lamp itself is about three inches long and a quarter of an inch in diameter. The lamp is rated at 1000 watts and the light output 65,000 lumens. This comes from a source one inch long and $^1/_{16}$ inch in diameter, giving a source brightness of over 193,000 candles per square-inch. The lamp must necessarily be cooled by a rapidly flowing stream of water. The quality of its light is such that it is not at present suitable for either motion picture photography or projection of colors. However, it is finding application as either a projection or general lighting source where a powerful actinic light is required. The *H-6* lamp and its potential applications have been described in considerable detail in the JOURNAL.[20]

(IV) TELEVISION AT THE CLOSE OF 1938

The year was marked by refinement of all parts of the system in a steady advance toward commercial television. Late in the year it was announced that a limited program service would be inaugurated in New York City with the opening of the 1939 World's Fair in that city, and that receivers would be offered for sale to the public at that time. Apparatus is available for sale to broadcasters for studio and transmitter service. Splendid progress was made through industry coöperation in establishing operating standards for a television system. Emphasis was placed on comprehensive field tests.

(*1*) *Studio Pick-Up Equipment.*—Steady progress has been made in the electrical and mechanical design of pick-up equipment for studio use. The frequency-band passed by the entire system has been widened and the circuit operation made more stable. The camera pre-amplifier and Iconoscope coupling circuits have been improved so that the signal-to-noise ratio has been increased. Operating technic has constantly improved so that more consistent performance is obtained. Much attention was given to the problems of program production.

(*2*) *Mobile Pick-Up Equipment.*—Mobile pick-up equipment mounted in trucks has been put in experimental operation and has given satisfactory performance for preliminary tests. The equipment includes an ultra-high-frequency transmitter for relaying the picture signal to the television transmitter for broadcasting. Location pick-ups have been successfully accomplished over moderate distances, and in one instance up to 27 miles.

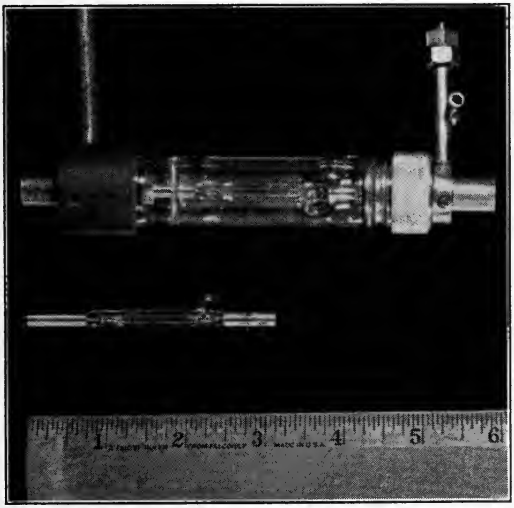

FIG. 23. Type *H-6* water-cooled mercury vapor lamp and water jacket.

(*3*) *Transmitters.*—Considerable improvement has been made in television transmitters. The modulating frequency characteristic has been widened. Circuits for inserting the direct current component in the transmitted signal have been developed which, in addition to that function improve the overall stability of the transmitter. Experimental advances have been made in higher powers at the higher-frequency television channels. A transmitter of nominal power output has been developed suitable for broadcast service.

In order fully to utilize a television frequency channel, it is desirable to attenuate most of one picture side-band at the transmitter. A method for doing this was evolved and tested in laboratory and field with satisfactory results. This was suitable for carrier-frequency operation at high power and included constant-resistance circuits and phase-correcting networks. Experimental work was also done on obtaining the same characteristic at a low level in combination with low-level modulation.

Improvements were made in the mechanical designs and electrical characteristics of transmitting antennas. Antennas suitable for installation on the small space available on top of tall buildings have been designed. The directivity pattern has been improved for horizontally polarized antennas so that they have a circular pattern in the horizontal plane and directivity toward the horizon in the vertical plane, resulting in a substantial power gain. The selectivity of these structures has been improved so that they have uniform impedance over more than one 6-megacycle television channel.

(*4*) *Signal Propagation.*—Study was given to propagation characteristics of ultra-short waves in the region of 40 megacycles to several hundred megacycles. Comparisons of polarization of the radiated wave have been made indicating that a better signal-to-ignition-interference ratio and less multipath interference is obtained with horizontal than with vertical polarization.

(*5*) *Receivers.*—Advances were made in television receiver design resulting in improved performance and simplification of operation. Circuits permitting pre-set station selection have been developed, and the number of operating controls has been reduced. The frequency-band width passed by the receivers has been increased to correspond with the increased effective fequency-band made available by suppressing one side-band at the transmitter. This results in more picture detail. Amplifier tubes of higher transconductance have been made available so that more gain and improved signal-to-noise ratios can be had, even with the increased band width. Screen material for Kinescopes has been developed so that pictures are bright and black and white.

(*6*) *Large Screen Pictures.*—Progress has been made in circuits and cathode-ray tubes for producing large pictures by projection. Experimental apparatus of this type has been demonstrated to large groups with success.

(V) PUBLICATIONS AND NEW BOOKS

Although no new publications appeared during the year, mention should be made of the Russian technical journal, *Kinomechanik*, which was in its third volume as a monthly issue.

The following books of noteworthy interest have been published since the last report of the Committee in April, 1938:

(*1*) History of Motion Pictures; M. Bardeche and R. Brasillach, translated from the French by I. Barry (*Norton & Co., New York*).

(*2*) Photographic Make-Up; W. Meltmar (*Pitman Publishing Corp., New York*).

(*3*) Der Schmalfilm Tont (Substandard Sound-Film); H. Umbehr (*Knapp Halle (Saale) Germany*).

(*4*) Color Photography in Practice; D. A. Spencer (*Pitman & Sons, London*).

(*5*) Color Photography for the Amateur; K. Henney (*McGraw-Hill Co., New York*).

(*6*) The Eighth Art—A Life of Color Photography; V. Keppler (*Morrow & Co., New York*).

(*7*) Photography—Principles and Practice; C. B. Neblette, 3rd Edition (*D. Van Nostrand Co., New York*).

(*8*) Photographic Chemicals and Solutions; J. I. Crabtree and G. E. Matthews (*American Photographic Publishing Co., Boston, Mass.*).

(*9*) Processing Miniature Films; P. K. Turner (*Link House Publications, Ltd., London*).

(*10*) How to Make Good Movies (*Eastman Kodak Co., Rochester, N. Y.*).

(*11*) Amateur Film-making; G. H. Sewell (*Blackie & Son, Ltd., London*).

(*12*) The American Cinematographer Handbook and Reference Guide; J. J. Rose (*American Society of Cinematographers, Hollywood, Calif.*).

Yearbooks were issued by the following publishers:

Quigley Publishing Co., New York.
Film Daily, New York.
Kinematograph Publications, Ltd., London.
Photokino-Verlag, Berlin.
M. Hess, Berlin-Schonberg.

Abridgements and compilations were issued as follows:

Abridged Scientific Publications of the Kodak Research Laboratories, Vol. 18 (1936) and Vol. 19 (1937) (*Eastman Kodak Company, Rochester, N. Y.*).

Fortschritte der Photographie (Process of Photography), Vol. 5, Ergebnisse der Angewandten Physikalischen Chemie; edited by E. Stenger (*Akademische Verlags. M. B. H. Leipzig*). Reviews progress from 1930 to 1937.

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[6] *Amer. Cinemat.*, **20** (Jan., 1939).

[7] *Kinemat. Weekly*, **261** (Nov. 3, 1938), p. 29.

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[9] *Amer. Cinemat.*, **19** (Dec., 1938), p. 523.

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[18] SCOTT, H. H., AND PACKARD, L. E.: "The Sound Level Meter in the Motion Picture Industry," *J. Soc. Mot. Pict. Eng.*, **XXX** (Apr., 1938), No. 4, p. 458.

[19] *Bulletin*, Academy of Motion Picture Arts & Sciences (Oct. 10, 1938).

[20] NOEL, E. B., AND FARNHAM, R. E.: "The Water-Cooled Quartz Mercury Lamps," *J. Soc. Mot. Pict. Eng.*, **XXXI** (Sept., 1938), p. 221.

(VI) APPENDIX A

THE MOTION PICTURE INDUSTRY IN JAPAN—1938

W. H. BAHLER

One of the major problems of the motion picture industry in Japan in 1938 was the complete ban of foreign pictures, which was made effective in September, 1937. This was done by the Finance Department of the Government for purely economic reasons in an effort to overcome adverse exchange balances incurred or worsened by the China Incident. It is hard to understand why the local producers did not find this ban advantageous until one considers that in Japan the producers control the major portion of the distribution of both local and foreign films. Imported pictures, especially American, as has been pointed out in a previous report, are very popular in Japan and easily account for their share of admissions. It can be readily seen how this source of profit directly assists the Japanese producer who happens to be the exhibitor. Furthermore, foreign films are a stimulus to the local industry. They furnish suggestions and patterns to be simulated; they provide the contact between the local producer and his western contemporaries. So it is not inconceivable that the local producers as well as the foreign distributors were eager to see the lifting of the ban.

Negotiations by the American Motion Picture Association of Japan were started in February but it was not until July that an agreement was reached and not until October that the ban was finally lifted. The agreement was only temporary; however, it allowed the importation of approximately 200 pictures before the end of the year, and the purchase of a certain amount of exchange in payment for the pictures and for the transfer to America of a good share of the previously accumulated royalties frozen in Japan. Until the end of the year, at which time the agreement was to expire, only about 100 pictures had been imported, but it is understood that the government has consented to a three months' extension to allow the agreement to be fulfilled. These newly imported pictures started to make their appearance in theaters during the latter prat of November. Approximately 40 German pictures were imported into Manchuria by the Manchurian Film Monopoly under a German-Manchurian Trade Agreement promulgated last year. It was planned that these films would also be exhibited in Japan but no adequate scheme had been devised for distributing them before the year closed. Several Italian films were imported into Japan during 1938. As far as is known, only one was exhibited and that with only moderate success. It has been suggested that with the Anti-Comintern Cultural agreements between Japan, Germany, and Italy, exchange of films on a barter basis may be favorably considered. Whether or not such a plan will be successful will probably be largely determined by the amount of active support given it by the governments involved. American distributors, while not prepared to meet such competition, will no doubt be materially aided by the recognized superior box-office success of American pictures.

Only one piece of governmental legislation was enacted in 1938 which pertained to the motion picture industry. This law enforced from February 1, 1938, limited each theater program to three hours. Prior to that time exhibitors screened two foreign features, one foreign and one Japanese or two Japanese pictures, plus newsreels and shorts, making a program sometimes as long as five hours. The new ruling was considered necessary by the authorities to promote the public health, to economize on film and to encourage the production of fewer but better pictures. This new ruling proved beneficial to foreign distributors since it came at a time when they were struggling with a shortage of films. There was no serious objection raised against the law by the exhibitors. It led, however, in certain instances to the objectionable practice of cutting pictures, both foreign and Japanese, to the point where continuity of the story was destroyed.

According to the censor's report, as published in the *Movie Times*, there were 560 Japanese pictures of the entertainment variety censored during the period from December 26, 1937, to January 10, 1939. The actual censored footage amounts to approximately 3,100,000 feet, not including newreels, whose censored footage is very difficult to ascertain. Of these Japanese pictures, 44 per cent are of the modern talkie type, 54 per cent are historical or classical talkies, 7 per cent are modern and historical silent pictures and 2 per cent are documentary or educational. These figures are based on the censored footage, which it is felt give the best indication of the activity of the studios, since only one print of each picture is censored. The percentage of silent pictures indicated above is open to question since other sources indicate that in 1938, as in 1937, the production of silent pictures approached 15% of the total.

On the basis of the above censored footage, the release footage of Japanese pictures is estimated between 35 and 40 million feet. The release footage of foreign pictures probably did not account for more than 10 million feet. Newsreels, whose censored footage is unknown but of which many prints are normally made, may have approximated a release footage of 5 million feet or more. It is hardly conceivable that the total release footage exceeded 55 to 60 million feet since import restrictions on raw stock limited the local supply to less than this figure. Inasmuch as the official censor's report is usually not released before October or November of the following year, precise figures are well high impossible to obtain at this time. Accepting the above estimates, the release footage for 1938 has fallen to about 80 per cent of that for 1937. Reasons for this decrease may be gleaned from what has been mentioned above concerning the ban on foreign pictures and from remarks to follow concerning import restrictions on raw film.

In 1937 American pictures accounted for more than two-thirds of the foreign pictures released in Japan and during 1938 they seemed to maintain this average despite the ban effective throughout the first nine months of the year. Of the foreign pictures censored in the above mentioned period, American pictures accounted for 75 out of a total of 110 or about 68 per cent. British followed with 12, German 11, French 8, and Italian 4. The total censored footage of foreign pictures, according to the *Movie Times* report, amounted to some 780,000 feet.

As was mentioned in the preceding report, European productions seem to be steadily gaining ground against American pictures, but this does not necessarily imply that they are achieving greater popularity. Pictures produced under the social and political restraint peculiar to European countries are much more likely to find favor in the eyes of the Japanese censors, especially in view of governmental amity. It must also be borne in mind that the exhibitor is able to make more favorable terms for those pictures than for American pictures.

Contrary to expectations, the ban on foreign picture importations did not stimulate home production. One reason for this, mentioned above, is the producer-exhibitor link peculiar to this market plus the decrease in box-office receipts resulting from the ban. A further factor, which should not be overlooked, was the shortage of raw film stocks. Available figures show that the imports of raw film into Japan in 1938 were hardly 15% of the quantity imported in 1937. It was beyond the ability of the local manufacturers to suddenly meet this tremendous increase in demand.

The hostilities in China caused a tremendous interest in the production and exhibition of newsreels. In 1937 the censors inspected a total of 21,869 prints of newsreels. While corresponding data for 1938 are not available, it is possible that the number may have reached that impressive total although after the fall of Hankow and Canton, public interest in newsreels of the China fighting slumped. During

1937 a considerable number of small theaters were opened for the express purpose of showing newsreels interspersed with shorts, each theater with a seating capacity of from two to three hundred patrons. Early in 1938 it was reported that the total number of theaters showing newsreels exclusively was 60 but a subsequent report released in June placed the figure at 32.

During 1937 there was considerable activity in the production of educational films. Government agencies, newspapers, universities, and cultural societies, as well as motion picture companies, participated in making a total of 287 such pictures, of which 232 were of the sound variety and 55 were silent. According to subject these films were: army and navy, 49; tourist, 47; education, 45; industry, 33; documentary, 30; cartoons, 22; advertising, 19; sports, 9; manners and customs, 8; sanitation, 7; amusements, 6; science, 5; art, 3; politics, 2; music, 2. Since these films are made primarily for private distribution, figures as to lengths of various subjects are difficult to obtain. Corresponding data for 1938 are not yet available but it is doubtful whether the 1937 mark was equaled due to film shortage.

It is believed that there were no new large theaters constructed during 1938 because of the rigid control exercised by the government over building materials, especially structural steel. Certainly not more than 20 to 30 small buildings with a seating capacity of about 250 each were built. At the end of 1937 the Department of Home Affairs reported a total of 1749 theaters in Japan proper which was an increase of 122 over 1936. With three or four exceptions, these latter were also predominantly small buildings. It was assumed at the end of 1937 that about 85 per cent of all these theaters were wired for sound and it is possible that this percentage has been slightly increased during 1938. Local made sound systems predominate and will continue to do so primarily because importation of such equipment is prohibited. Of the entire number of sound installations, not over 20% are of foreign manufacture.

The Fuji Photo Film Company, which is practically the only manufacturer of standard motion picture films in Japan, has in the past two years carried on an extensive program of expansion in an effort to supply the raw film necessary for the local market now that imported stocks are so severely restricted. Their products include a clear base panchromatic negative film, a positive film, and a sound recording film. It is also rumored that they will soon market a high-speed negative film on an anti-halation support. Although they have striven valiantly to overcome the shortage of raw stocks on the local market incurred by the import restrictions, it is believed that their production capacity is still insufficient to obviate imports entirely. The normal monthly demand in Japan is approximately six million feet of positive film, about one million feet of negative film, and about one million feet of sound positive film.

The use of educational film for teaching purposes is fairly widespread in Japan, particularly in the colleges and universities. Even the so-called middle schools occasionally make use of such film. The Department of Education is fully aware of the importance of using educational film for teaching purposes and had done much to encourage the domestic production of such films.

It has been reliably reported that in the small villages and towns in the rural sections of Japan, theater owners are becoming interested in the possibilities of showing releases on 16-mm films. Although at present there are only one or two such theaters, this promises to be important in the future. Reasons for this include the decreased cost of equipment and pictures as well as the fact that the projection of 16-mm safety film does not require halls of fireproof construction. This venture will not be an immediate success because of the present shortage of 16-mm film and also because the motion picture companies will have to be won over to the idea of making 16-mm prints. The fact that there are two locally manufactured 16-mm sound projectors is an encouragement to those interested.

REVIEW OF FOREIGN FILM MARKETS DURING 1938*

NATHAN D. GOLDEN**

Summary.—*American motion pictures continued to enjoy widespread popularity throughout the world during 1938, although the intensification of difficulties abroad has resulted in a drop of 70 to 65 per cent in America's domination of the world's motion picture screens. The obstacles encountered have been of diverse character, including legislative restrictions, quota systems, high taxes, foreign-exchange controls, occasional excessive censorship, so-called "racial" theories, fervent efforts to build up local film industries, active hostilities in the Far East and Spain, transfers of territories, and such intangible factors as uncertainty and apprehension.*

Various significant legislative enactments occurred during the year in Europe. Great Britain imposed a new quota system, to last for 10 years. Notwithstanding the erection of new barriers, American films have continued to enjoy a substantial European market.

During 1938, foreign motion picture production totaled 1706 feature films, against 1809 in 1937. The countries of the Far and Near East led in production, with 967 features, as compared with 959 in 1937. Production in Europe fell off sharply, the total for all Europe being only 609 features. Latin-American feature-film production increased by 40 films to a 1938 total of 130, Mexico being the largest producer, with 60 features.

The Latin-American market at present appears to afford a promising opportunity to offset the restriction of our picture markets in other parts of the world.

Spanish-dialog films have scored notable box-office successes in nearly every Latin-American country in which they have been shown, locally produced pictures having often exerted a powerful appeal during the past year, because they have portrayed familiar aspects of life, in a language understood by the audiences. On the other hand, a wealth of recent evidence demonstrates the grave defects and difficulties of the motion picture production attempted in certain countries abroad on wholly insufficient foundations.

American motion pictures continued to enjoy widespread popularity in every region of the world throughout the year 1938, although there was a decrease in the quantity and value of our film exports. As always, our American pictures have won friends during the past

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received March 18, 1939.

** Motion Picture Division, U. S. Bureau of Foreign and Domestic Commerce, Washington, D. C.

twelve months through their outstanding merits, but they have been confronted by the same impediments and handicaps as in other recent years—sometimes in accentuated form. The intensification of difficulties abroad has resulted in a falling off, from 70 per cent to 65 per cent, in America's domination of the world's motion picture screens.

The obstacles, which have been of diverse sorts, have more or less demoralized the local amusement business. Transfers of territories have involved drastic changes in the circumstances governing the motion picture trade. The intangible psychological factors of uncertainty and apprehension have had an appreciable effect. In many cases the spirit of nationalism has been heightened to the disadvantage of a product such as American films, whose appeal is ordinarily designed to transcend geographical boundaries.

During the past year the ardent fanning of that spirit of nationalism has meant, in numerous countries, an ever-increasing fervor and energy in the attempt to build up the struggling local film industries—industries which, despite their obvious faults and feebleness, are apt to be supported by governmental action. Often this has meant more frequent play dates for locally produced pictures at the expense of our American productions. Foreign restrictions on American pictures in 1938 assumed varied but generally vexatious and embarrassing forms. In certain countries, quota systems are entrenched, and that troublesome system shows a tendency to spread. Taxes on motion picture business abroad are usually high, and the trend is unmistakably upward. "Racial" theories and campaigns continue here and there to bring difficulties, which are not easy to deal with. Foreign exchange controls and censorship were continuing problems during 1938, though there have been few startling alterations in those fields.

It may well be noted, at this point, that certain foreign governments have been resorting somewhat oftener, and with more vigorous insistence, to the method of diplomatic intervention with neutral governments in order to prevent the local showing of American feature pictures which authoritarian states choose to regard as objectionable. The number of such interventions has not been particularly large—but the activity, in itself, deserves to be noted.

Legislative Restrictions.—Restrictive measures enforced in Europe during 1938 included a new quota system instituted in Great Britain on April 1, 1938, lasting for the next ten years. The purpose of this new law is to compel distributors and exhibitors to utilize a proportion of British-made films, and foreign producers, including American, are induced to produce in British studios quality films for both domestic and world distribution.

Italy has placed the distribution of all films, commencing January 1, 1939, under a Government monopoly. A decree to this effect was issued on September 4, 1938, establishing the Ente Nazionale Industria Cinematografica to purchase and distribute in Italy, its colonies and possessions, all motion pictures imported from abroad. Because of the severe terms of this decree and the scant opportunity offered for the showing of our American films, all American firms having their own distribution branches in Italy, and those distributing films through Italian agents, ceased doing business in Italy on January 1, 1939. This is something new in restrictions. It is the first time that a foreign government has gone into the business of distributing motion pictures for the outward purpose of profit. With the closing of American branches in Italy, Italian exhibitors will unquestionably feel the severe "pinch" involved in the lack of an assured supply of films. At best, Italian films average about half of the normal box-office receipts attained by American films, and, in the past, Italian audiences have not refrained from expressing their adverse reaction to Italian films.

Germany during 1938 widened its authority and influence in Europe by absorbing Austria and the Sudeten territory of Czechoslovakia. Not only did the Anschluss of Austria and the partition of Czechoslovakia bring some 1100 additional motion picture theaters under the German swastika but also the quota laws of Germany were applied—virtually shutting out American films. Coöperation and "compensation" agreements between Germany and other countries also have materially decreased the showing of our American pictures. This restrictive tendency is spreading over those countries that are looking to Germany for economic assistance.

On October 12, 1938, a Federal decree went into effect in Switzerland making the importation of motion pictures subject to an import permit to be issued by the Federal Department of Interior, which has also been empowered to fix import contingents. Up to now, however, no quotas have been fixed. It is understood that the primary purpose of this new decree is to establish a dependably functioning import control of films, which was not possible previously.

The new agreement of May 18, 1938, effective June 1, 1938, in Czechoslovakia permits greater facility of American film distribution.

It has removed certain threatening restrictions, decreased the cost of introducing features and dubbed versions (the recent ceding of the Sudeten territory to Germany has diminished the value of the concessions with respect to films dubbed in the German language), bound certain conditions, and established the right of American companies to establish their own distribution organizations under equitable conditions.

The Danish Parliament on April 13, 1938, revised the existing motion picture law and created a Government distributing agency called the Film Central, for the purpose of distributing Danish films that are not distributed by the producer himself or by independent Danish distributors. The law prohibits the distribution of domestic films by local branches or agents of foreign motion picture distributing companies.

Although restrictive barriers in many of the European countries are being enforced in greater number, the European market for American films is far from being lost. Countries such as England and France (even with their legislative barriers), Belgium, Denmark, the Netherlands, Finland, Norway, Poland, and Sweden, still remain important outlets for our American pictures.

The ban on the importation of American motion pictures into Japan was lifted in October, 1938. For a period of 13 months no new American films were permitted entry, in accordance with the law of September, 1937, banning luxuries—under which motion pictures were classified. The new plan permits the entry of 200 American films into Japan during 1938, and the transfer of 3,000,000 yen of frozen funds in Japan to the United States through the Yokohama Specie Bank at San Francisco, where such funds are held without interest for a period of 3 years. Second, it provides for the grant of import and exchange permits for the importation of $30,000 worth of films on the basis of a fixed valuation of 1.5 cents per foot. Third, it allows distributors to remit these funds on a monthly basis, converted into dollars and kept in the Yokohama Specie Bank in San Francisco under the same restrictions as noted above for the 3,000,000 yen of frozen assets.

While the lifting of the ban permitted the entrance of our American pictures again in Japan, uncertainty is reported to be felt in consequence of predictions that legislation is being drafted for presentation to the Diet, providing for rigid control over all phases of the motion picture industry.

On Dec. 22, 1938, the Governor of New South Wales, Australia, approved an amendment to the Cinematograph Bill of 1938 providing for a Theater and Films Commission to replace the Film Advisory Committee, and setting up new provisions of the Quota Act. The new act provides for a 15 per cent quota on the part of exhibitors for British quota films, and a $2^1/_2$ per cent quota on the part of exhibitors for Australian pictures. Exhibitors, under the new act, have a maximum rejection right of 25 per cent plus $2^1/_2$ per cent for Australian films, or a total of $27^1/_2$ per cent.

Latin-America.—The Latin-American market at present appears to be the market our American distributors are seeking to offset the restricted markets in other parts of the world. With 5239 potential theater outlets, and with new theater construction increasing each year, American companies are coming to the realization that here is a geographical area that should receive closer attention. Economically it would be unwise for our companies to encourage production in South American countries; however, American companies should produce in Hollywood Spanish-dialog films employing stage favorites brought from South America and placed in a Hollywood setting, with the use of reconstructed sets and Hollywood technic. In this manner, production costs can be kept at a minimum, and producers will have Spanish-language films available to carry their other American product which is now being frequently shoved into the background by Spanish-speaking productions from Mexico and the Argentine. A case in point is the drop in the showing of American films in Peru from 70 per cent of the total in 1937 to 49 per cent in 1938, which is attributed primarily to the augmented number of Spanish-dialog pictures from Mexico, Argentina, and Peru, itself. Although none of these films approached the quality and standard of our American films, they helped to consume playing time that might otherwise have been obtained by American films.

The one important market in Latin-America which may become beset with difficulties is Argentina. In the closing sessions of the Argentine Congress in 1938, a bill was introduced which would give definite powers of regulation and control of motion pictures to the Instituto Cinematografico Argentino. This bill would encourage a national industry through prizes, subsidies, and other means; it would establish a central censorship board, with Argentine films exempt from censorship taxes; it would exempt import duties on raw film and equipment accessories necessary in the production of

Argentine films; it would encourage the future establishment of a Government film studio. While the bill will not be acted upon until the next session of the Argentine Congress, it gives a clear indication which way the trend is moving, and may be the forerunner of a quota law. Recently in this market a ban has been placed upon the importation of film advertising matter. This ban forces our American companies in the future to print their posters and lithograph material in Argentina to aid the native printing and lithographing trade.

As an indication of the rising legislation designed to hamper the distribution of our American films, one finds that during 1938 a new tax was levied against American distributors in Guatemala. Formerly, distributors paid $300 per year for the right of operation. This has now been changed to 10 per cent of the distributors' share of entry receipts. A deduction of 25 per cent from the distributors' share may be made to cover expenses, and the 10 per cent is applied to the balance.

During the year 1938, Cuba attempted to pass an exhibitors' quota providing that for every 7 imported films one Cuban picture must be shown. The House of Representatives failed to pass this quota. When one realizes that only two Cuban films were produced during 1938, the impracticability of the proposed legislation is clearly evident.

American Film Exports.—Statistics of American motion picture film exports for the full 12 months of 1938 show a 13,000,000-foot decrease in positive and negative sound and silent films as compared with those exported during 1937. During the year 1938 a total of 202,526,821 feet of motion picture entertainment films, both sound and silent, with a declared value of $4,519,594, were exported to all foreign markets, as compared with 215,721,956 feet of film, with a value $4,797,641, for the year 1937. This is a decrease of 6.1 per cent during the year 1938 in the total of all films exported.

The valuation of these exports merely represents the declared value of the raw film cost at 2 to 3 cents per foot and does not represent the true value in dollars received by American distributors for rentals.

The foreign-exchange situation has not changed perceptibly during 1938. In 57 out of 94 countries throughout the world, up to December 31, 1938, foreign exchange was liberal and easy, ranging from prompt to retarded payment. In the remaining 37 countries, foreign exchange is "tight and normal" in 9 countries, "tight and slow" in 15, and "restricted" in 13 countries.

Censorship.—Censorship abroad has not been unusually troublesome during 1938. In most cases, the censorship rules have been carried out in a spirit of reasonableness, moderation, and judicious liberalism. In certain instances, though, it would seem that the literal terms of the local censorship regulations may be regarded as unduly stringent. For example, we learn of films being banned occasionally on such grounds as mere "banality" or "the conveying of prejudicial illusions." In Greece, pictures portraying stories of the French Revolution are taboo, because, though the events happened a century and a half ago, they are "connected with political or social movements of revolt." Great Britain forbids all films that it considers "horrific," and thus the picturization of certain novels written by that nation's own distinguished authors are excluded from its screens. "Anything that might offend local sentiment" is the broad and vague description of the sort of dramatic themes that might mean "thumbs down" in Germany. In India, one is forbidden to show, in motion pictures, "organized knuckle fights" or "profuse bleeding"—and the same country also bars scenes depicting "relations of capital and labor," a rather onerous restriction on producers interested in showing the vivid drama inherent in economic problems of the present day. One is inclined to agree with a report from British Malaya, expressing the opinion that apparently "the local censor does not take into consideration the growing sophistication of native audiences."

Foreign Film Production.—During the year 1938 foreign motion picture production totaled approximately 1706 feature films, as against 1809 features in 1937. The countries of the Far and Near East led in production, with a total of 967 features in 1938, as compared with 959 in 1937. Japan with 575 features was again the leading producer, followed by India with 200 features. The Philippine Islands account for 67 films, Hong Kong 53, China 33, Egypt 16, Siam 10, Australia 8, Chosen and Formosa 2 each, and New Zealand 1.

Production in Europe fell off sharply in 1938, primarily as a result of England's decline in production. For the year 1938, all countries of Europe produced a total of 609 features. The following countries were producers of feature films during 1938: Germany 137, France 122, England 85, Russia 51, Italy 47, Czechoslovakia 41, Sweden 30, Hungary 26, Poland 25, Finland 20, Denmark 9, Norway 4, Turkey, Belgium, and Portugal 3 each, Netherlands 2, and Switzerland 1.

Latin-American feature-film production during 1938 took an upward jump of 40 films. During 1938, 130 full-length features were produced as compared with 90 in 1937. Mexico was the largest producer, turning out 60 features. Argentina jumped its production to 50 features from 30 in 1937. Peru increased from 2 in 1937 to 11 in 1938. Brazil produced 4, Cuba and Uruguay 2 each, and Venezuela 1.

Increased production in Latin-America substantiates the fact of the Latin-Americans' desire to see and hear their own stars speaking their native tongue. In many markets these native pictures, regardless of their quality, have far outdistanced some of our biggest American productions. This especially is true in the rural communities of Latin-America. Films produced in Mexico and Argentina have scored notable box-office successes in nearly every Latin-American country in which they have been shown. This is true also of those Spanish-dialog films produced in Hollywood employing actors brought from Latin-American countries, speaking Spanish, and placed in stories having a Latin-American atmosphere.

It is keenly interesting to note some of the salient characteristics of "infant" picture-producing industries in various foreign countries during the past year, as recorded by competent observers on the spot. On the one hand (as just indicated) we must frankly recognize the fact that the locally produced pictures often exert a powerful, though naturally restricted, appeal; they do so not only because they speak the language of the people but also because they "portray outstanding aspects of the national life, showing typical landscapes, dances, and music" (to paraphrase one report from the Caribbean region). One picture in particular, produced south of the Rio Grande, is noteworthy as having achieved a really "tremendous hit" during 1938 in a number of Latin-American countries where the people welcomed it eagerly by reason of their perfect comprehension of the language and the animating moods of the action.

On the other hand, we have a wealth of recent evidence to demonstrate the grave defects, shortcomings, and often insuperable difficulties of the motion picture production attempted in certain countries, very largely on the basis of nationalistic ambition, without a solid foundation. From one European country we hear of complaints by audiences that "the local pictures seem 'stationary.'" Lacking the proper facilities for moving the cameras, or for creating a fascinating variety of settings, the local producers are unable to avoid, in their films, an annoying and exceedingly tiring "static" quality. Again, we learn that "the make-up of even the leading players in local pictures is often far from flattering," and the spectators are thereby repelled—or amused in the wrong places. (What is being said here does not refer, of course, to major producing countries such as France and Great Britain.)

"The lighting is generally hard and flat" is a criticism voiced of the pictures being turned out in one Far Eastern country—in vivid contrast to the magical lighting effects achieved in nearly every American picture. The music used in some foreign studios is that of old, imported phonograph records—and, when the picture is edited, there occurs from time to time an abrupt and disconcerting "chopping off" of the musical background, perhaps in the middle of a phrase.

"Direction is deficient," is the 1938 dictum from another part of the world, with respect to locally produced pictures. A basic handicap noted is that "many local films have been and are being produced 'on a shoestring.'" "Technic lags behind" is the point emphasized in still another discussion of foreign production, and, with respect to one major country, it is asserted today that the local producers "can not provide the spice and variety characteristic of American pictures."

In one foreign country, with a vast population, the motion picture production attempted by various local interests has, in general, "gained the reputation of being a poor financial risk and a highly speculative venture." In another part of the world, the local producers are described as being "unable to do any really serious work," the existing companies being "small, poorly organized, and inadequately financed." In one very substantial nation of western Europe, we find that "the high percentage of financial failures registered by local motion picture productions discourages fresh investments."

In northern Europe, one splendid new theater took the rather staggering loss of 2000 crowns daily while showing a locally produced picture, of which high hopes had been entertained. In that country, we ascertain, producers have experienced great difficulty in engaging satisfactory casts; one reason for this is the fact that they are compelled to rely exclusively on stage actors and actresses, and these artists can act in pictures only during the three months of their summer holidays. In one British Dominion, the year 1938 witnessed the production of one local feature—which was "shown in one theater and immediately forgotten."

In one of the European countries, in 1938, the sum of 600,000 francs was sunk in the production of a local film—which, when it was finished, found no market whatever. It is said that the film can not be sold and that the money invested in it is likely to represent a total loss. A number of firms, in the same country, are attempting to produce pictures in a structure converted from other purposes, where they have a working-room only 8 meters wide by 20 meters long.

Summation.—From such reports as these, covering 1938, one gets a clear idea of the flaws, misfortunes, frustrations, and frequent unfavorable reactions involved in the attempt by various foreign interests to establish local motion picture production abroad where there is actually scant necessity or justification for the effort. In numerous cases the difficulties seem well nigh insurmountable, since they arise out of the inherent limitations of the country. In other instances, of course, the present handicaps are to some degree temporary, and faults will be gradually corrected as circumstances are altered and development proceeds.

But whether the future, in a given country, presents one prospect or the other, today the fact is indisputable that a very considerable proportion of the motion picture production abroad is of a quality markedly inferior to prevailing American standards.

In view of that fact, what action should be taken by our American companies in order to maintain a position of superiority over their competitors in the markets of the world? To what major measure can they today resort, with the object of checking trends which we must acknowledge to be adverse? What dynamic attraction or allurement can be exerted, of greater potency than the local appeal of a spectator's mother-tongue and his natural fondness for familiar scenes and ways of life?

Plainly, before all else, we must emphasize to the utmost the *contrast in quality* between our good American pictures and the typical product of local producing industries abroad. We must make that contrast as vivid, as striking, as impressive, as it can possibly be made. Persistently and adroitly, we must make the foreign moviegoer acutely conscious that the American picture is a product of *decidedly superior* quality—of rich and varied artistry, of entertainment value unmatchable in the run-of-the-mine output of our competitors abroad. We must make this "high-quality" factor so universally recognized that local audiences abroad will have no desire to see inferior films that owe their existence simply to some government legislation or subsidy.

Very recent news dispatches tell us how certain foreign audiences, deprived of American pictures, have manifested their displeasure in the strongest possible terms.

It is unwise for us to try to export mediocre films. Foreign audiences, in numerous countries, get an abundance of that kind of pictures from their own studios. American distributors should send only their choice Grade *A* films to the foreign market. If the choice is between our *B* type of films and a picture from a native studio, the latter (one need hardly say) is almost invariably preferred. An examination, over the past few years, of our best revenue-producers in the foreign market discloses that those films listed among the best pictures shown here in the United States have also been the biggest revenue-*remitters*.

Certainly, therefore, it behooves our American companies today, more than ever before, to make a very careful selection of the films to be exported—and not to send, more or less at random, pictures that might affect unfavorably the ultimate gross returns, while impairing our indispensable prestige and reputation for superior quality.

As we advance into the new year 1939, the factors to be relied upon, in maintaining our position in foreign markets, may still be defined as the simple, basic elements of our unmatched scientific skill in motion picture production—our amazing capacity for devising new and really wonderful methods—our determination to achieve artistic and enthralling camera-effects—the incomparable richness of our material facilities and resources—and our unequaled variety and range of every type of acting talent. Together, these things spell *quality*—and it is quality that will continue to attract foreign audiences to American pictures.

DISCUSSION

Mr. Crabtree: With regard to foreign versions, what percentage are produced with foreign actors; what percentage have superimposed titles; and what percentage are "dubbed," with an attempt to synchronize the lip movements with the foreign language?

Mr. Golden: In certain markets of Latin-America our pictures are preferred in their original versions with superimposed titles, but in other markets we can get away with dubbed versions. A great number of Latin-Americans are trying to improve their knowledge of English, and the use of motion pictures as an educational aid is very valuable. Dubbing is done in certain of the European countries, particularly in Paris and London. In other markets a great deal of superimposing is done. We send our pictures in the original version and superimposing of the titles is done where facilities are available.

MR. CRABTREE: Mr. Sponable once showed us a very interesting example of synchronization of lip movement in the English version with a foreign language. Perhaps he can tell us whether this business is growing or diminishing?

MR. SPONABLE: I think it is about stationary. As Mr. Golden has said, we dubb a large number of our pictures abroad in French, Italian, and Spanish.

MR. CRABTREE: I suppose the reason for this is that when separated from the source, one loses the colloquialisms of a language.

MR. RYDER: Relative to the number of foreign dubbed pictures, it might be interesting to know that in the past Paramount has dubbed about 60 per cent of its pictures. This means that French or Spanish lines are used to replace the original English dialog. The recent foreign situation, I feel sure, has changed the percentage and the uncertainties that now exist will cause a further change so that the percentage will be somewhat different from what it has been in the past.

MR. ERMOLIEFF: I think every American producer and distributor adapts as many pictures as he can. If a picture is some sort of success we try to adapt it because the greater masses care to see the picture in their own language.

In *Snow White* we had a picture that made tremendous money abroad. It was dubbed in about ten languages, even in the languages of small countries, in which we would not dubb other pictures. Pictures that we dubb in French are released in Belgium and other French-speaking countries; we dubb in Italian for all the Italian-speaking countries; and for the Scandinavian-speaking countries we usually dubb in Swedish.

MR. CRABTREE: With what degree of success is synchronization of the lip movement accomplished or do you let the foreigners worry about that?

MR. GOLDEN: They worry very much about it. You can not synchronize quite perfectly, and there is always some sort of difficulty. We do not have as much trouble with German, because the German lip movements are more similar to ours. We have more trouble with French, and still more with Spanish, depending more or less upon the picture.

MR. LESHING: Mr. Crabtree would like to know how successful we are in synchronizing the lip movements. We do it not only in the foreign versions but in our own productions, when we give the voice of a singer to someone else who can not sing. I do not know how much of the dubbing is being done here. We do, however, supply material to our foreign department for practically every country that uses our productions, and they do their own dubbing. Whether they are doing it in Italy, France, or Spain we do not know, but we do supply them with material for the dubbing which a couple or three years ago was done here in the United States.

MR. GOLDEN: This dubbing is one of the worse worries that the industry has to face in the foreign market. The quota laws or legislative barriers that exist in some of the countries require that the dubbing be done in the country in which the picture is to be shown. France and Italy have definite laws in this regard, as well as some of the Scandinavian countries, and these provisions are designed primarily to keep the local struggling industries going.

MR. CRABTREE: As in the example that Mr. Leshing mentioned, there can be a great amount of effort put into studying the lip movement and then changing the foreign dialog so as to synchronize with these movements. Are the foreigners putting any degree of concentrated effort into the dubbing or do they just make the lines of the dialog fit the time of projection?

MR. GOLDEN: The dialog must fit the time of projection. In France it is required that something be said in the French titles that the film was dubbed in France and that the actors are not speaking the French language. That is a part of the law. Some eight years ago I had the privilege of seeing at the M-G-M Studio some of their German-dubbed pictures. Mrs. Golden who is quite a student of German was with me. We looked at a picture starring Marie Dressler and Wallace Beery and after about ten minutes had passed Mrs. Golden said to me, "I never knew Marie Dressler or Wallace Beery spoke German." That is how well it was done then, and I imagine the improvements today far exceed the accomplishments of eight years ago.

DR. FRAYNE: In sending the sound effects and the music on these pictures for dubbing are those sent on duplicate positive material, negative, or what?

MR. RYDER: In the case of Paramount our dubbing (re-recording) procedure is as follows: On each sequence or section of the picture to be dubbed, we first make a take for our domestic release, using the English dialog. Subsequently, for foreign dubbing we make a second take on the same sequence, omitting the English dialog, but incorporating all the music and effects used in the original take, plus such added effects as are necessary to give continuity of sound after the dialog has been removed. Prints from the negative thus obtained are sent to the foreign country, where the foreign dialog is recorded and composited by re-recording with the track that we supplied, thus obtaining a new negative for foreign release. Incidentally, the prints that we send to foreign countries are printed heads and tails so as to save film footage.

DR. FRAYNE: In foreign countries they are favored in getting an original recording of their own, as they then do not have to go through a re-recording process. I presume in case of negatives made in foreign countries the final print is made frequently from this negative without going through a re-recording process resulting in loss of quality usually entailed in this process.

MR. RYDER: The sound prints that we supply to the foreign market, for instance to Paris, have effects and music but no dialog. The Paris studios synchronize the dialog to the picture action and substitute French dialog for the English. Then, by the dubbing process they put the two together and obtain a new composite negative with French dialog and the re-recording effects. That new composite negative then is used for release printing in French.

DR. FRAYNE: This might still be better than a photographic duplicate. If they took a foreign language negative made here, and made a photographic dupe over there, the quality might be inferior to what they are getting now in their present dubbing scheme.

MR. RYDER: That is correct. Further, from a commercial standpoint, I believe it pays them to do as much work as possible in the foreign country.

PARAMOUNT TRIPLE-HEAD TRANSPARENCY PROCESS PROJECTOR*

A. FARCIOT EDOUART**

***Summary.**—During the past year a special triple-head projection mechanism has been in use at the Paramount Studio for transparency process work. This device permits the projection of three separate background positives, through three separate projection heads, superimposing the images upon a single screen to form a single registered image of greater size and brightness than would otherwise be possible. The general construction, use, and applications of the device are described.*

The projected background or transparency process of composite cinematography, has come into its present widespread use not merely because it permits the accomplishment of scenes which would be impossible or dangerous to film by conventional methods, but because it makes possible substantial savings in time, effort, and money. To send a major-studio production unit on an extended location trip can, under modern production conditions, be fantastically expensive; such units have been known to cost their studios five and ten thousand dollars per day, and to spend weeks at a time on location, waiting for favorable weather.

If a comparable location result can be achieved in the studio, with the only added expense involved being that of sending a skeleton transparency background camera crew, with perhaps an assistant director and such supernumerary players as doubles, for the principal actors, extras, stunt riders, and the like, to the location, and thereafter completing the scenes with the principals in the studio, it is obvious that worth-while economies must result.

But if such a method or process is to achieve these economies, two basic considerations must be fulfilled. First, and most important, the overall screen effect of the composite picture must be real and convincing in its appearance and it must preserve the illusion that both the foreground action and the background were filmed together, at the same time and place. Second, the physical scope of

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 21, 1939.

** Paramount Studios, Hollywood, Calif.

the process must be such as to place a minimum of technical restrictions—or better, if possible, no restrictions at all—upon the creative efforts of the director and writers.

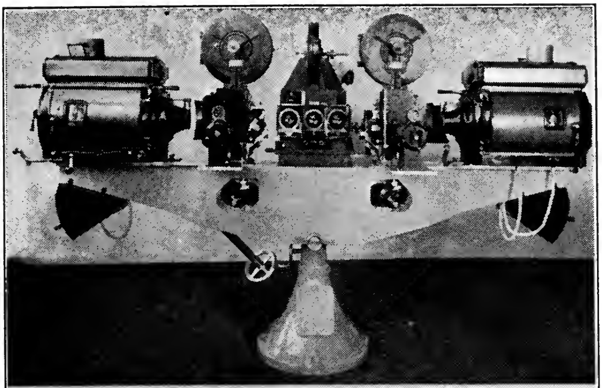
Modern methods, materials, and equipment are enabling modern transparency cinematographers to meet these requirements with increasing success. The detailed story of the progressive steps of these various methods and their evolution has been related so frequently at previous conventions of this Society, and published in the JOURNAL, that it seems unnecessary to go into that detail at this time or to attempt to retrace this familiar ground.

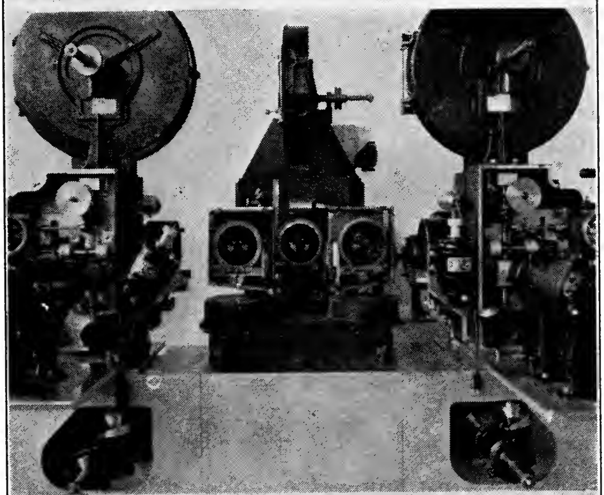
It is significant to note that the most highly important transparency development made during the past year is that of the triple-head projection mechanism. This device permits the projection of three separate background positives, through three essentially separate projection heads, superimposed upon a single screen to form a single registered image of greater size and brightness than would otherwise be possible. Such devices were developed independently and practically simultaneously, unknown to each other by the Transparency Department of the Paramount Studio and the Special Process staff of Warner Brothers-First National Studios. The Paramount device will be described here.

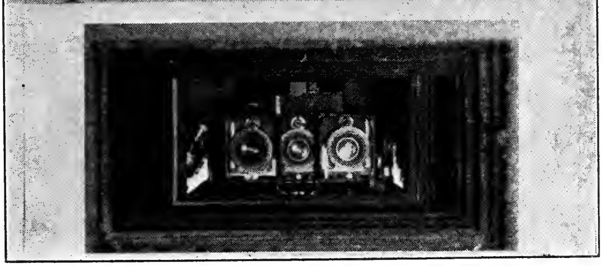
The triple-projection head was the outgrowth of the acknowledged difficulties of securing sufficient screen brightness for extra large screens for black-and-white work and also for an added exposure level when working with three-color systems of natural-color cinematography.

The first experiments were along the lines of utilizing in reverse the same idea in projecting, as Paramount had in the dual screen camera set-up; for photographing original background plates. In other words, a double projector with superimposed images to secure more scope on larger black-and-white scenes. This idea almost immediately expanded, however, into the present triple-head idea.

At the same time we were invested with the problem of securing greater scope in color transparencies. Bearing in mind the economic angle of requiring three color plates to project at a time, the first experiments were along the logical lines of additive projection, using black-and-white background plates with appropriate tricolor filters. This method proved unsatisfactory due mainly to the great loss of light, attributable to the transmission factor of the filters, so we adopted the use of Technicolor subtractive full color plates. The







(Courtesy of Paramount Pictures, Inc.)

FIG. 1. (*Upper.*) Front view, showing the triple projection head layout. The left and right lens images are reflections from the left and right heads, respectively.

FIG. 2. (*Center.*) Front view of the three heads, mirror assembly, the right and left-hand lens remote focus motors, and synchronous drive motors.

FIG. 3. (*Lower.*) Front view of triple projection lenses through silencing funnel. The right and left lens images are reflections from the two first surfaced reflecting mirrors.

ultimate resulting method employs in color three full-color positive plates and has proved most satisfactory for color transparencies.

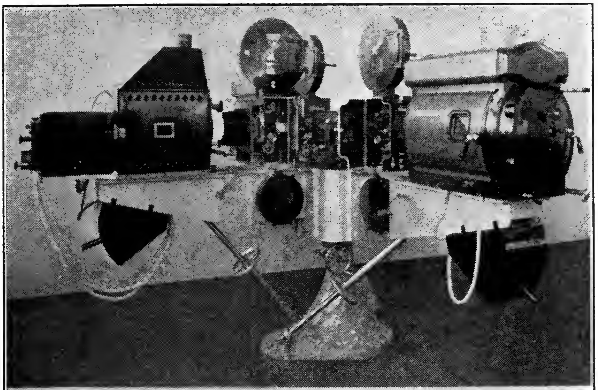
The projection unit consists of three fundamentally standard transparency projection units, each with its own lamp house, movement, and optical system, all three sharing a common base (Fig. 1).

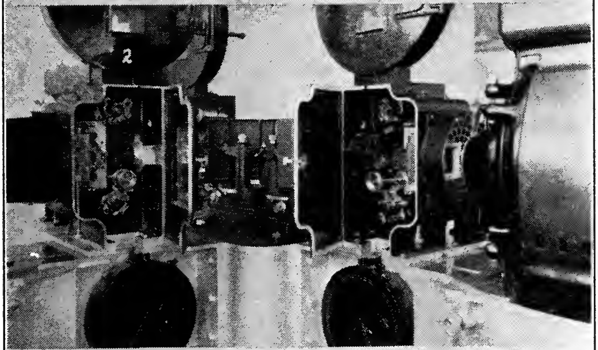
One of the three heads—the one located in the center—is mounted in the conventional position, parallel to the axis of projection. The other two are mounted at right angles to the axis of projection, facing respectively inward to that axis. These two outer heads project their images onto the screen by means of first surfaced aluminized mirrors reflecting their images at an angle of slightly more than 45 degrees to superimpose themselves over that of the directly projected center lens into a single registered triple image. All three projection mechanisms are driven by electrically interlocked synchronized motors. The lenses are focused separately by a reversible type motor operated remotely from the camera.

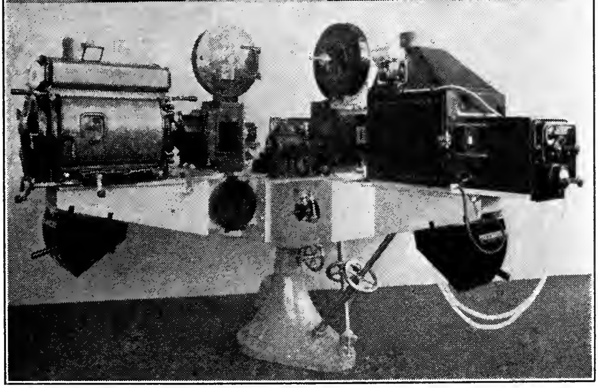
The two outer lenses are mounted in the same horizontal axis plane with the center lens, having their respective reflecting mirrors mounted in front of the lenses, allowing sufficient space between the mirrors to permit the image from the center lens to pass between them (Fig. 2). All lining up work is done with the center machine first, then each side machine is focused and aligned up separately to match that of the center machine. When completed, all three images are superimposed into perfect registration as a single image of beautiful photographic quality, of smoothness, of light steadiness, and of flatness of field.

Parallax is adequately compensated for by independent horizontal and lateral movement of each of the outer lenses, in a manner directly comparable to the sliding front-board of a still camera. The outer lens images are adjusted individually, to coincide perfectly with that of the center lens and each other (Fig. 3). The reflecting mirrors have micrometer lateral and horizontal adjustments to bring the images of any focal length lenses into coincidence with each other at the screen.

The base supporting all three heads may be pivoted horizontally or tilted up or down vertically, moving all three heads, lenses, mirrors, and lamp houses as a unit (Fig. 4). After the center image is in proper perspective and focused for the shot, it does not generally take longer than from three to seven minutes to register perfectly the other two images.







(*Courtesy of Paramount Pictures, Inc.*)

FIG. 4. (*Upper.*) Right side view looking forward, showing center and right-hand equipments. The right-hand head is a left-hand thread up.

FIG. 5. (*Center.*) Center and right-hand projection heads. The right-hand head is a left-hand thread up.

FIG. 6. (*Lower.*) Left side looking forward.

The use of the triple-projection device naturally increases screen illumination enormously. A conservative figure for this increase, which may be varied by any of several controllable factors, is approximately 280 per cent more than is possible with any similar single projection equipment.

This inevitably means that a large picture area may be used. But in addition, it gives several added advantages in flexibility and cumulative quality, as mentioned above.

With the increased illumination, when used under normal circumstances, darker prints may be used than heretofore, thereby obtaining a wider gradational scale, and as a result improved screen quality. In the same way, the triple-head provides a vastly greater reserve of illuminating power, and it is possible to utilize this increased light output to secure finer quality results rather than be forced to strain single-unit illuminants of the same type to the maximum, and be required to use lighter prints.

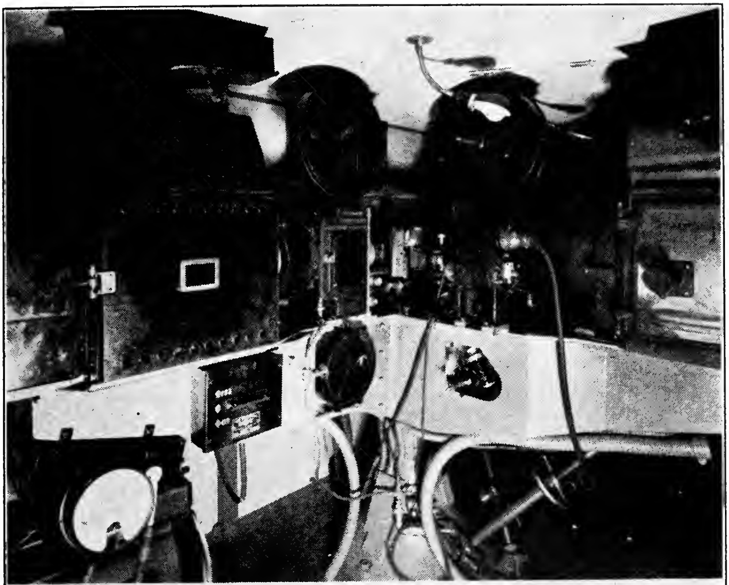
In the same way, it is possible if desired on smaller picture areas, to stop down fast projection lenses to assure maximum definition in the projected picture.

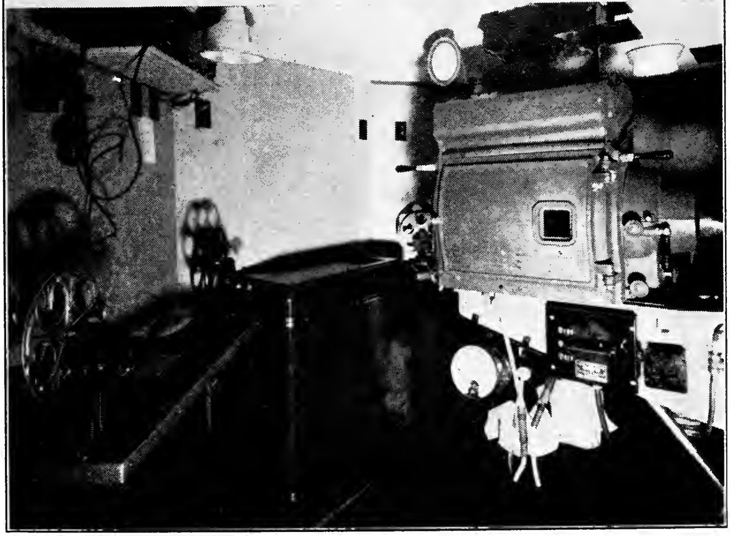
The increased screen brilliance naturally makes it possible in many cases also to stop down the lens of the composite camera and thus obtain a desirable increase in depth of focus.

Graininess in the projected picture has always been a difficulty in the transparency process. The triple-projection method, as can be readily seen, will obviously lessen this problem. The superposition of three separate prints necessarily tends to minimize the visual effect of grain by one-third, since the individual grain-images tend to overlap and cancel each other out. The same is true with other print imperfections.

The use of three light-sources likewise tends to minimize flicker and light fluctuations caused by variations in the intensity of the projection lamp. It is extremely unlikely that the three arcs could ever flicker synchronously. Therefore, when compared to the effects of arc flicker in a single projector, a comparable flicker in any of the three arcs of the triple projector would result in only a $33^1/_3$ per cent variation on the screen, instead of 100 per cent variation, as in the case of a single light-source.

A flatter field of illumination naturally results. Since so great a quantity of light is available for normal shots, the light-source focus does not have to be concentrated to so intense a spot on the aper-





(*Courtesy of Paramount Pictures, Inc.*)

FIG. 7. (*Upper.*) Left side of the transparency projection equipment as mounted in booth.

FIG. 8. (*Lower.*) Rear of booth showing, rewind table and film cabinets. The center cabinet is for air conditioning.

tures, thereby giving a more even illumination, and in addition helps smooth out the center hot-spot so common with single projection. This method also has the additional advantage of tending to lessen the heat falling on each of the prints, resulting in their longer useful life.

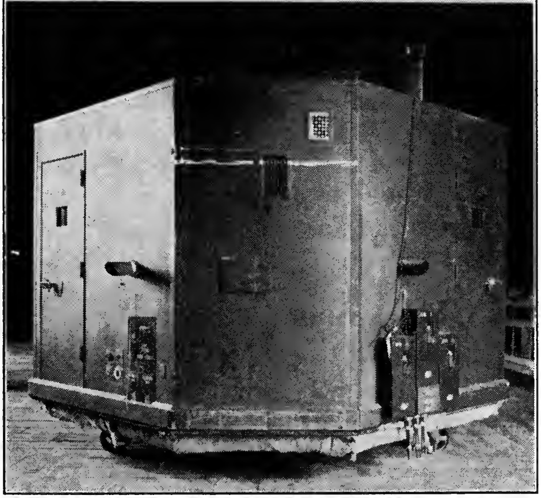
In addition to all these logical duping advantages, the triple-projection system gives added light-control possibilities. It is, for instance, entirely possible to vary the intensities of each of the three arcs, balancing the overall intensity to the requirements of the scene in hand.

Furthermore, it is by no means necessary, nor even always desirable, to utilize three prints of identical densities in this system. It is quite possible (and very frequently done), for example, to use one light print and two darker ones, or one dark and two light ones; or prints of three entirely different densities. This gives a great range of control not alone of screen brightness, but of contrast, gradation, and shadow illumination in the projected picture.

To summarize, the triple-projection system, through increasing the available illuminating power approximately three-fold, not only increases the scope of the transparency process by making possible the use of larger background screens, but improves the quality obtainable on transparency scenes of normal scope by yielding increased gradational scales and definition and minimizing the undesirable effects of graininess print imperfections and light-source fluctuation.

One comment, however, is now necessary in connection with further consideration of the transparency process problem. It must always be kept in mind that the composite picture resulting is the effect of a blend of two photographically contradictory elements. The foreground action is an original photograph, consisting as it does of images of action taking place directly before the composite camera. The background, on the other hand, is essentially a "dupe," consisting of re-photographed images of the scene projected upon the background screen.

The foreground portion naturally partakes of all the favorable qualities of definition, gradation, *etc.*, of any well photographed original. The background must be prevented from partaking of the equally familiar, unfavorable characteristics of a dupe, including impaired definition, gradation, and exposure values, as well as all other imperfections, such as scratches, digs, abrasions, development



(Courtesy of Paramount Pictures, Inc.)

FIG. 9. (*Upper.*) Front and left side of the transparency triple projection booth.

FIG. 10. (*Lower.*) Back of the booth, showing doors and service outlet connections.

fluctuation, *etc.* If the composite scene is to be convincing, the entire scene must maintain uniform photographic quality, visual perspective, and mechanical registration. This can only be obtained through coördinated perfection of a long chain of individually small details extending through every step from the exposing of the original background negative to the processing of the ultimate composite negative. Errors in any of these details are extremely likely to be cumulative and to build up to an overall error of such magnitude as to seriously jeopardize the illusion, or even spoil the shot.

It has already been pointed out that the dramatic and economic usefulness of the process is dependent upon the physical scope of the process being sufficient to allow the director freedom closely comparable to what he would enjoy if his company was working upon the actual location. It is of very little use to have a process that can put Gary Cooper in Paris, or Barbara Stanwyck in Wyoming, if such scenes must be restricted to close shots of one or two players, or if the movements of the actors must be restricted.

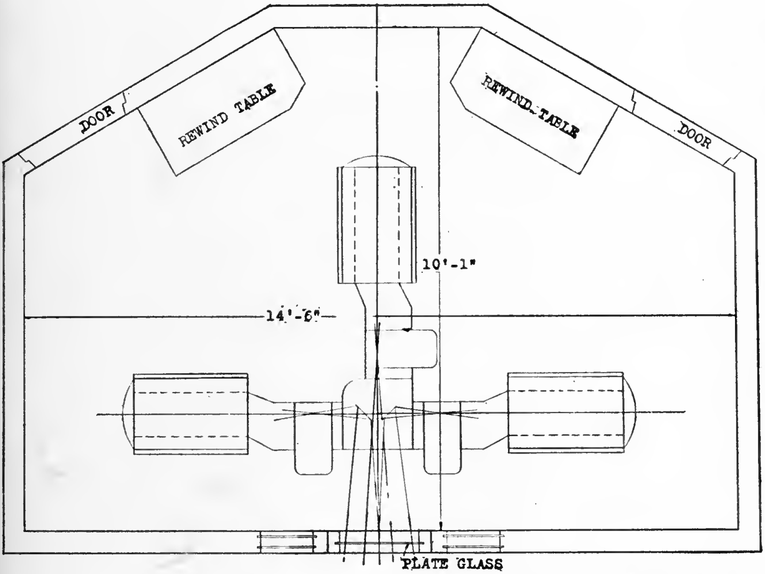
When the transparency process was first introduced, we were happy when we could use background screens measuring six or eight feet wide, and perhaps make scenes showing our foreground actors from head to ankles. As both the technic of the process and the equipment and materials for it improved, screens ten, twelve, and fourteen feet in width came into use. When, about a year ago, we found it possible to use screens twenty and twenty-four feet wide, we felt that we had achieved very nearly the ultimate. Today, with the development of the triple-head machine, we are able to use thirty-six foot screens for black-and-white work, and look forward confidently to the time when improved equipment now on the drafting-boards will enable us to use screens fifty feet or more in width!

A very important contributing factor in this advance of quality improvement has been the relatively recent introduction of the modern high-speed films. To the production cinematographer, the introduction of these films has meant primarily an opportunity to reduce illumination levels. To the transparency cinematographer, however, the same development meant quite a different application of this extra speed—one which means an even greater asset than using less illumination.

One of the greatest problems of transparency process camera-work has always been that of keeping the actors and the projected background both in adequate focus. In close shots, where screen and actor are close to each other, this is relatively simple, even when using the lens at or near maximum aperture. But as screen-size and the physical scope of transparency shots increase, this problem becomes more serious, as the physical separation between actor and screen increases.

The greatest benefit derived from the new films, from the transparency standpoint, is therefore not as might be expected, simply the added speed, making it possible to utilize the lower illumination-levels that would follow; but instead, profiting by the added speed to a greater measure by stopping down the lens of the composite picture, thereby obtaining considerable increased depth of focus.

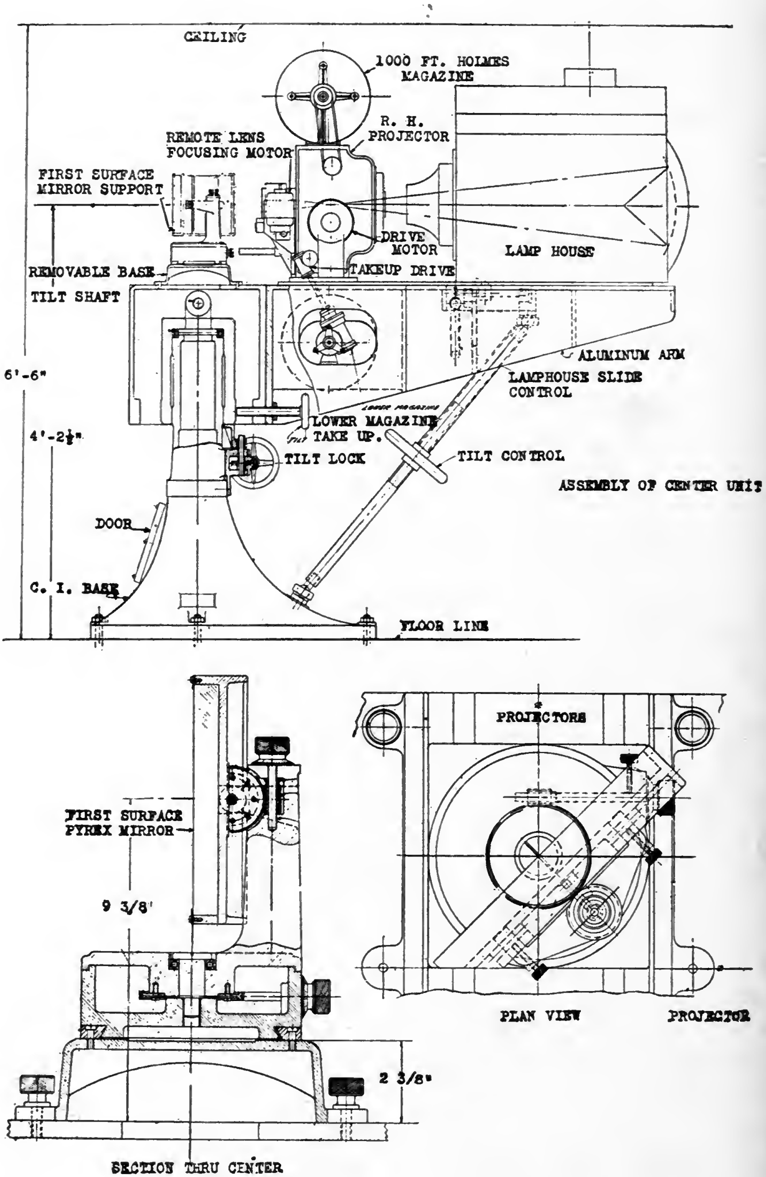
How greatly this factor helps us is best brought out by referring to some of the transparency scenes currently being made for Paramount's production *Geronimo.* In some of these scenes, the set represents the encampment of an army detachment being attacked by Geronimo's Apaches. In the long shots, dual projectors and screens are used, the composite camera and background projectors are at the extreme opposite ends of the big stage—a separation of 195 feet. The screens are at times as much as 70 feet or more distance from the camera, while the distance from the actor nearest the camera is not more than 12 to 18 feet.



(Courtesy of Paramount Pictures, Inc.)

FIG. 11. Layout of projection booth.

Obviously, if the shot is to be convincing the actors as well as the intermediate set and the background screen's image must all be in adequately sharp focus. In addition, during some of these scenes,



(Courtesy of Paramount Pictures, Inc.)

FIG. 12. Details of equipment.

40 to 50 horses and their riders, representing the attacking Indians or the rescuing cavalry, must ride through the set at various points, sometimes quite close to the screen, while important foreground action is taking place.

It is clearly an optical impossibility for any lens of normal focal length, used at the maximum aperture of $f/2.3$; and focused on the most important foreground or intermediate plane action, or even with a split focus, to carry adequate depth of focus to cover the overall range, which is virtually from 12 to 18 feet to four or five times this foreground distance. However, with the present fast negative film, which permits stopping the lens down to a $f/3.5$, or a sometimes smaller aperture, such an achievement becomes possible. It is not too much to say that without the aid of these new modern fast films, the dual screen or other type large-scale transparency scenes could not be nearly so well accomplished.

Under modern present-day economic conditions, it is likely that many productions would not, or could not, be made for any cost even remotely permitting hope of a profit, were it not for the advancements made in film manufacture, combined with the use of the advanced scope of the transparency and other special processes.

In conclusion, the writer wishes to stress one vital factor concerning the employment of the transparency method. In its most accustomed applications, it is not intended nor used as a "trick" for the purpose to deceive the audience, but rather to make possible the photographing of scenes which, if filmed by conventional methods, would prove too difficult, too dangerous, or too costly to be considered practical. As such, the transparency process is not a miraculous "cure-all," but, intelligently and properly used, it can and does add immeasurably to the scope and efficiency of motion picture production.

Regarding the future general use of triple-projection equipment, while its operation requires longer time and a more carefully set up organization, the resultant increased quality and scope amply justify its use. It is the author's opinion that the system makes a definite step forward.

There will always be the problem of how to accomplish the many difficult and apparently impossible things that are written into scripts. However, our present-day process technicians are outstanding in their resourcefulness and versatility. They have the potential ability and capacity to be one of the industry's greatest economic assets of the future. Their aptitude and skill in combining the real with the fictitious, maintaining precise and critical realism, are amazing, and are limited only by the capacity of their equipment to perfectly accomplish their ideas. Their understanding and appreciation of the dramatic, artistic, and economic values in combining a photographic process embodying mechanical, illuminating, and chemical engineering, place the transparency and special process branches of the cinematographic profession in an unparalleled position.

With the advent of new and improved equipment, the physical scope and photographic effectiveness of the transparency process will definitely make further notable advances. With these advances, as with the present status of the process, the key to success, as already stated, is and always will be the technical expertness and artistic skill of the individuals utilizing and operating it. Such adroit performances have, in a very few years, brought the transparencies to their present excellence; while with improved equipment, allowing greater scope for the artistic imagination and better results technically and mechanically, the process seems bound to become a yet more useful instrument for the improvement of modern production.

METHODS OF USING AND COÖRDINATING PHOTOELECTRIC EXPOSURE-METERS AT THE 20TH CENTURY-FOX STUDIO*

D. B. CLARK**

Summary.—*Consistency in negative printing values is one of the most desirable factors in modern cinematography. Photoelectric light-measuring devices help the cinematographer maintain such consistency to a far greater degree than is possible otherwise.*

Several requirements in these devices must be recognized, among which are freedom from error and photocell fatigue, changes in humidity or temperature, and the like, and good uniformity.

While these requirements are not wholly met in existing meters, it has been found possible to use such meters to advantage. Coördination is effected by use of a special, portable testing unit of the photometer type. Further developments should include complete acceptance of strict time-and-temperature methods of negative development and some form of automatic, photoelectric-cell-controlled print-timing. This would remove all variables from the processing problem, and leave the responsibility for results solely in the hands of the cinematographer.

Probably the most desirable single quality in modern studio cinematography is consistency in negative printing values; in other words, the ability to maintain throughout all the scenes of a production a uniformly correct exposure level, so that no corrective modifications in negative development or printing need be made.

Such consistency would be desirable from almost every possible viewpoint. From the purely theoretical viewpoint of the engineer, it has long been axiomatic that a completely accurate reproduction of a scene is possible only when every factor from negative exposure to the printing of the positive maintains a normal relationship to every other factor in the chain, and that alteration of any of these factors may be offset, but can not be completely corrected, by modification of the other factors involved.

From the viewpoint of the practical cameraman, maintaining this sequence of normal relations unbroken would mean positive

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** Twentieth Century-Fox Studio, Hollywood, Calif.

assurance that the photographic effects obtained on the set would be preserved in the positive print. In other words, the cameraman would be, in truth, master of the results obtained on the screen, free from the fear that misunderstandings in the studio laboratory, or carelessness in the release-print laboratory might, as has so often been the case, distort his photography.

From the viewpoint of the studio or laboratory operations executive, labor, time, and money could be saved by reducing laboratory operations to a simplified norm.

American cinematographers have deservedly been acclaimed for their remarkable consistency in this respect. But this consistency, great as it is, is relative, rather than absolute, due to the inevitable element of human fallibility. Visual fatigue and any of several other factors introduce minor variations from day to day and from one set-up to the next. These variations are well within the laboratory's corrective range, but nevertheless they represent a departure from the ideal.

For this reason modern photoelectric light-measuring devices can be regarded as one of the most potentially valuable developments of recent years, substituting, as they do, an untiringly accurate electric eye for the customary visual judgment.

However, to make practical use of such devices, it is not enough that the device merely exist. Methods of applying the device to the practical problems of the cinematographer must be worked out, and methods of coördinating the meters used in a studio with that studio's processing methods and with each other must be evolved. This we believe we have accomplished, so far as is possible with existing commercial meters, at the 20th Century-Fox Studio.

Before describing these methods, however, it may be well to clarify the relationship existing between photoelectric light-measuring instruments and studio cinematographic methods. While for convenience these devices are generally referred to as "exposure meters," such is by no means their purpose when applied to studio cinematography. On interior scenes especially, exposure is a constant factor, while illumination is varied to obtain the desired exposure level. In other words, instead of following the practice general elsewhere, and modifying the lens aperture to suit the illumination available, the studio cinematographer keeps his lens opening almost invariably constant, and modifies his illumination to suit the lens aperture chosen. A basic reason for this is that the scenes must be intercut, and the varying optical quality given by constantly varied apertures would in most cases tend to prevent the scenes from maintaining consistent visual quality.

In the same way, the professional cinematographer finds little or no gain from a light-measuring instrument that gives him merely an overall reading of the *average* illumination of a scene. Many papers presented at previous Conventions of this Society have stressed the fact that no two cinematographers employ the same lighting levels or the same lighting technic. The technical and artistic stock-in-trade of the studio cinematographer is his method of balancing lighting, exactly as the brush-work of a Rembrandt or a Corot is, so to speak, the painter's individual trade-mark. It is entirely possible that two cinematographers might on a given scene use the same overall average of illumination, yet because of their different methods of balancing the light obtain startlingly different results on the screen.

The basis of modern lighting technic is the so-called system of "key lighting." In this, the principal illumination of the scene, usually that falling on the face of the most dramatically important player, is considered the key. All other gradations of lighting, both in stronger highlights and in shadows, on players and setting, are balanced to this key light. If this key light is correct, the balancing of the scene, and with it, the overall exposure value, will be correct. If it is incorrect, the entire scene can be thrown off balance.

Therefore we at the 20th Century-Fox Studio, in common with the majority of meter-using cinematographers, have found it best to use the meter simply to measure this key light. This method has proved to be the most economical of time and effort. In addition, it leaves the cinematographer free to balance his lighting as he sees fit, thus completely preserving his artistic originality. Yet it gives him the benefit of a starting point that he knows to be accurate.

But to gain these benefits, both the method of using the meter and the meter itself must be accurate, with all possible variables, both personal and mechanical, minimized or if possible eliminated. Under studio conditions, using a meter for reading the light reflected from the subject seems susceptible to considerable error. It is too easy for the meter-reading to be made inaccurate by the direct rays of some one of the many supplementary lighting units behind, above, or to one side of the subject reaching the cell of the meter. In some instances, too, the meter may accidentally be reading in its own shadow, again introducing an error. Further, the acceptance angle of a reflection type meter is seldom sharply defined, and when such a meter is used under production conditions, it can introduce considerable error. Therefore, we have standardized on direct-reading meters.

But this is only the first step. Such meters must be inherently accurate, and some means must be provided for checking that accuracy at frequent intervals, and for coördinating the meters with the methods of the laboratory processing the film.

Before standardizing on any type of meter, we made tests of a number of samples of meters of various makes over a considerable period. The tests were made on a simple optical bench, in which the meters were always tested at a measured separation from a light-source operated at constant intensity. The factors of photocell fatigue, effects of changing weather-conditions (including humidity) and the like, were carefully noted. Variations between individual meters of the same manufacture were particularly observed.

While it would be far too optimistic to infer that the ultimate in meter consistency has yet been attained, a commercial type sufficiently accurate for our use was found. While still subject to error—especially in cases of changes in humidity—the type selected proved the most nearly consistent of all those tested, and accordingly has been accepted as the studio's standard equipment. Meters have been provided by the studio for the use of all the staff Directors of Photography (First Cameramen). This is believed to be the first instance of a studio's providing such instruments for its staff.

It should be emphasized here that while the meters have been provided for all the staff, no attempt is made or will be made to force their use. This decision is left strictly to each individual. The record of those who have accepted the meters and used them correctly, however, is such that virtually all the staff have of their own volition accepted the aid of these instruments.

While the optical-bench testing set-up used in these initial tests was technically accurate, it lacked the simplicity and portability desirable for every-day use. Therefore Grover Laube, of the Studio's precision machine shop, and the writer developed a convenient test-box which, if necessary, can be easily carried to any set or location where an immediate check of a meter is needed.

This device consists of a small wooden case which houses a battery-operated automobile headlight bulb, which is used as a light-source. Between the light-source and its power supply are interposed an ammeter and a rheostat. The bulb is fixed rigidly in one position, and has a long useful life; and by applying a known current to it, as indicated by the ammeter, its light-flux will be constant.

At one end of the test-box is an aperture, faced with a suitable ground-glass diffuser, to which the meter being tested is applied. A suitable shield fits closely around the meter-casing and excludes all external light.

In testing a meter, the instrument is applied to the aperture of the test-box and two readings are taken: first a zero reading, with the testing light off; second, the testing light is turned on and brought to its predetermined normal intensity by manipulating the rheostat. At this intensity the meter being tested should give a predetermined reading.

A wider range of test readings would easily be possible; but in view of the methods of using the meter in the studio, such does not at present seem necessary.

As has been explained, we have found it desirable to measure only the key light, thereafter leaving the cinematographer free to balance the rest of his lighting visually, as he may see fit. Superintendent Leshing, in charge of the studio's laboratory, has found—as every laboratory man has—that regardless of lighting balance or of the effects sought, under the conditions applying at any given laboratory, the most faithful result will be obtained by having a negative that will print on a given normal printer-light setting. Precisely which of the twenty-two printer lights is available for this normal may vary considerably among different laboratories, as it is affected by the processing methods and equipment used at the plants, including such variables as negative developing solutions and methods, positive development, and in some cases not only the types of printers used but also the modifications made in these printers to coördinate them with the plant's standards. Since any concrete figure I might give would apply only to the 20th Century-Fox Studio's laboratory, suffice it to say that we prefer a negative that will print very closely in the middle of the printing scale.

Thus if our cinematographers know that their key light is pinned rigidly to a value that will allow negative printing normally on this most favorable printer-light, they can balance the rest of the lighting to suit the effect they want, confident that both negative and positive will receive strictly normal—and favorable—treatment in processing, and that the result on the screen will be as desired.

Therefore all that is necessary is to determine a point on the meter's primary scale that will, when the meter is used for direct reading on the key light, correspond to an exposure-level that will give this optimum printing density. As has been already pointed out, while it would be perfectly possible to take additional readings of the shadows, background, and so on, it is not necessary due to the skill with which a capable studio cinematographer can balance lighting visually. On the other hand, the meter's guidance in assuring a constantly normal starting point in the key light is invaluable.

The sunshade fitted to the type of meters we use has proved a valuable feature under studio conditions, as it excludes unwanted rays from lamps other than those producing the key light. The slotted cover of this hood, intended by the manufacturer for reducing high intensities to fractions that, while still accurately measurable, will not overload the photocell, is not so useful to us, as it makes the meter too strongly directional for our purpose. Therefore we fit a metal plate having a small rectangular aperture directly over the meter's inner opening. This cuts down the illumination activating the cell in the same proportion, but at the same time does not exaggerate the directional characteristics.

In practice, the meter is used in a position close beside the face of the subject, and a direct reading taken on the key light. If this is found to have the correct value for normal printing, all is well. If not, the key light is raised or lowered to give the desired reading, and the balance of the lighting modified accordingly by the usual visual methods.

As a general rule, the meter-reading is most frequently taken only when the lighting set-up is virtually completed, since experience enables most cinematographers to read lighting visually with great accuracy, and the meter need be used only as a check.

It may well be asked, "Does this use of photoelectric meters improve the consistency of a studio's cinematography?" The answer in our case is a definite affirmative.

Before the system was adopted, an extensive series of tests was made. On two successive days, a cameraman was sent to film identical scenes. His only instructions were to make long-shots, medium-shots, and close-ups, always keeping the meter-reading of the key light on the predetermined figure. The third day he was sent to make similar tests on a different set, of different coloring and design, with different actors and different costumes. The fourth day this test was repeated. The fifth day he was assigned to make tests of exterior night-effect scenes. To summarize briefly, every take printed on the desired printer-light setting, and showed uniformly satisfactory negative values.

Since then the system has been used by an increasing number of the studio's camera staff. Where previously virtually the entire range of printer-light adjustments had to be used daily in making rush prints of the various scenes made by the various men, today a maximum range of three to four printer-lights will accommodate virtually all the variations encountered on normal interior scenes.

Here, for example, is the laboratory's printing record for the last nine productions completed at the studio, expressed in terms of overall printing averages for all the footage printed as daily prints: The first three printed on an average of 12+; the next three averaged on light 14; the next two, both of which included more than the ordinary number of special effect-lightings, averaged on light 15; the ninth, a melodrama with an uncommon proportion of abnormal effect-lightings and night exteriors, averaged on light 17. The average printer-light setting for the nine productions was 13.8. In other words, these nine productions could virtually have been printed on one printer setting—say, light 14—without serious harm.

This average must be qualified yet further. The averages quoted above are those obtained in making the daily or rush prints—the first prints made of the scenes, for use in cutting and in checking the acceptibility of action, *etc.* Such prints correspond roughly to a portrait photographer's proofs; they are not the finished product. Almost inevitably the timing of at least some of the rush-print scenes proves to be inaccurate, especially in the case of related scenes or sequences made some days or weeks apart, and printed without specific consideration of the contiguous scenes the cinematographer is striving to match. When the master print and the release prints are made, these inaccuracies are equalized, and it is certain that the averages for the release prints of the same nine productions would fall within even closer limits.

The assistance of the meters can be given much credit for the ease with which our cinematographers have accomplished the recent transition from yesterday's slower films to today's ultra-fast emulsions. Before the film was put into general use, Mr. Leshing and the writer made tests to determine the best photographic and laboratory treatment for the new emulsions. In the course of these tests, the meter-readings corresponding to the best photographic values were determined. Thus when the men were given the new film for production use, they were also furnished these data. With this positive information as to the normal key light requirements of the new film, their knowledge of lighting balances and their trained visual judgment enabled them to make the transition with perfect assurance and success.

The same general technic of using the meter can be applied with equal benefit to the making of exterior scenes. However, some modifications are necessary due to the changed conditions. No practical meter commercially available in this country can be used for taking a direct reading on the sun, which is of course the actual key light on an exterior scene. Further, while the cinematographer can exercise some degree of control over exterior lighting, he can do so only over a relatively restricted area, usually in the foreground of his shot. The background can not be controlled to any great extent.

For this reason, in making exterior scenes we consider this virtually uncontrollable background illumination as the key light, and take a *reflection* reading on this, positioning the meter to exclude the immediate foreground. Using this as the known and relatively fixed factor in our problem, we can manipulate the foreground lighting—especially that upon the players—to give us balanced exposure values.

At the 20th Century-Fox Studio we are singularly fortunate in our attempts to apply this system. It is a real asset that the studio's laboratory adheres to a strict time-and-temperature system of negative development. With such a system we know that, granted consistently correct exposure values, which we are obtaining with the meters, and consistent negative development, gained from the time-and-temperature methods followed, we should be able to count on consistent printing values for our negatives.

It is to be admitted that there still remain some variables that all of us would like to see overcome. There will, for instance, probably always be some slight variation in the way individual cameramen will read their meters—a few inches' difference in the position at which the reading is taken can mean a difference of two or three printer-light values in the resulting reading. There are also minor but cumulative variations possible in negative processing, as, for instance, in solution strength, temperature, *etc.*, which despite all reasonable precautions will vary slightly from day to day. But the worst variations have been taken out of photographing and negative processing.

The same is true of the printing and development of the positive film. The greatest remaining variable is in the "timing" or determination of printer-light settings for positive print-making. This is done visually, and is subject to lively variations which could very advantageously be eliminated.

The first of these is the element of visual fatigue on the part of the print timer, so familiar it need hardly be dwelt upon here; second is visual misjudgment. Visual print-timing is almost always based upon estimation of the printing value of face-textures of the principal players. This is subject to considerable error at times, for contrast between face areas and adjacent densities may be highly deceptive, even to the trained eye.

A very simple illustration will prove this. Consider three pairs of concentric circles; let the center circle in each set be of an identical pure white. Let the outer circles be respectively black, light gray, and dark gray. It will be found that in every case the white circle surrounded by the darkest black ring will look whitest, while the one surrounded by a ring of light gray will seem a dirtier white. This same optical illusion affects the visual judging of small areas, such as faces, in timing motion picture prints.

Third, and often the most irritating, is the element of misunderstanding between the laboratory and the cameraman as to what is sought in the scene. Lacking specific instructions to the contrary, the timer may jump to the conclusion that the cameraman is seeking an effect entirely different from his real aim. To cite an extreme instance, night-effects have sometimes been known to be printed up as day-effect shots. More common is the less obvious error of printing a scene too light or too dark. This often passes unnoticed in its true aspect, and results instead in an impression that the man at the camera was at fault in lighting or exposure.

Since the general acceptance of meters by our studio's cinematographers, the writer has frequently noticed such instances of misinterpretation. Viewing the "dailies," the comment would be that such-and-such a scene or sequence was too dark or too light. In almost every instance since the use of meters has been general, investigation has shown that the camera crew, guided by the meter, lighted the scene for normal printing; but misjudgment in print-timing had caused the scene to be printed incorrectly. A reprint, made at the normal printer setting, has almost invariably shown that the cameraman, backed by his meter, was right, and the visual judgment of the timer was wrong.

Is it not logical to expect, therefore, that ultimately some satisfactory method of applying the photoelectric cell to print-timing can be introduced? Certain types of 16-mm reversal film are already processed with an automatic control of this type which adjusts the flashing or printing exposure to the overall transmission value of the developed negative image. It is possible that this precise method might not prove satisfactory for professional use, due to inability to make the allowances necessary for special light-effect scenes. But could it not be possible at least to develop a technic of reading negative face-values by means of a semi-automatic photoelectric densitometer that would eliminate the element of human fallibility, and give a reading, not in densities, but directly in terms of printer-light settings?

The practical results of such a development, when coupled with consistent time-and-temperature negative processing and the consistent photographic results obtainable with the use of coördinated meters, should be of worth-while practical value. Laboratory operations would be simplified, and greater consistency and economy obtained. The cinematographer would have an absolute normal to which to peg his lighting. Granted such a standard, free from variation, he would be free to exercise his creative individuality without fear that subsequent variations or misunderstandings in the laboratory would possibly nullify his efforts.

Admittedly this would place the responsibility for results exclusively on the shoulders of the cinematographer. That, however, is where it belongs—and where he wants it. The guidance of the meter would keep him within the mechanical tolerances set by the limitations of emulsion and processing. The rest would be solely up to the man behind the camera, to his judgment of lighting balance, and to his artistic skill.

At present, we have made commendable progress toward this goal with the increasing acceptance of meters, and, I believe, with the development of the methods here outlined of testing and coördinating meters at the 20th Century-Fox Studio. It is a demonstrable fact that the confidence of our cinematographers and the consistency of the results they obtain has been improved by adding to their acknowledged skill the guidance and mechanical accuracy of the meter.

In closing, I would like again to stress the fact that while today's meters are good, they do not by any means represent perfection in meters for studio use. In making this statement I do not overlook the fact that the two types of photocell meters almost exclusively used by monochrome cameramen were designed primarily for amateur use, and that other models, designed more primarily for laboratory use, offer certain technical refinements impossible in these smaller, lower-priced meters. However, there are certain requirements that a meter for use under modern conditions in a motion picture studio should fulfill; some of them, as will be seen, rule out most of these advanced laboratory-type instruments. These requirements include:

(*1*) *Dependability.*—The ability to withstand at least moderately rough usage.

(*2*) *Uniformity.*—Consistent accuracy, sufficient so that all the meters used by a studio can be expected to give, under comparable conditions, readings sufficiently comparable as to remain within a minimum corrective range in the printing process.

(*3*) *Freedom from Variations Caused by Change in Humidity, Temperature, Etc.*—This at present is not always the case. Tests of our own meters showed that all of them read several printer-lights below normal under conditions of low humidity, and above normal when humidity is high. In my own previous experience, using a meter on location in the South Seas, where temperature and humidity were both high, the meter read abnormally high. Members of the Byrd Antarctic Expeditions have informed me that the many meters taken to Little America by both professional and amateur photographers in the party all gave uselessly low readings in the antarctic.

(*4*) *Wider Sensitivity.*—This is especially needful in the case of meters used in connection with projected background cinematography. In this process, the illumination transmitted through the background screen is necessarily the factor to which all foreground lighting must be keyed. The meter-reading upon this must inevitably be taken with the photocell directed upon the screen, from the same side as the camera. In the tests we have so far made we have not as yet succeeded in finding a meter capable of giving us such a reading, despite the fact that at the same time the foreground camera was indisputably receiving sufficient light through the screen to make a satisfactory exposure. The use of meters on these scenes would be of especial value.

(*5*) *Compactness.*—For studio use, a meter must be small, convenient, and inconspicuous, for several reasons. A small, handy meter that, like the ones now in use, can be carried easily in the pocket, will be used much more regularly than any larger device. In addition, the disturbance necessarily incident to bringing a large meter into the set and using it tends to upset even the most even-tempered of players when trying to concentrate on action and dialog. It must be confessed, too, that some directors—men of sufficient reputation and experience to know better—have been known to grow sarcastic when their cameramen employ such aids, though they themselves take full advantage of every possible aid to their own work, such as using public address systems whenever there are more than four or five players in a scene. Under such circumstances, the small, inconspicuous meter is the only one likely to be used.

Another important improvement would be, in the case of reflection-type meters, an instrument with an acceptance angle more closely coördinated with that of the camera. Many such meters have an angle as great as 60 degrees, while the two most commonly used objectives, the 40-mm and the 50-mm, have horizontal angles of 30 and 25 degrees, respectively. Some form of finder would be a desirable addition, and one which should be even more useful in the wider amateur field, as well.

In general, however, it must emphatically be stated that during the past year, especially, the industry has made great progress in adapting the electric eye of the meter to studio use. It has been most spectacular in the way it has facilitated the change from conventional to fast films. It has increased the consistency of every cameraman's work, and freed him from the ever-present fear that physical or visual fatigue might be distorting his judgment of lighting. It is relieving the First Cinematographer of the burden of routine work and leaving him more free to exert his creative artistry. It is therefore logical to expect that as meters continue to gain in acceptance, individuals become more accustomed to their use, and as improved and more dependable instruments are developed, we should witness magnificent advances in both the art and the science of cinematography.

DISCUSSION

DR. MILLER: The subject of accurate control of exposure and processing of motion picture negative is one that has received a great deal of attention within recent years. Accurate processing control has been demanded since the introduction of sound recording on film, and the general adoption of sensitometric control of processing has served greatly to improve both picture quality and uniformity. It has only been within the last few years, however, that the cinematographer has been afforded an instrumental means of determining proper exposure, and it seems inevitable that here again the substitution of instrumental control for human judgment will result in further improvement in picture quality.

Mr. Clark, what degree of variation in sensitivity has been noted among the various meters employed? Is the percentage variation in sensitivity of rather high value or are the meters reasonably uniform?

MR. CLARK: The meters produced by a given company, for instance, may vary as much as three or four printer points in reading and when tested alongside each other. On exteriors I have known five meters to vary as much as one hundred per cent in exposure.

MR. SKINNER: I use incident light on both interiors and exteriors. The same factor can then be followed all the way through, as the meters are sensitive enough. It is a matter of reducing their sensitivity so they can be used for exterior light as well.

MR. CLARK: Measuring reflected light on exteriors is very easy, so we have never tried reducing the sensitivity for measuring direct sunlight.

MR. HYNDMAN: Present available photoelectric meters for measuring light-intensity have photocell reception cone angles of approximately 50 to 60 degrees, and consequently it is practically impossible, except at very close range, to make a light-intensity measurement of the reflected light from a definite small area of the subject. In other words, to measure the light reflected from a finite, small area necessitates placing the meter within a few inches of the subject, otherwise a large area is included in the measurement. On a studio set it is possible to control the lighting by photoelectric measurement of the intensities reflected from various areas of the subject, whereas it is often difficult to control daylight or sunlight falling on a subject or series of subjects out of doors. The problem of the proper use of photoelectric meters on studio sets and out of doors is quite different, but with intelligent application present meters can be used satisfactorily in both circumstances. To measure a small finite area on a given subject with a photoelectric meter at a distance of several feet would necessitate using a meter with a cone angle entrance pupil to the cell of approximately 3 to 5 degrees, but unfortunately available photoelectric cells do not have sufficient sensitivity to make reflected-light measurements in these circumstances with normal lighting conditions. It is therefore impossible with the present type of photoelectric meter to measure a small area on a given subject from the position of the camera which may be several feet from the object of interest. Furthermore, it appears that a meter that would accomplish this purpose will not be available until the sensitivity of the photocell is materially increased.

MR. PALMER: With regard to measuring incident light in color photography, the cells commonly used in photoelectric meters are not equally sensitive to all colors. It is possible to get rather erroneous readings on subjects of different color. When using a meter such as Mr. Clark suggested in connection with black-and-white photography, we rule out the question of non-uniform sensitivity of the cell to color. My experience in taking readings for color exposures has shown that the results are more reliable by incident light than by light reflected from the subject.

MR. SKINNER: It appears that Mr. Clark described two different methods in his paper; has one any particular advantage over the other?

MR. CLARK: We have had satisfactory results on exteriors only by measuring reflected light. We do not get satisfactory results with reflected light on interiors although we have instruments that will read reflected light. The meters are not satisfactory.

A SOUND-TRACK PROJECTION MICROSCOPE*

GERALD M. BEST**

Summary.—*Practically all precision sound-track measurements are made with a microscope, which has been the accepted standard in the industry. This method is necessarily slow, and in an effort to speed up track position, printer alignment, and other technical measurements, a projection microscope has been developed. Using equipment available at a reasonable cost, a projection microscope which can be used by anyone in the sound and laboratory departments has been developed and is herein described.*

One of the most important advantages of the instrument is its ability to detect printing machine defects, and by its use the quality of sound printing has been greatly improved.

Since sound was first recorded on film, the instrument by which precision adjustments of recording machines, printers, and sound reproducers are made has been the microscope. This instrument will be found in most of the sound department engineering staff offices and in the sound-track control rooms of our laboratories.

The microscope generally used is 100 power, with a 50-power objective additionally provided for non-precision work. By means of a very accurate jig, and a scale calibrated in 0.001-inch divisions in the microscope eyepiece, the negative or print to be measured is mounted in the jig and moved back and forth until the section of track that is to be inspected is within the field of vision. With the 100-power objective, the actual field of vision is a circle about 50 mils in diameter, so that the entire sound-track can not be viewed at one time. The 50-power objective will permit viewing the entire track of 100 mils, but the scale becomes so difficult to read as to preclude accurate measurements.

To overcome this handicap and provide an instrument that would not require a trained eye to read the results, the writer began experimenting with various types of optical projectors in an effort to find a combination that would replace the microscope in this type of work.

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 18, 1939.

** Warner Bros.-First National Studios, Burbank, Calif.

We are all familiar with the method frequently used of projecting sound-track in a standard picture projector, to watch overloads or printer weave; but this method has the handicap that the film passes intermittently through the aperture at the rate of 24 frames per second and can not be stopped for examination and measurement of a small section.

However, as the standard pressure-plate, shoes, and guides of a picture projector seemed to be the best method of supporting the film, it was decided to use this method of film suspension as a nucleus around a suitable optical system and source of light. The finished projection microscope is shown in the accompanying illustration.

The source of light was obtained by modifying a Spencer Type *C* Delineascope, a projector intended to show single frames of motion picture film on a screen about 2 × 3 feet in size. This equipment consists of a 500-watt lamp in a compact housing, with condensing lenses of special heat-reducing glass so as to concentrate sufficient light while removing most of the heat from it without water-cooling or air-blast. The film-slide attachment and optical system of the Delineascope is not suitable for sound-track, so it was not used. In its place, the gate and aperture plate of a Simplex projector were mounted on a heavy base, the aperture being masked down to a slot 0.20 inch wide and 4 sprocket-holes long, with a slot cut out to show the extreme edge of the film. Th lens used is a $1^1/_2$-inch *f*/1.5 objective, which, with a throw of $14^1/_2$ feet, will produce an image equivalent to one frame of sound-track magnified 120 times.

By setting the aperture plate so that the sound-track center is in the center of the light-beam, sufficient illumination is obtained to permit very accurate measurements of sound-track position, if the room is well darkened. Naturally a superbrilliant image can not be projected to such large dimensions with a 500-watt source, but this amount of light is the maximum permissible without fire hazard. Additional protection against fire was provided by placing a quiet, low-speed ventilating fan in an extended stack on top of the lamp house, and by building a protecting metal screen around the lamp house to keep the film from touching the hot metal parts. With this set-up, film can remain motionless for 10 minutes in the light-beam without overheating or curling.

A pair of rewinds are mounted above and below the projector, which is, in turn, mounted on a platform bracketed to the wall, thus permitting a long reel of film to be run and stopped at various points wherever inspection is required. The concave mirror provided in the lamp house produced a double image when high-frequency recordings were projected, so that it was necessary to front-silver the mirror to eliminate this effect.

For a screen, the wall on the opposite side of the room was coated with a flat, white paint, and a scale permanently painted in the center of the screen, as shown in Fig. 1. This scale marks the center-line of the track, the position of the bias lines in bilateral variable-width recording, the limits of 100 per cent modulation, and, at the edge of the screen (not shown in Fig. 1) is a base-line representing the guided edge of the film. The objective lens is mounted on a micrometer base, with an adjusting worm to move the lens back and forth until the guided edge of the film coincides accurately with the base-line on the screen. Using the scale mentioned above, track position, bias width, percentage modulation, and all other dimensions can be accurately measured. In addition to the horizontal scale, a vertical scale of frequency calibration is included, this scale permitting the identification of the speech or music frequencies that may be causing trouble. Often an overload is caused by a single frequency at periodic intervals,

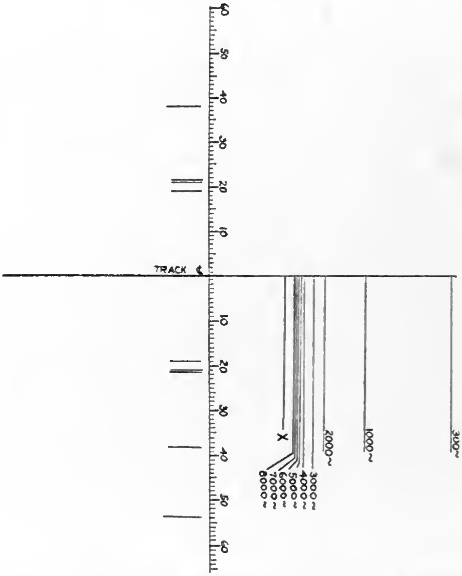

FIG. 1. Scale for checking sound-track with projection microscope.

and by this scale the frequency can be determined within a reasonable range by setting the tip of one of the striations on the base-line *X* and observing where the next striation tip falls on the scale.

Another use for the projector is in measuring the opening and closing times of noise-reduction shutters, negatives of shutter opening and closing tests being projected on a special scale temporarily superimposed over the regular scale.

One of the principal advantages of a projection microscope is that a number of persons can view the sound-track at the same time. Frequent use has been made of the projector to demonstrate to groups during technical discussions, and mixers, engineers, recording machine maintenance men, and laboratory supervisors are expected to use the projector whenever needed. But by far the greatest use to which the projector is applied is checking the printing machines in the laboratory. Quite by accident it was discovered that if a 9000-cycle frequency print were moved past the aperture at a rate of about 2 frames per second, any printer slippage or lack of contact would show up on the screen in the form of "ghosts" or dark patches. A printer that has perfect contact and no slippage will produce a 9000-cycle print which when run at 2 frames per second on the projection microscope will produce a uniform blurred image that does not vary. A poor print will flicker in much the same manner as a picture pro-

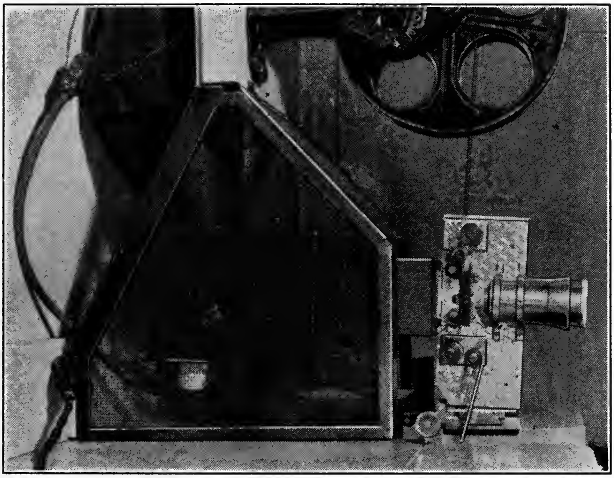

FIG. 2. Projection microscope.

jector with a light-source of alternating-current carbon arc, with the shutter not properly timed.

It is now the custom at Warner Bros. Studios to project daily a sample 9000-cycle print from every printer to be used during the day, thus reducing printer troubles to a minimum due to the better supervision obtained. The RKO parallel-line test, which consists of a series of 1-mil exposures approximately 2 mils apart across the full width of the track, is also useful when used in conjunction with the 9000-cycle contact test, the same ghosts appearing in this track as are observed on a frequency print. Too rapid motion of the film eliminates this effect, so that a little practice will soon tell the operator at what speed to propel the film to get the best results. Printer weave, the presence of 96-cycle modulation due to poor contact around the sprocket-holes, and poor track illumination in the printer are all easily detected, and several of these projectors have been built by foreign laboratory heads who have seen it, with notable improvement in their product after being put to use.

DISCUSSION

DR. FRAYNE: Can you tell us anything about this printer?

MR. BEST: The printer used for all the tests shown in this demonstration utilizes the RCA non-slip principle, and there is nothing about it that has not been adequately covered in papers previously presented to the Society. The demonstrations of bad printer slippage were made on an old sprocket-type printer which has been in service for seventeen years and is of a type no longer generally used for high-quality sound printing. The sample of 96-cycle noise caused by poor printing was produced by disturbing the adjustment of the drum roller so as to cause contraction of the film around the sprocket-holes. Improper adjustment of this roller produces 96-cycle difficulties found in practice, and it is very easy to put the roller out of adjustment deliberately.

MR. KELLOGG: Were you able to find any way of changing the 96-cycle modulation? Do you think the burrs on the sprocket-holes actually push the film apart, or does it seem that the film bends into a polygon rather than a circular arc?

MR. BEST: I think that is due entirely to the bending at the sprocket-holes due to weakening one edge of the film. The entire film from the dividing line between the sound-track and the picture to the edge of the film is not supported by a roller; it is free, and contact between the negative and positive depends entirely upon the excellence of contact through the picture area. By proper design of the drum, contact roller, and guides, and accurate adjustments of all three elements, the difficulty from 96 cycles can be reduced to such a small amount that it can not be detected. If the contact is poor at the extreme edge of the film, the effect may be apparent for ten or fifteen mils into the sound-track, in which case the level of the 96-cycle note may be so far down with respect to the signal that it is not audible in normal theater reproduction.

FURTHER IMPROVEMENTS IN LIGHT-WEIGHT RECORD REPRODUCERS, AND THEORETICAL CONSIDERATIONS ENTERING INTO THEIR DESIGN *

A. L. WILLIAMS**

Summary.—*Direct recording is becoming commercially more and more important. Acetate blanks are used for high-quality recordings, but these materials are essentially softer than pressed records, and therefore make necessary new considerations in the design of a high-quality pick-up to be used with them.*

It is shown that a dynamic stylus pressure of approximately 25 grams is the maximum force that acetate can tolerate without permanent deformation of the modulated grooves, even when due consideration is given to the proper matching of stiffness and inertia of the vibratory system of the pick-up.

A simple formula is given for the most suitable condition of the matching of inertia and stiffness for a complex wave-form. Other factors that interfere with the construction of a light pick-up, such as uneven record and turntable surfaces, are explained, and suggestions are made for the reduction of these effects.

The advantages of "constant amplitude" as a method of recording and reproduction are shown, and a constant amplitude system is demonstrated.

The phonograph is the earliest development in the art of sound recording. Since Edison built the first machine and visualized its great commercial value, the method of mechanical recording has been steadily expanding. As early as the last century, the phonograph has commanded public recognition. We find an interesting quotation from *Scientific American* of fifty years ago, which refers to this subject:

"The improvements in the phonograph have now been carried to such a degree of perfection that the instrument is practically ready for general introduction. Undoubtedly means will be hit upon from time to time to enhance the value and efficiency of the phonograph, but it stands today, in our opinion, far more practical and complete than was the typewriter when first brought out and placed on the market. Back of all the tall talk and exaggeration on the subject. . . is a machine of admirable performance, whose utility is so wide and various that it is hard to determine just which work will give it the largest field of employment. . . . And

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** The Brush Development Co., Cleveland, Ohio.

then, too, it is the wonder. . . that not only can the human voice be registered, but it can be duplicated in countless electrotypes."

There is scarcely another art that has undergone such extensive improvement as the technic of sound transmission and sound reproduction. Quality acceptable a few years ago is not acceptable today, and what was considered a good sound recording a decade ago, would not be tolerated today. Without any doubt, the reason for this is that the sound picture and the radio have educated the public to demand better quality in recorded sound. This should not be surprising, if we consider that every tenth person in the world is provided with a radio. Engineers and physicists have steadily put forth their efforts to investigate and analyze the requirements for good sound reproduction, and to find new ways to apply their knowledge to obtain further improvement. The method of mechanical recording so far, however, has been commercially exploited only in the manufacture of disk records.

It is somewhat surprising that the use of direct recording, with the exception of dictating machines, has not found as much acceptance as it should be entitled to. But nevertheless, quite a few companies nowadays are concentrating their efforts toward improving and promoting instruments of this kind. The writer is of the opinion that direct recording will eventually be as commercially important as the manufacture of completed disk records.

In the light of these considerations, this Company has given a considerable amount of attention to perfecting electroacoustic apparatus for sound reproduction. In the past few years, experience has taught us that direct recording has not only considerable entertainment value, but also that it has important educational adaptations. The entertainment possibilities of such a vehicle are very obvious, since it means that favorite radio programs can be preserved, and the music enthusiast is enabled to build up a musical library of his own choice.

The educational possibilities are being more widely recognized today, and this fact is reflected by the acceptance of direct recording machines by many schools and colleges, orchestra leaders, and artists. There is every reason to believe that the preservation of sound will in the near future be as important as the preservation of appearance. What the candid camera has done commercially for photography, the instantaneous sound recorder may well do for its industry. It seems timely, therefore, to analyze the problems involved in setting up a machine for high-quality instantaneous recording.

Since in the art of mechanical sound recording the laterally cut record has a predominant place, this paper, for the sake of simplicity, will restrict itself to considerations of this method. Regardless of whether a disk, a cylinder, or a film is used, the problems are very similar.

The method of lateral recording requires that the sound carrier be in relative motion to the cutter or the pick-up. The record is made by cutting or embossing the signal to be recorded. The cutting or embossing stylus moves in the plane of the disk perpendicularly to the relative motion of disk material, and causes modulation of the groove corresponding to the vibrations of the signal. In the process of reproduction, a stylus is guided by these modulated grooves, and being forcefully moved in accordance with the modulations, transfers them into electrical energy.

The cutting stylus cuts a groove into the record in such a way that the groove walls are inclined to each other at an angle of approximately 90 degrees. Such a groove has a *V* shape. Since it is impossible to provide an ideally sharp point on the cutting stylus, the stylus is rounded and has, for most commercial applications, a radius of 0.0023 inch. If a disk is used as record material, the procedure is to cut in helical form. To provide a long-playing capacity for such recordings, it is desirable that the grooves be as close to each other as possible. While most commercially available records are cut with approximately 96 lines per inch, direct-recording machines are on the market that cut as close as 160 lines per inch. Since, as pointed out above, these grooves are laterally modulated by the recorded signals, the amplitude of recording is limited by the separation of the grooves. It is necessary to avoid "over-cutting," which may occur when adjacent grooves are not sufficiently separated by the intervening wall. Even for the greatest signal amplitude, over-cutting must be eliminated. For this reason, the usual commercial practice is to cut "constant velocity" in the higher frequencies, and "constant amplitude" in the lower frequencies. The frequency at which the transition between constant velocity and constant amplitude is made to occur is generally between 300 to 800 cycles.

Instantaneous recording requires much softer record material than the so-called pressed records. More and more nitrate-coated disks are coming into use, and the probability is that even if new record materials are found, they will, mechanically, be very like the nitrate disks now available. It is easy to see that a different record material, particularly since it is a softer one, must necessarily call for a different pick-up design. Frequent reproduction of a record can be satisfactory only if the forces that have to be supplied by the record to the pick-up are not great enough to deform the disk material permanently. It is necessary, therefore, to investigate these forces, with the view of determining optimum design features. But before this can be done successfully, the basic design of a pick-up will be briefly mentioned. A pick-up is an electric generator, whose mechanical force is supplied by the groove modulation through the stylus assembly to the generator element. Since vibratory motions are taking place, the pick-up generator must respond to vibratory motion; consequently, each pick-up represents a vibratory system in itself, having a certain amount of stiffness and a certain amount of inertia.

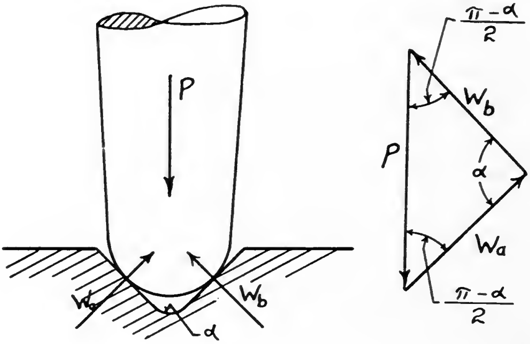

FIG. 1. Stylus resting in unmodulated groove.

Fig. 1 is a diagram of a stylus resting in an unmodulated groove. It is under a pressure P, and both walls exert a force normal to their surface counteracting force P. In the vector diagram, the three acting forces are shown, and it is obvious that the forces exerted by both walls are equal. Referring to Fig. 1,

$$\frac{P}{\sin\alpha} = \frac{W_b}{\sin\dfrac{\pi-\alpha}{2}} = \frac{W_a}{\sin\dfrac{\pi-\alpha}{2}}$$

$$W_a = W_b = \frac{P}{\sin\alpha}\cdot\sin\left(\frac{\pi}{2}-\frac{\alpha}{2}\right) = \frac{P}{\sin\alpha}\cos\frac{\alpha}{2}$$

$$\sin\alpha = 2\sin\frac{\alpha}{2}\cos\frac{\alpha}{2}$$

$$W_a = W_b = \frac{P}{2 \sin \frac{\alpha}{2}} \tag{1}$$

if α is the angle between the walls. If the stylus has to track a modulated groove, an additional force St is effective. This force St is equal to the difference between the inertia force and the stiffness force. For the lower frequencies, it is very nearly equal to the stiffness force of the system; for the higher frequencies of the audible spectrum, it is a function of the difference between inertia and stiffness. In any event, the force St will act horizontally against one wall of the groove, as shown in Fig. 2. If the system is stiffness controlled, the stylus will bear toward the neutral position; while if the system is inertia controlled, the stylus will bear away from the neutral position.

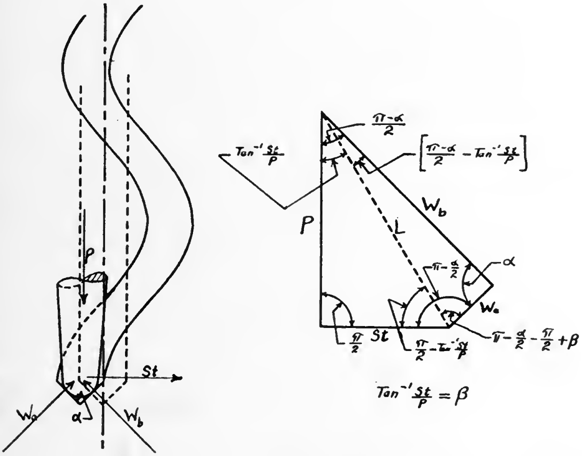

FIG. 2. Forces acting on groove.

The new vector diagram for this condition which is shown for the stiffness controlled system indicates that the wall force W_b becomes greater, while the wall force W_a becomes smaller. Referring to Fig. 2:

$$\frac{W_a}{\sin\left(\frac{\pi}{2} - \frac{\alpha}{2} - \beta\right)} + \frac{W_b}{\sin\left(\pi - \frac{\alpha}{2} - \frac{\pi}{2} + \beta\right)} = \frac{L}{\sin \alpha}$$

$$\frac{W_a}{\cos\left(\frac{\alpha}{2} + \beta\right)} = \frac{W_b}{\cos\left(\frac{\alpha}{2} - \beta\right)} = \frac{L}{\sin \alpha} \cdot$$

$$\frac{W_a + W_b}{\cos\left(\frac{\alpha}{2} + \beta\right) + \cos\left(\frac{\alpha}{2} - \beta\right)} = \frac{L}{\sin \alpha}$$

$$\frac{W_a + W_b}{2 \cos \frac{\alpha}{2} \cos \beta} = \frac{L}{\sin \alpha} = \frac{L}{2 \sin \frac{\alpha}{2} \cos \frac{\alpha}{2}}$$

$$W_a + W_b = \frac{L \cos \beta}{\sin \frac{\alpha}{2}} = \frac{P}{\sin \frac{\alpha}{2}} = \text{constant}$$

The arithmetical sum of both wall forces always equals a constant (Fig. 2). In fact if stylus pressure and stiffness force are equal, W_a becomes zero, and W_b will become 1.414 P, if α is 90 degrees, as in commercial practice. If the stiffness force should exceed the stylus pressure, the stylus will climb up the side of the groove, and the result is that the stylus will no longer track the groove. If we assume that the system is inertia-controlled, similar conditions exist, except that the force St will be oppositely directed. To find the necessary stylus pressure P, it is necessary to investigate under which conditions the wall force St reaches its maximum. Most vibratory pick-up systems are stiffness-controlled for the low frequencies until the resonance point is reached, and are then inertia-controlled for frequencies above this point. At any frequency the stiffness forces are always oppositely directed to the inertia forces. Since this is the case it follows that it should be possible to find a balance between the higher-frequency forces and the lower-frequency forces. Or, stated in another way, it would be desirable that the maximum wall force developed by a complex wave-form involving considerable inertia forces should be equal to the maximum wall force at a low frequency involving the stiffness forces only. In order to develop this thesis, it will be necessary to make certain assumptions concerning the character of the wave-forms to be engraved. The assumptions will be justified later in this paper.

It is the inherent character of music and speech that we very rarely find pure tones. Instead, a complex combination of frequencies is ordinarily the case. In recent literature, it has been frequently pointed out that the ability of a device to transmit a square wave is, in general, an indication of the fidelity of the device. Taking this consideration as our fundamental assumption, such a wave-form engraved in a disk will be expressed by

$$y = A \sin \omega t + \frac{1}{3} A \sin 3\omega t + \frac{1}{5} A \sin 5\omega t + \ldots \frac{1}{n} A \sin n\omega t \quad (2)$$

In analyzing the inertia forces that would be developed upon a stylus constrained to track such a groove, we find the second derivative of the wave-form with respect to time. Such an operation gives the acceleration in the wave-form.

$$\frac{dy}{dt} = \omega[A \cos \omega t + A \cos 3\omega t + A \cos 5\omega t + \ldots A \cos n\omega t] \qquad (3)$$

$$\frac{d^2y}{dt^2} = -\omega^2 \left[A \sin \omega t + 3A \sin 3\omega t + \frac{1}{5} A \sin 5\omega t + \ldots nA \sin n\omega t\right] (4)$$

To find the point of greatest acceleration for a square wave, it is necessary to investigate the point at which sin $n\omega t = 1$, or where $n\omega t = \pi/2$. For this point, the equation may be written in the following form:

$$\frac{d^2y}{dt^2} = -\omega^2 \left[A \sin \frac{\pi}{2n} + 3A \sin \frac{3\pi}{2n} + 5A \sin \frac{5\pi}{2n} + \ldots nA \sin \frac{\pi}{2}\right] \quad (5)$$

It can be seen that all the angles in the above equation, with the exception of that of the nth member, must give a value smaller than 1. We therefore have a more severe case of acceleration if we consider such a phase-shift between the components that all of the angles will equal $\pi/2$. For this particularly serious case, the acceleration will be expressed by equation *6*

$$\frac{d^2y}{dt^2} = -\omega^2[A + 3A + 5A + \ldots nA] \qquad (6)$$

The member on the right is a simple arithmetic series, the sum of which is

$$\frac{d^2y}{dt^2} = -\omega^2 \left(\frac{n+1}{2}\right)^2 A \qquad (7)$$

And since this sum is an acceleration term, the force of acceleration is given by multiplying by the mass factor:

$$F = mA\omega^2 \left(\frac{n+1}{2}\right)^2 \qquad (8)$$

Where ω is, from the above development, the lowest frequency of the series; A, the amplitude at that frequency, and m the mass that is being accelerated by the given wave-form. Assuming that the damping forces are negligible, the forces supplied by the wall of a groove equal the inertia or acceleration force just considered, minus the stiffness force. The stiffness force is found from the product of the total displacement and the coefficient of stiffness. The total displacement for this case is given by:

$$A' = A + \frac{1}{3} A + \frac{1}{5} A + \ldots + \frac{1}{n} A \qquad (9)$$

Taking 500 cycles as the fundamental, and 10,000 cycles as the upper limit of components, the total displacement for the complex wave will be 2.133 A and the consequent stiffness force will be given by 2.133 AK, where K is the coefficient of stiffness.

Two cases of maximum wall force are conceivable. In one case only a low-frequency fundamental note, without overtones, is considered. The walls of such a groove have only to overcome the stiffness of the system, and set up a force depending upon the displacement of the stylus. The second case is based upon the hypothetical wave-form we have analyzed. We have already advanced the theory that for best design, the force generated by stiffness at low frequency should be equal to the resultant force developed by the complex wave.

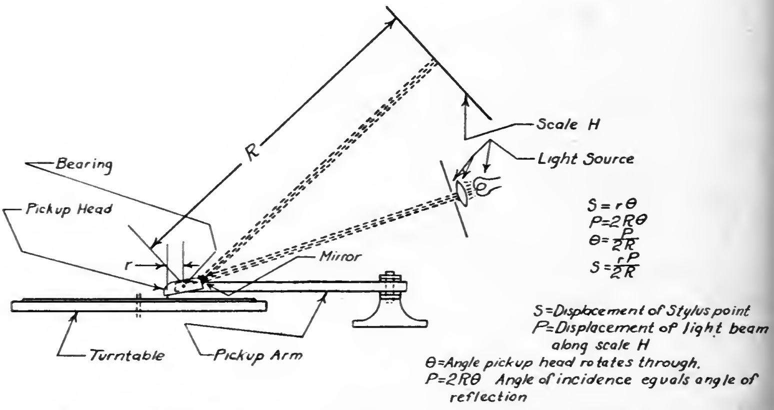

FIG. 3. Method of measuring vertical unevenness of disk motion.

$$mA\ (2\pi f)^2\left(\frac{n+1}{2}\right)^2 - 2.133\ AK = AK \tag{10}$$

Solving this equation for the stiffness factor K, in terms of the mass, gives:

$$K = 3.15 \times 10^{+8}m \tag{11}$$

This relation makes it possible to determine the optimum condition for inertia and stiffness of the pick-up system. It is obvious that the stiffness can be made as small as required but that certain definite limitations exist in regard to the inertia of the system. After all, the stylus, at least, has to be kept in motion, but even this is not sufficient. In the magnetic pick-up, the generator also must suffer motion.

Either a piece of magnetic metal must be moved in a magnetic field, or a coil of wire must be moved. The crystal pick-up distinguishes itself by the fact that the crystal element is a pressure device, and generates an electrical voltage proportional to the pressure applied to it, and does so with almost negligible motion. A crystal pick-up, therefore, can be built with extremely small inertia. The design of a pick-up based upon these considerations will be mentioned later.

The considerations have thus far been limited to the pick-up cartridge itself. Obviously, since this cartridge rides upon a rotating disk, at the end of a not inconsiderable arm, it is necessary to examine conditions brought in by this pick-up arm and the record itself. It is ideally desirable to provide a very light stylus pressure, but several disturbing factors may occur in practical design. While the record is moving and the stylus rides in the groove, two points must be considered. First, the friction between the stylus point and the record; and second, the fact that most of the records are not absolutely true. Nor do most commercial turntables run true. In addition to the side motion of the pick-up arm, imposed upon it by the helical character of the groove, there is also the factor of vertical motion caused by the unevenness of the record or turntable. While the stylus is moving up, all parts of the cartridge or arm assembly participating in this motion experience acceleration and generate force, adding to the stylus pressure. In the case of the stylus moving downward, the ac-

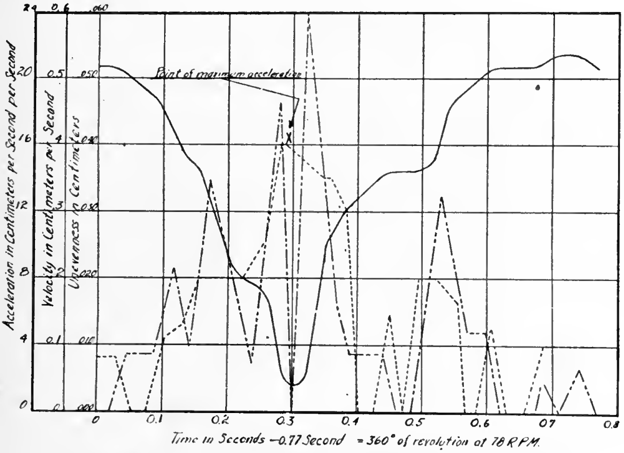

FIG. 4. Vertical unevenness of typical disk motion.

celeration of the participating parts generates a force directed oppositely to the stylus pressure.

Measurements have been made on commercial disks with the view to determining the unevenness and the accelerations caused by such unevenness. These measurements were made as follows: A stylus riding in a groove, as shown in Fig. 3, had attached to it a small mirror that reflected a light-ray upon a screen at a considerable distance from the mirror. The motion of the light-point was measured in relation to the angular position of the disk. Fig. 4 shows the vertical unevenness of a typical disk as a function of the angular position, and shows, in addition, the resulting vertical velocity and the acceleration of the stylus caused to track such an unevenness. The point of maximum acceleration is indicated, and is 16 cm per sec^2, assuming a disk velocity of 78 rpm. These considerations make it desirable to reduce the inertia of the pick-up assembly to vertical motion.

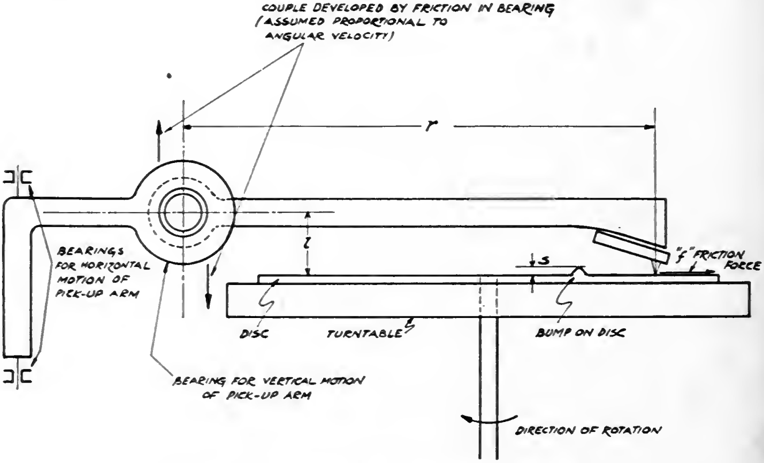

FIG. 5. Showing frictional force on disk.

The stylus pressure develops a frictional force between the moving disk and the stylus, which acts upon the contact point of the stylus in a horizontal direction, and actually has a tendency to lift the pick-up arm if the arm is vertically pivoted at a point above the plane of the disk. The couple of these friction forces is fl, f representing the friction forces and l the height of the pivoting point above the plane of the disk. To eliminate this couple, the pivoting point must be brought into the plane of the disk ($l = 0$). To reduce greatly the effect of the couple, however, the pivoting point may be remotely located in the horizontal plane from the stylus point, and the distance l may be made as small as possible. Since the lifting forces are expressed by fl/r, it follows that the above procedure will greatly reduce the moment expressed by the equation. In Fig. 5, the forces and their effect are shown. It is obvious that l/r should approach zero. These considerations make plain the fact that under certain conditions, if the disk is uneven, or if the pivoting point is not in the plane of the disk, there will be a difference between the static and the dynamic pressure of the stylus. This condition is expressed by the following equation:

$$P_{\text{dynamic}} = P_{\text{static}} \pm \frac{I\dfrac{d^2s}{dt^2}}{r^2} \pm \frac{K\dfrac{ds}{dt}}{r^2} + \frac{fl}{r} \qquad (12)$$

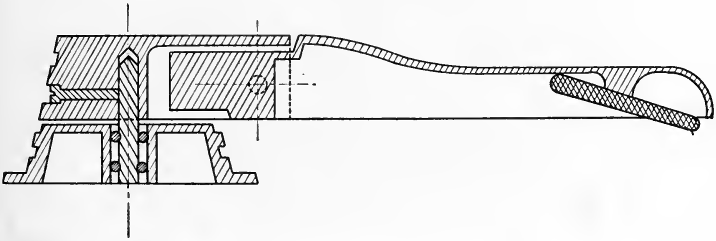

FIG. 6. Section of pick-up arm.

where $(I/r^2)d^2s/dt^2$ represents the force due to unevenness of the disk, and I is the moment of inertia of the whole pick-up assembly and arm. $(K/r^2)ds/dt$ represents the friction forces of the pivoting point, where K is the coefficient of bearing friction, assuming that these forces are proportional to the velocity. fl/r represents the lifting forces caused by friction.

In Fig. 6 is shown a section view of a pick-up arm designed after the above considerations. It consists of two sections, one of which has a horizontal pivoting point where the pick-up arm is mounted, and forms a bearing for the other part, which holds the cartridge. This first part is made heavy, so as to give the pick-up arm a considerable moment of inertia in the horizontal plane. This helps to bring the arm resonance down to a very low frequency, where it is not a problem. The other section, holding the cartridge, and pivoting vertically in the first section, is very light, to reduce the moment of inertia in the vertical plane. This makes the pick-up relatively insensitive to the unevenness of the record and turntable surfaces. Fig. 7 shows a finished arm, designed after these considerations.

It has proved quite a problem to determine the maximum stylus pressure that can be used without causing apparent wearing of soft disk materials. In connection with the investigation of the relation between stylus pressure and friction, we come to some very interesting conclusions. In Fig. 8 the friction forces are shown as functions of the dynamic pressure. Curve *A* shows this relation for an unmodulated groove. Curve *B* is taken from a 200-cycle groove modulated at an amplitude of 0.0004 inch and curve *C* is from 2500 cycles at the same amplitude. Curve *A* shows a proportionality between pressure and friction up to around 60 grams, and the curve then bends and starts to rise more rapidly beyond this point. Curves *B* and *C* depart from linearity at about 25 grams' pressure. Microscopic examination has shown that no excessive wear takes place on the record grooves at stylus pressures below the inflection point in the curve. Beyond that point, however, noticeable wear takes place. From these observations, we conclude that a groove cut in nitrate material, and modulated at peak amplitude with a fairly high frequency will not stand more than 25 grams' pressure.

FIG. 7. Photograph of pick-up arm.

When it is considered that most of the conventional pick-ups are still engineered to operate at stylus pressures in excess of $1^1/_2$ to 2 ounces, it is easy to see that permanence in nitrate records is still a pleasant fantasy. Using the improved Brush pick-up, however, acetate recordings have been reproduced many times, without the slightest depreciation in quality. The stylus pressure in these tests has always been less than 25 grams.

The method which has been used for measuring the friction force developed between the stylus tip and the groove of a record is as follows: The requirement is to measure the drag of the disk upon the pick-up assembly, in a line tangent to the groove being tracked, and in the plane of the disk. Since it is required that the dynamic stylus pressure being used should be known as accurately as possible, the device must combine low bearing friction and high sensitivity, and the vertical pivot must be in the plane of the disk being tested.

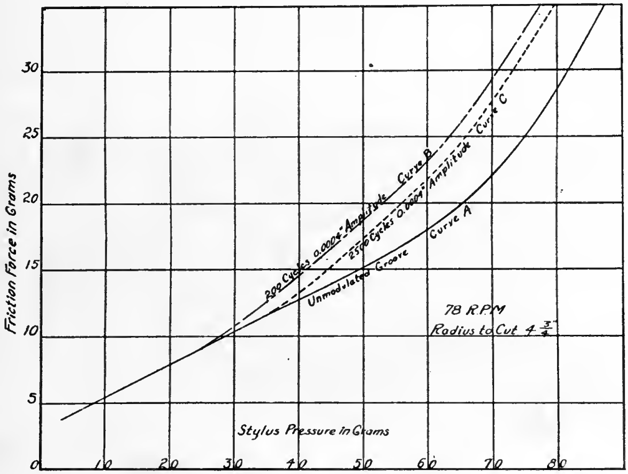

FIG. 8. Frictional forces in terms of dynamic pressure.

The apparatus is shown in Fig. 9. The pick-up head *A* is mounted in arm *B*. Arm *B*, constructed of a light alloy, is pivoted at *K*, on a bearing allowing free vertical motion of the arm. Arm *F* is secured solidly to arm *C*, and springs *G* are fixed to the pick-up arm *B* and connected together at their other end by a cord running over pins *L* and passing through a clamp at *E*. The pressure of the stylus on the disk may be adjusted by changing the relative tensions in the springs *G*, and such adjustments are held by clamping the cord connecting the two springs, at *E*. *D* is an arm pivoted at *H* in a ball bearing allowing horizontal motion and having affixed to its free end the whole assembly heretofore mentioned, at bearing *M*. Bearing *M* allows the sidewise motion required for the apparatus to track. It will be noted that the assembly hangs from M as a pendulum bob, but for the relatively small time required to take a reading with the apparatus, the pendulum will be only very slightly displaced from its neutral position, and the error introduced by this factor is of vanishing importance.

Connected to arm D by means of a light thread is the spring balance P, constructed after the idea of a Jolly balance, so that the reading is taken after the arm D is returned to a neutral position by the force of the balance. This procedure tends to cancel out errors that would be introduced if the arm were at different points for different friction forces. The set-up measures friction force directly in grams.

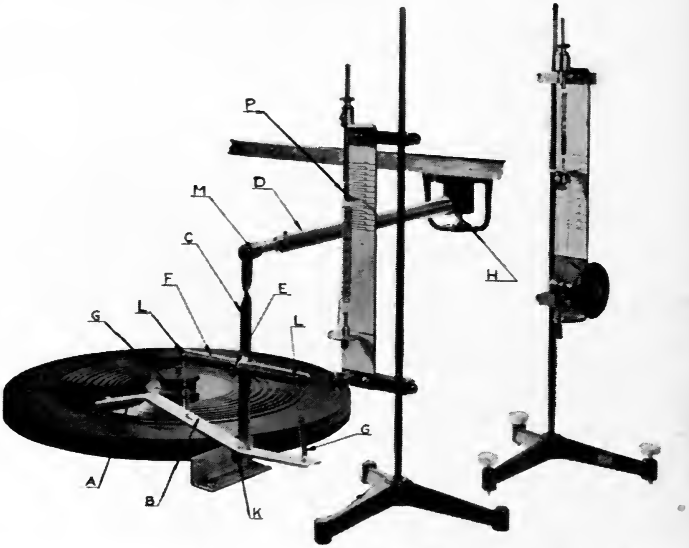

FIG. 9. Apparatus for measuring friction between stylus tip and groove.

The stylus pressure was measured with a spring balance. The balance was constructed with an eye to the special requirements of the measurements to be made, but is essentially a sensitive spring balance, calibrated in grams. A saddle from the spring holds the stylus, and the tension on the spring is increased until the saddle just lifts the stylus free from the disk surface.

Some of the design features used in the Brush pick-up will now be taken up. In Fig. 10 the disk reproducer cartridge is shown. The sapphire stylus is held in a hollow tubing which is connected to a drive wire. This wire is fastened to the crystal element. The wire itself is held in bearings which permit torsional motion. The stylus point is forced by the grooves to describe an extremely small section of the periphery of a circle, so small that the arc is essentially equal to the chord. While doing so, the wire is twisted, which develops a torque pressure on the crystal element. The crystal element generates a voltage proportional to this pressure, and it may be again pointed out here that this voltage will at any time be proportional to the displacement of the stylus tip and not proportional to the velocity.

We do not have to concern ourselves with details about the crystal element because this element neither adds substantially to the stiffness nor to the inertia of the vibratory system consisting of stylus and tubing and wire drive. Due to the fact that the wire moves only in torque, it adds negligibly to the inertia of the system, and represents the force of stiffness in our record reproducer. The inertia of the system is concentrated mostly in the sapphire point and the extremely thin-walled tubing that holds the sapphire. It has already been pointed out that the mass of the system is the determing factor for the stiffness. The mass must be made as small as possible, and in this connection a signal step has been taken forward in the design explained above. The entire structure of this assembly is contrasted with that of a conventional chromium stylus in Fig. 11.

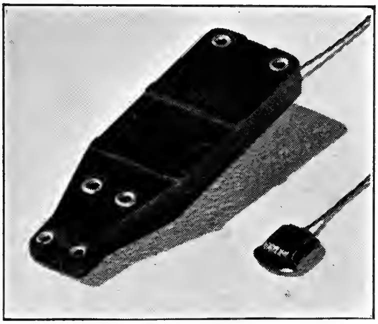

FIG. 10. Disk reproducer cartridge.

The resonance frequency of the crystal assembly has been raised still higher above the audible range, oil damping has been added to the crystal, the inertia of the stylus has been greatly reduced, and the stiffness of the drive wire has been readjusted to coöperate properly with this reduced inertia. The effective inertia of the stylus assembly may be reduced to 2.22×10^{-6} gm sec^2 cm^{-1} at the stylus point. The stiffness, therefore, after formula *10*, should be equal to

$$K = 3.15 \times 10^8 m = 700 \text{ gm/cm}$$

By actual measurement, the assembly has a stiffness of approximately 800 gm/cm.

For purposes of testing a pick-up, it is extremely desirable that a single frequency should be found that would simulate the conditions imposed by the complex-wave hypothesis. Since 10,000 cycles per second is assumed to be the highest frequency to be reproduced, this frequency is selected as the single frequency to simulate the complex wave-form. The total wall force generated by the complex wave-form is given by:

$$F = mA(2\pi f)^2\left(\frac{n+1}{2}\right)^2 - 2.133\,AK \qquad (13)$$

Setting this equal to the wall force of a 10,000-cycle note and solving for the amplitude of this 10,000 cycle note:

$$A\left[m(2\pi f)^2\left(\frac{n+1}{2}\right)^2 - 2.133K\right] = A_1[m(2\pi f)^2 n^2 - K] \qquad (14)$$

$$A_1 = 0.0973A$$

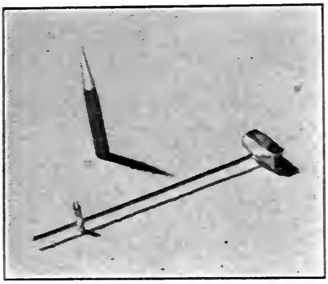

FIG. 11. Sapphire stylus assembly, contrasted with conventional chromium stylus.

It follows that the hypothetical wave-form will generate a wall force equal to that generated by a 10,000-cycle pure tone, recorded at an amplitude 0.0973 A, where A is the amplitude of the fundamental frequency of the hypothetical wave.

Even assuming, however, that the wall forces are negligible, that in itself will not assure tracking of the 10,000-cycle note. It is required that the stylus tip shall follow the undulations of the wave, but obviously this is possible only if the radius of curvature of the stylus tip is less than that of the wave-form being tracked. It is necessary, therefore, to determine the radius of greatest curvature of the hypothetical wave-form. The radius of curvature is expressed by the following equation:

$$\rho = \frac{\left[1 + \left(\frac{dy}{dx}\right)^2\right]^{3/2}}{\frac{d^2y}{dx^2}} \qquad (15)$$

It has been shown previously in this paper that for the hypothetical wave form:

$$\frac{dy}{dt} = \omega\,(A \cos \omega t + A \cos 3\omega t + \ldots + A \cos n\omega t)$$

$$\frac{d^2y}{dt^2} = -\omega^2 (A \sin \omega t + 3A \sin 3\omega t + \ldots + nA \sin n\omega t)$$

The greatest curvature will be at the point where the greatest acceleration takes place, or where $\sin \omega t = \sin 3\,\omega t = \ldots = \sin n\omega t = 1$. In this case $dy/dt = 0$ and we find that

$$\rho = \frac{1}{A\omega^2 \left(\frac{n+1}{2}\right)^2} \tag{16}$$

It must be possible to find a single frequency of the nth component that will have the same curvature. This frequency is expressed by:

$$\rho = \frac{1}{A_2\omega^2 n^2} \tag{17}$$

By setting both curvatures equal:

$$A_2 = \left(\frac{n+1}{2n}\right)^2 A \tag{18}$$

From this we find that $A_2 = 0.276\,A$, assuming 10,000 cycles is the highest frequency in the complex wave-form, or to express the same idea in different terms, if A is the amplitude of the fundamental frequency of the hypothetical wave, the amplitude of a sine wave of nth order which has the same curvature as the complex wave-form must be approximately $^1/_4\,A$.

It will be of interest to mention a specific example where the formula for the radius of curvature is used to determine what minimum disk diameter is necessary to reproduce the hypothetical wave. The formula for the radius of curvature can be reduced to the following simple equation:

$$\rho = \frac{1.69r^2}{Af^2} \tag{19}$$

where r is the radius of the disk at the groove being considered; f is the frequency of the signal, assumed to be a sine wave; and A is the amplitude of the signal at that frequency. The constant 1.69 is based upon a disk speed of 78 rpm (0.308 is the constant for $33^1/_3$ rpm).

The conventional tracking stylus has a point radius of 0.0025 inch. Fig. 1 shows such a stylus resting in a 90-degree stylus cut, and it will be seen that the curvature in contact with the groove walls will have a radius of $^1/_2$ the length of the chord connecting the contact points of the groove and the stylus. This value will always be less than the radius of the stylus point, and for a 90-degree cut, is given as 0.707 the stylus point radius. Returning, now, to our example: The frequency of the highest component in the hypothetical wave is 10,000 cycles. The conventional tracking stylus has a point radius of 0.0025 inch and from above considerations, the radius of the contact circle is 0.707 × 0.0025 or 0.00177 inch. Therefore, in formula *19*, ρ must be 0.00177 inch. The amplitude of the equivalent 10,000-cycle wave, from previous considerations is 0.276 A, and assuming that 0.0002 inch is the fundamental amplitude A, the amplitude to be used in the formula is $0.0002 \times 0.276 = 0.0000552$ inch. Solving the formula for r shows that at 78 rpm the minimum disk radius that will reproduce the hypothetical wave-form is 2.4 inches.

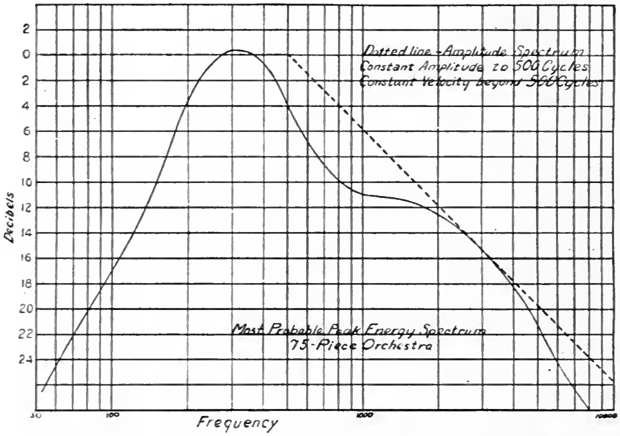

FIG. 12. (*Solid curve*) Energy spectrum (H. Fletcher).

Since we have discussed, to a great extent, the effects of a complex wave-form upon a pick-up, and have used a specific example of such a wave-form from which to draw our conclusion, it is, of course, very desirable to justify the assumptions inherent in these considerations. Such justification, fortunately, can be found from an analysis of the energy spectrum for speech and music.

Very pertinent information of this nature is supplied by Fletcher,[1] as shown in Fig. 12. This curve has a definite peak at about 350 cycles, and falls off both above and below this point. As indicated in this figure, an envelope curve is shown that is flat from 0 to 500 cycles, and falls thereafter in such a way that the product of the amplitude and frequency is constant. While it can be seen that this envelope curve somewhat exaggerates the condition, it certainly shows a condition that is rather more severe than measurements indicate. Taking this envelope curve as the basis for consideration, and assuming that the turnover point of this curve represents the fundamental frequency, we find that our hypothetical wave built up by this fundamental frequency and all odd harmonics having amplitudes inversely proportional to their order (Eq. *2*) is expressed by the dotted envelope curve. It is almost inconceivable that the wave-form would contain all the harmonics, in the relationship expressed by the envelope curve. It is somewhat more in accordance with the law of greatest probability to assume that only every other harmonic is present, and this is what has been done in the hypothetical wave. Making this assumption we more closely approach reasonable expectancy for speech and music. It will now be seen that these considerations are based upon an envelope spectrum which would be found recorded upon a disk if that record were cut with a constant-amplitude device.

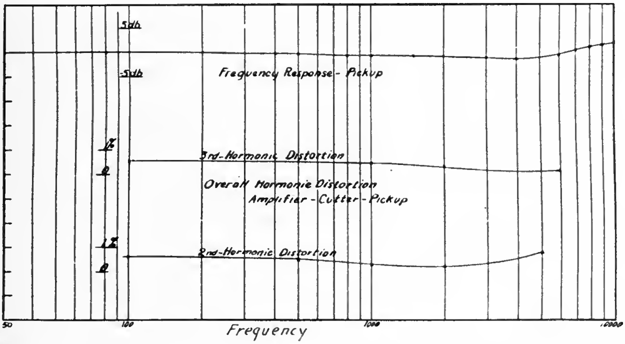

FIG. 13. Frequency response and harmonic content of reproducer cartridge.

Very successful records have been cut with an amplitude of 0.0002 inch maximum displacement. This amplitude is approximately 20 db down with respect to the average amplitude of a Victor record for the low frequencies, but it is approximately 10 db higher for 10,000 cycles. Since the scratch noise of a record is in the higher range, constant-amplitude recording means that the scratch noise is considerably reduced. It has the other advantage that the grooves can be cut closer to each other, leading to a longer possible playing time of a record of the same diameter.

Using a crystal cutter and a crystal pick-up, it is even more natural to consider constant-amplitude recording. With the crystal as a driver in a record cutter it is easy to produce a motion that is proportional to the voltage applied to it. Conversely, any crystal element generates a voltage corresponding to pressure applied to it. The Brush pick-up can be used without any equalization whatever for the reproduction of a record cut with constant-amplitude characteristics, so long as it is terminated into a high-impedance input. All that has to be done, therefore, is to connect the pick-up to the grid of the first stage of the amplifier. Provisions are made for either push-pull or single-channel input.

In Fig. 13 the frequency response and harmonic content of this cartridge are shown. In the frequency range of 30 to 10,000 cycles, the amplitude variation is less than ±2 db, and the total harmonic content is less than 1.5 per cent. It should be pointed out that the distortion curves are for the complete system, including the oscillator, amplifier, cutter, disk material, and reproducer. It is reasonable to believe, therefore, that the actual amount of distortion due to the pick-up is considerably less than that shown in these curves.

Measurement places the resonance frequency of the crystal assembly in the neighborhood of 24,000 cycles, which is well above the audible range. Even so, sufficient damping is used so that the resonance peak at 24,000 cycles is less than 10 db.

By the use of the "off-set" principle, of which much has been said in the literature of the past few years, maximum tracking error on a 12-inch disk with a 12-inch arm is held to approximately 1 degree, a negligible error.

REFERENCE

[1] FLETCHER, H.: "Some Physical Characteristics of Speech and Music," *Bell Syst. Tech. J.*, July, 1931.

DISCUSSION

MR. KELLOGG: How is the shaft pivoted at the upper end of the stylus bar?

MR. WILLIAMS: The beryllium bronze rod is supported in metal bearings. Rubber could be used.

MR. KELLOGG: Your diagram indicates a spherical reproducing stylus resting entirely on the side of the groove. Is it my understanding that for lateral disk recording steel cutters are sharpened and that the sapphires are rounded? Of course, in all standard recordings the round-ended cutting stylus is used with substantially the same radius as the reproducer.

Mr. Williams: It is our practice to use 0.0023 inch for the cut and 0.0025 inch for the pick-up. The diagram showed 90 degrees for simplicity, which is a little broader than the angle used.

Mr. Kellogg: Have you found using the same size superior, or have you found any difference?

Mr. Williams: I believe it is definitely superior. Of course, with the steel needle it is not possible, as the needle will wear. We do not expect any wear on the stylus and very little on the record. We always expect a tight fit. You can not have good reproduction unless you do have a tight fit.

Mr. Crabtree: What improvement in quality are we to expect by the use of this pick-up? In other words, what is there on the record that we can not get with existing pick-ups?

Mr. Williams: Most of the records do not have the higher frequencies. One of the reasons for this, I believe, is that when they do record at high frequencies, the large mass of the moving parts of the ordinary pick-up due to the size of the stylus, *etc.*, wears off at these higher frequencies very quickly, causing an increase in surface noise. If this record can be brought out recorded with constant amplitude, it will be possible to get a quarter on an hour's playing time with a 12-inch record using the same amplitude as we were here and going up to 10,000 cycles without any trouble.

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.

American Cinematographer

20 (June, 1939), No. 6

Problems Faced by Labs in Australia (pp. 246–247)	E. Huse
Television Highlights Engineers' Convention (pp. 254–257)	W. Stull
Improved Wild Cinemotor Developed (pp. 259–260)	R. N. Haythorne
Filtering Arcs for Matching Quality in Monochrome (pp. 269–270)	C. B. Lang, Jr.

British Journal of Photography

86 (May 5, 1939), No. 4122

Progress in Colour (pp. 279–281)

86 (May 12, 1939), No. 4123

Progress in Colour (pp. 294–295)

Educational Screen

18 (May, 1939), No. 5

Motion Pictures—Not for Theaters (pp. 153–156) Pt. 9	A. E. Krows

International Photographer

11 (May, 1939), No. 4

The BNC Mitchell Silent Camera (pp. 7–9)	S. Polito
Fundamental Photographic Physics (pp. 12–14) Pt. 3	D. Hooper
Grip Equipment (pp. 14–15)	G. M. Haines

International Projectionist

14 (May, 1939), No. 5

Many Important Changes in N. F. P. A. Projection Room Regulations (pp. 15, 27–28)

Process Projection Specifications. Pt. 1. Report of Research Council, Academy of Motion Picture Arts and Sciences (pp. 17–18, 24–27)

Film Preservative Tests. Abstract of a report on Release Print Quality Committee Research Council,

Academy of Motion Picture Arts & Sciences (pp. 20–21)	
New Erpi Mirrophonic 'Master' Theater Sound System (pp. 21–22)	

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Messungen an Bildschirmen. (Measurements on Projection Screens) (pp. 89–92)	J. RIECK
Der vollkommene plastische Films (The Perfect Stereoscopic Film) (pp. 92–97) Pt. 2	W. HESSE
Projektion mit Quecksilberlicht (Projection with a Mercury Light and Discussion) (pp. 98–101)	H. NAUMANN
Italienische und englische Filmatelier-Betriebe (Italian and English Film Studios) (pp. 101–106)	F. W. DUSTMANN

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Bearbeitung des Sicherheitsfilmes, 35 Mm. (Work on 35-Mm. Safety Film) (pp. 116–118)	A. SCHILLING
Ein neues Material für Tonaufzeichnung in Zachenschrift (A New Material for Variable Width Sound Recording) (pp. 118–122)	A. KUSTER
Artgleichungen (Comparison Tables) (pp. 122–126) Pt. I	R. THUN
Unvergangliches Lichtbild und Metallfilm (Imperishable Pictures and Metal Films) (pp. 127–129)	L. KUTZLEB
Versuch der DKG Betr. die Negativ-Entwicklung in Kopieranstalten (Investigation of the DKG Negative Development in Printing Establishments) (pp. 129–131)	L. KUTZLEB

Motion Picture Herald (Better Theaters Section)

135 (May 27, 1939), No. 8

The Advantages of the Smaller Image for Color Films (pp. 38–39)	F. H. RICHARDSON

Photographic Society of America, Journal

5 (May, 1939), No. 2

16-Mm. Sound Films by Direct Recording (pp. 16–19)	J. A. MAURER
Recent Developments in Photographic Objectives (pp. 22–24)	R. KINGSLAKE

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Ladies' Reception Committee

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Mrs. H. Griffin
Mrs. J. Frank, Jr.
Mrs. E. J. Sponable
Mrs. R. O. Strock
Mrs. A. S. Dickinson
Mrs. G. Friedl, Jr.
Mrs. E. A. Williford
Mrs. P. J. Larsen
Mrs. L. W. Davee

Headquarters

Headquarters.—The headquarters of the Convention will be the Hotel Pennsylvania, where excellent accommodations have been assured, and a reception suite will be provided for the Ladies' Committee.

Reservations.—Early in September room reservation cards will be mailed to members of the Society. These cards should be returned as promptly as possible in order to be assured of satisfactory accommodations. The great influx of visitors to New York, because of the New York World's Fair, makes it necessary to act promptly.

Hotel rates.—Special *per diem* rates have been guaranteed by the Hotel Pennsylvania to SMPE delegates and their guests. These rates, European plan, will be as follows:

Room for one person	$ 3.50 to $ 8.00
Room for two persons, double bed	$ 5.00 to $ 8.00
Room for two persons, twin beds	$ 6.00 to $10.00
Parlor suites: living room, bedroom, and bath for one or two persons	$12.00, $14.00, and $15.00

Parking.—Parking accommodations will be available to those who motor to the Convention at the Hotel Fire Proof Garage, at the rate of $1.25 for 24 hours, and $1.00 for 12 hours, including pick-up and delivery at the door of the Hotel.

Registration.—The registration desk will be located on the 18th floor of the Hotel at the entrance of the *Banquet Room* on the ballroom floor where the technical sessions will be held. Express elevators from the roof will be reserved for the Convention. All members and guests attending the Convention are expected to register and receive their badges and identification cards required for admission to all the sessions of the Convention, as well as to several *de luxe* motion picture theaters in the vicinity of the Hotel.

Technical Sessions

The technical sessions of the Convention will be held in the *Banquet Room* on the ballroom floor of the Hotel Pennsylvania. The Papers Committee plans to have a very attractive program of papers and presentations, the details of which will be published in a later issue of the JOURNAL.

Luncheon and Banquet

The usual informal get-together luncheon will be held in the Roof Garden of the Hotel on Monday, October 16th.

On Wednesday evening, October 18th, will be held the Semi-Annual Banquet and Dance, also in the Roof Garden of the Hotel. At the banquet the annual presentation of the SMPE Progress Medal and the Journal Award will be made, and the officers-elect for 1940 will be introduced.

Entertainment

Motion Pictures.—At the time of registering, passes will be issued to the delegates of the Convention admitting them to several *de luxe* motion picture theaters in the vicinity of the Hotel. The names of the theaters will be announced later.

Golf.—Golfing privileges at country clubs in the New York area may be arranged at the Convention headquarters. In the Lobby of the Hotel Pennsylvania will be a General Information Desk where information may be obtained regarding transportation to various points of interest.

Miscellaneous.—Many entertainment attractions are available in New York to the out-of-town visitor, information concerning which may be obtained at the General Information Desk in the Lobby of the Hotel. Other details of the entertainment program of the Convention will be announced in a later issue of the JOURNAL.

Ladies' Program

A specially attractive program for the ladies attending the Convention is being arranged by Mrs. O. F. Neu, *Hostess*, and the Ladies' Committee. A suite will be provided in the Hotel where the ladies will register and meet for the various events upon their program. Further details will be published in a succeeding issue of the JOURNAL.

New York World's Fair

Members are urged to take advantage of the opportunity of combining the Society's Convention and the New York World's Fair on a single trip. Information on special round-trip railroad rates may be obtained at local railroad ticket

offices. Trains directly to the Fair may be taken from the Pennsylvania Station, opposite the Hotel: time, 10 minutes; fare, 10¢. Among the exhibits at the Fair are a great many technical features of interest to motion picture engineers.

Points of Interest

Headquarters and branch offices of practically all the important firms engaged in producing, processing, and exhibiting motion pictures and in manufacturing equipment therefor, are located in metropolitan New York. Although no special trips or tours have been arranged to any of these plants, the Convention provides opportunity for delegates to visit those establishments to which they have entree. Among the points of interest to the general sightseer in New York may be listed the following:

Metropolitan Museum of Art.—Fifth Ave. at 82nd St.; open 10 A.M. to 5 P.M. One of the finest museums in the world, embracing practically all the arts.

New York Museum of Science and Industry.—RCA Building, Rockefeller Center; 10 A.M. to 5 P.M. Exhibits illustrate the development of basic industries, arranged in divisions under the headings food, industries, clothing, transportation, communications, *etc.*

Hayden Planetarium.—Central Park West at 77th St. Performances at 11 A.M., 2 P.M., 3 P.M., 4 P.M., 8 P.M., and 9 P.M. Each presentation lasts about 45 minutes and is accompanied by a lecture on astronomy.

Rockefeller Center.—49th to 51st Sts., between 5th and 6th Aves. A group of buildings including Radio City Music Hall, the Center Theater, the RCA Building, and the headquarters of the National Broadcasting Company, in addition to other interesting general and architectural features.

Empire State Building.—The tallest building in the world, 102 stories or 1250 feet high. Fifth Ave. at 34th St. A visit to the tower at the top of the building affords a magnificent view of the entire metropolitan area.

Greenwich Village.—New York's Bohemia; a study in contrasts. Here are located artists and artisans, some of the finest homes and apartments, and some of the poorest tenements.

Foreign Districts.—Certain sections of the city are inhabited by large groups of foreign-born peoples. There is the Spanish section, north of Central Park; the Italian district near Greenwich Village; Harlem, practically a city in itself, numbering 300,000 negroes; Chinatown, in downtown Manhattan; the Ghetto, the Jewish district; and several other such sections.

Miscellaneous.—Many other points of interest might be cited, but space permits only mentioning their names. Directions for visiting these places may be obtained at the Convention registration desk: Pennsylvania Station, Madison Square, Union Square, City Hall, Aquarium and Bowling Green, Battery Park, Washington Square, Riverside Drive, Park Avenue, Fifth Avenue shopping district, Grand Central Station, Bronx Zoo, St. Patrick's Cathedral, St. Paul's Chapel, Cathedral of St. John the Divine, Trinity Church, Little Church Around the Corner, Wall St. and the financial district, Museum of Natural History, Columbia University, New York University, George Washington Bridge, Brooklyn Bridge, Triborough Bridge, Statue of Liberty, American Museum of Natural History, Central Park, Metropolitan Museum of Art, and Holland Tunnel.

SOCIETY ANNOUNCEMENTS

ATLANTIC COAST SECTION

At a meeting held on June 21st at the RCA Photophone Studios, New York, an elaborate demonstration of equipment, with descriptive paper, was given by Messrs. A. Goodman, R. J. Kowalski, W. F. Hardman, and E. S. Stanko of the RCA Manufacturing Company, Camden, N. J. The subject of the paper was "Safeguarding Theater Sound Reproduction with Modern Test Instruments." The emphasis of the presentation was on the instrumental means used by field engineers in servicing sound reproduction equipment. Among the instruments described were a cathode-ray oscillograph for plotting upon the fluorescent screen the response characteristic of an amplifier system; an instrument for plotting rapidly, with the aid of a warble-frequency film, the acoustic response of an auditorium; an extremely sensitive bridge for measuring electrical constants of reproducing circuits; a sound-level meter; and other instruments of great aid to the installation and service engineer.

PACIFIC COAST SECTION

At a meeting held at the General Service Studio at Hollywood, on June 27th, a special introduction and demonstration of the Vocoder was given through the courtesy of Electrical Research Products, Inc., and Bell Telephone Laboratories. The technical discussion and demonstration were made by Mr. H. Dudley of Bell Telephone Laboratories. The Vocoder, or voice analyzer-synthesizer, is somewhat similar to the Voder, which is on demonstration at the World's Fair. Its main difference is that the control is by a speaker's voice rather than by manually operated keys. Sounds are first separated into frequency bands, any of which may be treated in various ways at the will of the operator before recombining to produce some desired effect.

With this instrument, means are provided for changing speech or music in innumerable ways, by altering the tonal quality or characteristics, by varying or reversing the inflection, by raising or lowering the pitch, by adding other effects such as tremolo, to simulate the quavering voice of an aged person; and by modulating music or sound effects. The change in voice, as well as the creation of rather weird and inhuman, but still intelligible speech, has suggested the possibility of using the Vocoder principle in motion picture work, particularly for cartoons and in regular dubbing and sound-effects recording.

PROJECTION PRACTICE COMMITTEE

A meeting of the Sub-Committee on Fire Hazards was held at the office of the Society on June 28th, the principal subject of discussion being the heating of projection rooms.

A meeting of the general committee was held on July 20th, at the Paramount Building, New York, N. Y., at which time reports of the various sub-committees were considered for inclusion in the report of the Committee for the approaching Fall Convention. The Committee is pleased to announce that the proposed revisions of the NFPA Regulations for Handling Nitrocellulose Motion Picture Film were adopted, in their principal features, at the recent NFPA meeting at Chicago. A new edition of the Regulations is being prepared by the NFPA.

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:

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Holmes, O. J.
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Nickel, F., Jr.
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Pariseau, S. M.
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Stace, F. N.
Wellington, New Zealand.

Weiss, M.
210 Butler Ave.,
Buffalo, N. Y.

S. M. P. E. 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 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. 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.

16-Mm. Sound-Film

Approximately 400 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 6000 cps.; the constant-amplitude frequencies are in 11 steps from 50 cps. to 6000 cps.

Price $25.00 each.

16-Mm. Visual Film

An optical reduction of the 35-mm. visual test-film, identical as to contents and approximately 225 feet long.

Price $25.00 each.

* * *

SOCIETY OF MOTION PICTURE ENGINEERS
HOTEL PENNSYLVANIA
NEW YORK, N. Y.

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OF THE SOCIETY OF
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* Term expires December 31, 1939.
** Term expires December 31, 1940.

FLICKER IN MOTION PICTURES*

LORIN D. GRIGNON**

Summary.—*Flicker in motion pictures has been receiving attention ever since the beginning of the art, and most of the sources of this defect have been minimized, if not eliminated, by technical accomplishments. The paper constitutes a qualitative review of the now prevalent sources of flicker, presenting some new concepts, emphasizing the sources of major importance at the present time, and reporting on two investigations made on the problem. Flicker and "registration jump" are differentiated, and the latter, which is really a separate problem, is not considered. Some data are presented to indicate the magnitude and characteristics of the flicker effect.*

Constant efforts have been directed in the technical branches of motion picture production and exhibition toward the removal of effects which make the mechanical processes in pictures obvious to the observers and detract thereby from the realism and entertainment value. Aside from features such as camera angle, lighting, sets, backgrounds, sound, *etc.*, two completely mechanical effects in pictures can cause serious loss of entertainment value. These two are flicker and registration.

This paper does not propose to discuss registration; therefore it is necessary to differentiate this effect from that of flicker. Briefly, registration is an irregularity in the *position* of successive picture frames on the film or screen. Flicker is an irregularity between successive frames in the total amount of reflected light from the screen, other than that purposely created, from a given scene.

Flicker still is an important problem in the industry although the serious defects are intermittent in nature. Flicker is due not only to the frame frequency (24 per second) but also is the result of other variations superimposed upon the frame frequency. This latter effect can be considered in the same light as flutter in sound recording and reproducing. This paper will lay the greatest stress on these harmful superimposed variations.

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 20, 1939.

** Paramount Pictures, Inc., Hollywood, Calif.

Consider now the many sources of flicker, and group them as follows for later consideration:

- (*A*) *Original Photography*
  - (*1*) Set lighting
  - (*2*) Negative film
  - (*3*) Irregular camera motion including motor system
  - (*4*) Development
- (*B*) *Printing*
  - (*1*) Lamp irregularity
  - (*2*) Positive
  - (*3*) Printer motion
  - (*4*) Development
- (*C*) *Projection*
  - (*1*) Arc flicker
  - (*2*) Intermittent shutter
  - (*3*) Projector mechanics
- (*D*) *Background Projection*
  - (*1*) All of *A*
  - (*2*) All of *B*
  - (*3*) All of *C*

With so many possible sources of flicker it is very easy to understand how flicker may easily occur. Also, although each of the above might be small in absolute value, in instances when two or more occur at the proper frequencies and phase relationships the effect becomes pronounced. This likewise accounts for the difficulty in tracing, separating, and minimizing the major sources.

Two analyses and investigations made at the Paramount Studios in Hollywood disclosed four important facts:

First, considerable change in reflected light can be tolerated by the observer provided this change occurs at random intervals which are not closely spaced or of excessive duration. The moment the light change becomes cyclic the amount of tolerable difference decreases sharply to a surprisingly small value.

Second, the rate at which the cyclic flicker occurs determines the amount of disturbance to the observer. No accurate determinations of this fact have been made. However, the rate of maximum disturbance appears to be between 6 and 8 cycles per second. Fig. 1 shows an approximate curve representing the apparent disturbing effect versus the rate of flicker.

Third, the change in transmission for perceptible periodic flicker occurring at the greatest disturbing rate of 6 to 8 cycles is about 3 per cent. The greater the change in transmission the greater the effect.

Fourth, the disturbing effect is related to the amount of light. The greater the intensity the more obvious the defect.

We shall now discuss the various sources of flicker, some briefly and others in more detail.

(*A*) *Original Photography.*—The first cause of flicker in this group occurs in the set lighting. The intensity changes of incandescent lamps are of a relatively slow and random nature, and cause changes in the average brilliance of the scene and are dependent upon the regulation and stability of the power supply. Arc lamp flicker is more likely to be cyclic and therefore of a more serious nature. Arc lamp flicker generally resolves into slow periodic changes such as line-voltage and carbon-rotation effects and very fast random fluctuations. The very rapid fluctuations cause the most trouble in background process work while the slow variations can cause serious trouble on split-screen shots. This is acknowledged and must be solved by the lamp and carbon manufacturers.

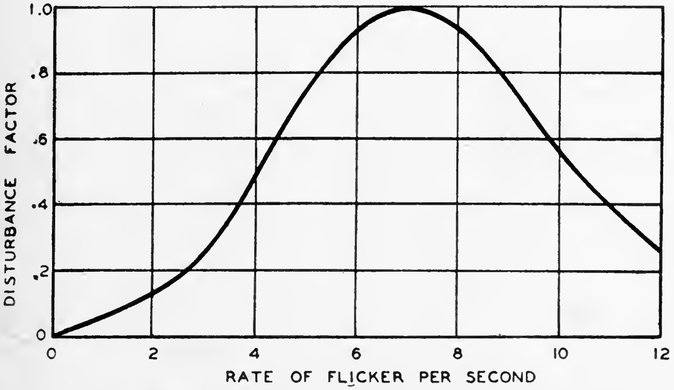

FIG. 1. Apparent disturbing effect of cyclic flicker *vs.* the rate of flicker.

Negative film is known to have random changes in sensitivity, and some stocks have cyclic changes occurring at a rate of one cycle in 7 to 12 seconds, at a speed of 90 feet per minute. These variations are not in themselves too serious, but should they fall in phase with other cyclic changes then the resulting flicker would be noticeable. Stocks having cyclic and random sensitivity have been submitted for use. In general these defects have been minimized.

Irregular camera motion is one of the worst offenders at present, but the motor system is not blameless and can be the cause of flicker. For some time the interlock motor system, when used, was condemned for all this trouble; the fact is that the interlock motor system was not the source, but its basis of operation allowed the trouble to persist and frequently amplified it. It would appear that, to obtain a steady exposure, the speed of the rotating shutter, which exposes the film, should be as smooth and constant as the movement of film through a sound recorder. A great deal of time and money has been spent by sound equipment manufacturers and users to reduce flutter, and as previously mentioned, picture flicker is nothing more than flutter. However, cameras generally use a slipping belt directly coupled to the shutter shaft for a film take-up mechanism. Belt condition greatly influences the steadiness of take-up, and each instant that a sudden change in load occurs the motor system reflects that change. Even with a motor having no resilience, changes in load can cause flicker. The camera undoubtedly contains mechanical inductances and capacities (which would include the shutter, motor rotors, gears, backlash, motor air-gap, flux, *etc.*) that can become resonant. Even though these reactances are inherently stable, the system might be thrown into oscillation by a sudden shock of small magnitude. This is evidenced by circumstances that have occurred when belt condition, mechanical looseness, and shutter action have all combined to become oscillatory and persistent at a rate well within the greatest disturbing region of Fig. 1. It was while working on a new motor system in conjunction with Electrical Research Products, Inc., that a full realization of the true nature of the

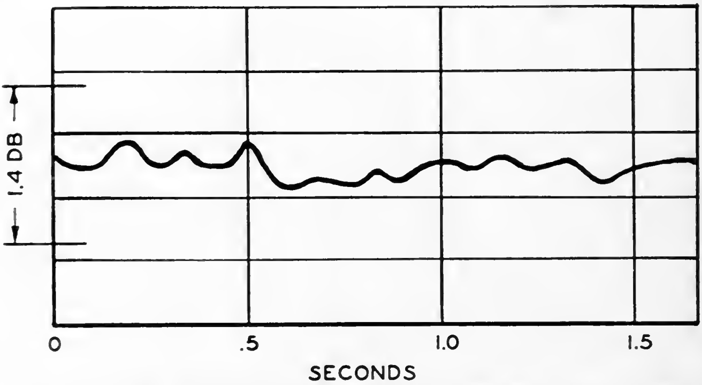

FIG. 2. Chart of section of picture negative in which photographic flicker is just perceptible, representing about 3 per cent in transmission.

difficulty was reached. A few clutches have been tried that gave varying degrees of improvement but none completely solved the problem. Fig. 2 shows a chart of a section of picture negative in which the flicker was just perceptible, representing about 3% variation in transmission. Fig. 3 shows a similar chart having flicker amounting to about 8% to 10% variation in transmission.

Those who have never seen the action of a camera shutter might observe the opening or closing edge of the shutter with a stroboscope, which is accurately synchronized with the motor, as either of these edges pass the aperture. Obviously, any variation in the shutter while it is fully open will have no deleterious effects.

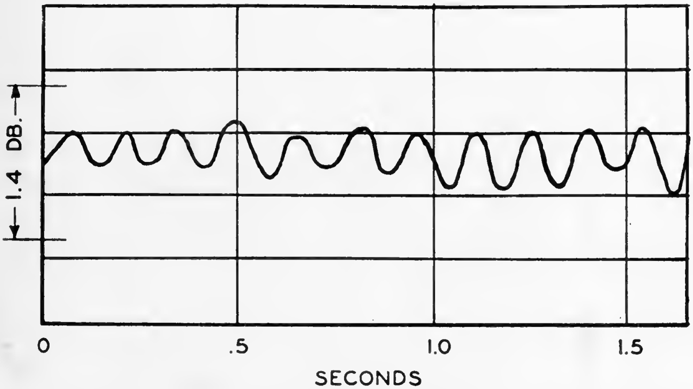

FIG. 3. Chart showing objectionable flicker amounting to about 8 to 10 per cent variation in transmission.

Development of negative is suspected of causing some variations but no conclusive data are yet available. It should not be deduced, however, that the laboratory is entirely faultless.

(*B*) *Printing.*—When the printer light is supplied from a generator or rectified alternating current, sufficient filtering must be used to reduce intensity changes to a small value. The ripple voltage should be less than 1 per cent. It is true that the normal ripple frequencies are beyond the greatest disturbing flicker rate, but the existence of 120 cycles in conjunction with other flicker frequencies produces a creeping density pattern in the projected picture. Frequencies increasingly higher than 120 cycles would undoubtedly cause less and less trouble. This particular effect is greatly dependent upon the amount of light and the density of the various parts of the scene.

It becomes most apparent in scenes including dark skies such as in night shots made with filters in the daytime. Fig. 4 shows the transmission change caused by a ripple voltage of 10 to 15 per cent.

Periodic flicker has been traced to printer motion on an earlier type of machine but no data exist on machines of current manufacture. In the case under investigation the flicker was caused by the belt splice which created periodic film-speed changes as the stock passed the aperture; *i. e.*, as the belt splice passed over the pulley the effective radius of the pulley was changed, causing a corresponding film-speed variation. Fig. 5 shows this effect under two conditions, that of normal operation and with an exaggerated splice. Only the amplitude of the variations has changed; the rate having remained fixed.

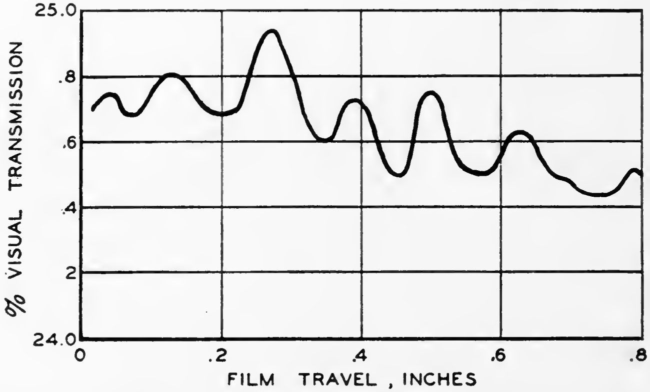

FIG. 4. Flicker due to printing: transmission change caused by a ripple voltage of 10 to 15 per cent.

Print development, the same as in negative development, has been suspected of some trouble since, of two prints from the same negative, one may have flicker and the other not. It is true that the printer itself may cause this trouble but no analysis has been made.

(*C*) *Projection.*—The whole subject of background projection has been well covered by the work of the Research Council Process Projection Equipment Committee of the Academy of Motion Picture Arts & Sciences[1] under the chairmanship of Farciot Edouart, and a great number of the conclusions arrived at apply to projectors in general.

The first item of particular importance in projection is steadiness of the arc lamp. This factor has been appreciated for some time and efforts have been directed toward its reduction. The work done by the above-mentioned Committee has further advanced arc lamp technic.

Shutter flicker in projection is still an important problem and resolves into two separate factors. First, constancy of light from frame to frame of a particular scene; mechanical accuracy of all parts; lack of mechanical resonances; and a stiff or non-resilient and well damped motor-drive will all contribute to improvement. Shutter variations amounting to 7 degrees have been observed. Second, the effects of shutter rate and the manner of eclipsing the picture must be considered. The minimum rate is established by the frame frequency. During the period that the shutter is open a still picture is being projected, but it is possible to demonstrate a reduction in flicker by interrupting this still picture for a short interval of time by an additional blade. This, of course, essentially increases the frame frequency but leads further to the possibility of other physiological factors. The question of two-bladed *versus* four or more bladed shutters of various dimensions, and one-sided or two-sided wipes, is certainly worthy of investigation. Undoubtedly the best approach to a real solution is by an extensive series of studies. These tests should be made by projecting a single frame or still picture at an intensity equalling that of the good theater picture and always maintaining the same average amount of light on the screen regardless of shutter de-

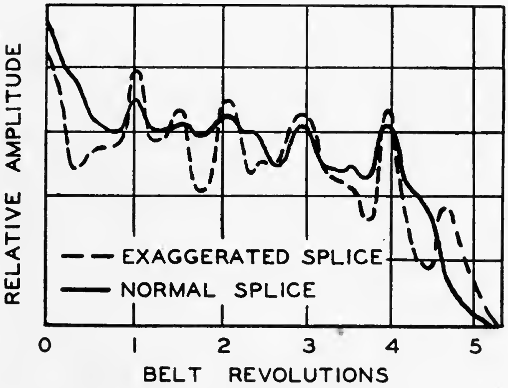

FIG. 5. Flicker effect in printing, due to belt splices.

sign. Further, these tests should include various values of eclipsing times from zero up, with all the darkness occurring in one interval and the same total amount of darkness broken up into two or more intervals, single *versus* double wipes, and instantaneous *versus* dissolving wipes. After reaching a definite conclusion for the most satisfactory combination, various periodic rates of irregularity could be superimposed upon the shutter action to obtain more definite and scientific data on this particular flicker effect.

(*D*) *Background Projection.*—Background projection suffers from all the above ailments except one, with the additional penalty of having all defects increased two-fold under certain circumstances. The one exception is shutter flicker in the background projector, and this can be eliminated only by careful synchronization and by making either the camera shutter or projector shutter sufficiently greater than the other so that the irregularities of the two will not overlap. If the synchronism does not remain accurate overlapping causes a disastrous result.

The author appreciates that all the matters discussed in this paper are controversial, particularly when so little concrete evidence can be presented; but certainly enough is on hand to indicate that progress along this line of endeavor should be stimulated. Much work remains to be done, and this work must be coördinated in such a manner that all persons involved in the final result on the screen work toward the same end. Like so many problems in complex art, it will not do much good for one branch to assume that its contribution is commercially sufficient. Taken by itself it might be, but when put in combination with other units to form the complete system, the final result may not be good, due to additive effects.

The purpose of presenting this paper has been to call the industry's attention once again to this serious problem, to indicate present major sources of difficulty, and to discuss them in a limited manner; and also to offer whatever assistance our results may provide to those who are qualified and equipped to carry out further studies.

The author wishes to acknowledge the assistance of all those who have contributed to this study in work, thoughts, and suggestions, and, in particular, the following: L. L. Ryder, A. F. Edouart, and A. Aton (Paramount Pictures, Inc.); A. L. Holcomb and C. R. Sawyer (Electrical Research Products, Inc.); and H. R. Berry (Lockheed Aircraft Corp.).

REFERENCE

[1] "Recommendations on Process Projection Equipment," Research Council of the Academy of Motion Picture Arts & Sciences. *J. Soc. Mot. Pict. Eng.*, **XXXII** (June, 1939), p. 589.

DISCUSSION

MR. MORGAN: Why is it that flicker has now become such a problem? Have we always had flicker and not noticed it, or have we been adding small distortions to the photographic processes so that they now add up to make a noticeable flicker? How do you determine what you say is appreciable flicker? What is the percentage of flicker when you begin to worry about it?

MR. GRIGNON: We, as sound men, are interested in picture problems, first, because we are interested in improving our employer's product; and second, the Sound Department is generally connected with the Camera Department through the necessity of interlocking motor drives. For years we have blamed the motor system for most of the causes of flicker but, as pointed out in the paper, we have found that it was not the motor system itself, but generally the type of operation, which permitted the flicker to exist and did nothing to damp it.

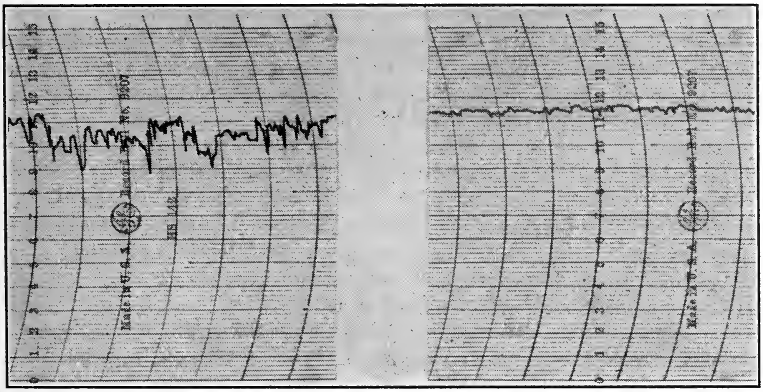
8-mm. M.P. Studio Trim New 8-mm.—7-mm. Trim

FIG. 6. Light-steadiness curves. *MR-40* Duarc lamp; 40 amperes, 37 arc volts.

The motor system was not faultless but we did need a new motor system from that standpoint. Flicker has always been in pictures to some extent but I can not give you a complete answer to that question. Perhaps one of the reasons we notice flicker more easily now is that we are using more brilliancy in projection. With better pictures on the screen it is very definite that there will be an increase in intensity of screen flicker and that it will be more noticeable.

In answer to the last question: the amount of perceptible flicker was determined by having a number of persons observe results of pictures taken under various conditions, and then obtain the average transmission differences of the samples that were considered as just perceptibly degraded.

A discouraging thing about this flicker problem is that flicker has not existed day after day and week after week. Flicker has been definitely an intermittent problem, and during times of serious trouble has demanded the attention of many men, who, however, to my knowledge have not yet arrived at a true and final answer. The intermittent nature of this problem is undoubtedly due to the many factors involved. With all the work that the sound engineers have done on flutter it seems odd that a situation should exist that requires the same quality of motion but very little has been done about it, and the studios think the manufacturers should seriously undertake the problem because it is rather costly to have to make re-takes.

MR. JOY: This is an interesting paper. As manufacturers we have always worked along the lines of producing a carbon which will give a steady light. In fact, we have been working along the very same lines which Mr. Grignon suggests. As evidence of this I refer to Fig. 6, which is taken from our paper on "Recent Improvements in Carbons for Motion Picture Studio Arc Lighting."* This illustrates that improvement in the carbons has resulted in a very appreciable improvement in light steadiness. It should be realized also that a good lamp mechanism is necessary for the steady burning of the carbon.

In the Technical Bulletin "Recommendations on Process Projection Equipment" of the Research Council of the Academy of Motion Picture Arts and Sciences, specifications and suggestions are given for burning a carbon in a projection system under conditions which, if followed, will go a long way toward eliminating any objectionable flicker. This illustrates again that besides having a good carbon it is necessary also to burn it properly to obtain the steady light desirable for either background projection or other lighting applications connected with the motion picture industry. It is evident that the work of Mr. Grignon and also of the Process Projection Equipment Committee of the Academy indicates that we are all striving toward the same common end, that is, to make a perfect motion picture.

Mr. Grignon stated in his paper that a flicker of around 6 to 8 cycles per second in frequency was most noticeable to the eye. Was this critical frequency established by observation or by some theoretical consideration?

MR. GRIGNON: With a large series of tests we finally realized that those irregularities that were causing us the greatest amount of disturbance existed in the region of six and eight cycles. This statement is not founded on any actual measurement because to make such a measurement would require a series of studies and other technical data involving a great deal of work. However, it was quite apparent that this region presented the greatest disturbing frequencies.

MR. LAUBE: What is the reaction in regard to the way we drive the Twentieth Century cameras—by drive from the motor to the shutter?

MR. GRIGNON: It has been our experience that that would probably be better than the current type of drive. The best way to check this point is with a stroboscope which is accurately synchronized with the driving motor, preferably using a contractor on the motor to determine the flashing periods of the stroboscope. Early tests with a non-synchronized stroboscope were found to be misleading.

MR. LAUBE: We feel that we have very good motion in the shutters on the Twentieth Century cameras. Stroboscopic tests are quite perfect. In back-

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* To be published in a succeeding issue.

ground projection shots it is very desirable that each frame of projected picture remain on the screen for a longer time than the total length of time the camera requires to record it. When I refer to the length of time the projected picture remains on the screen, I am not including the element of time during which the shutter in the projector is uncovering or covering the aperture, but only the time when the picture has its full value on the screen and is not being dissolved in or out by the projector shutter. If this time period is long enough to overlap that of the camera's total recording time period, I feel that the condition thus described would be most ideal for flicker elimination in background projection shots.

MR. GRIGNON: In background projection work that is important. If we assume a seven-degree variation in shutter operation, which we have observed, then, the projection shutter should be fourteen degrees wider than the camera shutter, or *vice versa*. In using a three-head or three-projector type for projection there is some improvement because the change in any one shutter affects only one-third of the total light and the result is only one-third as great also, there being three shutters, the change is more at random and the defect is not as serious.

MR. KELLOGG: Would you consider a disturbance that might occur every four seconds as disturbing?

MR. GRIGNON: Offhand I would say that such a disturbance, unless of large magnitude or occurring simultaneously with other factors, would not be disturbing.

MR. RICHARDSON: In the illumination of motion pictures, we do not have any rotary arc that carries the rotation of the positive carbon as high as 15 rpm. Practically all the modern lamps of the high-intensity rotary type operate at a positive rotation speed from 6 to 12 rpm.

There is another potential cause of flicker in the taking of pictures. In some studios it has been a practice to stop the rotation of the positive carbons during picture takes. This has come at the insistence of the sound recording departments in an attempt to reduce the mechanical noises from the high-intensity spot equipment. Some time ago a Committee of the Academy of Motion Picture Arts and Sciences made a study of arc noise reduction. For the test work done in this connection, we had available to the Committee one of the quietest stages in the industry, a stage on which the ventilation system was made inoperative and the ground-noise cut to a very low level. The test was made with a battery of ten 150-ampere high-intensity arc spots centered around a microphone of the type used for recording dialog, in a semicircle having a 25-ft. radius. Studies were made to ascertain the effects resulting from bringing the arcs into good trim and then cutting the motors off. Our interest was primarily in sound. Careful records of this test were made, and they are available through the Academy to those who wish to study them.

While it is unquestionably desirable to eliminate all possible noise in these arcs, the test revealed that the mechanical noise is a small factor of the total noise, the principal disturbance coming from the phenomena in the electrical arc.

The point I want to bring to your attention particularly is the decay of light and the production of flicker in the photographing illumination. When motors are cut off on the studio arcs, not only is the rotation stopped, but also the feed of the positive and negative carbons. Under these conditions the arc rapidly becomes unsteady. The decrease in the illumination is practically linear, and five minutes of operation after the motors have been cut off produces a decrease of over 50 per cent in the total illumination. The unsteadiness of the illumination during this period of decrease steadily becomes worse and would surely, at the end of three minutes, be highly contributive to flicker. However, it might be well to note that the flicker in illuminating sources under these conditions are random in each lamp. Those who are familiar with the studies made by the Sound Reduction Committee will agree, I believe, concerning the inadvisability of shutting off the motors on rotary arcs during photographic operations, both from the standpoint of its increasing light flicker and actually increasing, rather than decreasing, the noise produced by the arc's operating in a very erratic manner.

MR. GRIGNON: From what Mr. Richardson says the arc rotational speed is about one revolution every four seconds and, as stated before, that in itself, as a result of our studies, would not show in the projected picture. However, in split-screen work if the lamp intensity changes should happen to be in opposition on the two halves of the picture then a push-pull effect obtains which is definitely disagreeable to the observer.

MR. RICHARDSON: Many studies and tests have been made relative to these light-projection problems. Commercial rotary arcs are in operation today that limit the light fluctuation from rotation of the positive carbon to a variation of ±3 per cent, and it is possible by refinement to reduce the effect still further.

MR. GRIGNON: With respect to the rest of your point, Mr. Richardson, I do not have to defend the sound departments with regard to stopping the arc motors. I think that the motor noises that existed were of a periodic type that attracted attention. You are perfectly correct in saying that after a short period of time the general arc noise is increased. I also heard the tests you speak of. The noise, after a definite length of time is increased, but, however, that noise can be more readily tolerated since it is a random type of noise which shows up more as a constant sort of background behind the scene. Further, the tests of which you speak indicate clearly that even with lamps having acoustic treatment the motor noise is objectionable and for a period of about three to four minutes after disconnecting the feed motors a definite improvement in noise is obtained. Incidentally, three to four minutes time represents 270 to 360-foot takes, which are generally above the average take length.

MR. RICHARDSON: In photographing Shirley Temple's first Technicolor picture at 20th Century-Fox, the sound engineers had a particularly difficult situation. In this picture there were a number of very intimate scenes which required the recording of the children's voices talking either together or to their nurse. The intimacy of the scenes and the diminutive voices had to be recorded against a background of almost constant level. When some of the first scenes were taken we were called upon to analyze a problem of underexposure which Technicolor encountered in their photographic operations. This led to a special study of the decrease of light resulting from shutting off the motors of the rotary arcs, which had been the practice in taking these intimate sequences. The records of these studies are available to anyone who is particularly interested in studying this effect.

Some of these studies have revealed the effect of the "flash" type of flicker, which I think very definitely falls within this subject. These "flash" flickers are particularly prevalent in high-intensity arcs when the carbons are not operated at their normal consumption rates, and when the arc craters become unsymmetrical, which is always the case when the positive carbon which has been purposely designed to rotate, has its rotation slowed down, or is stopped.

MR. CRABTREE: How do you measure the flicker?

MR. GRIGNON: We are not equipped to make accurate determinations of the various flicker effects. The pictures used for observation were made by photographing a neutral gray wall under various conditions of the mechanism, take-up belt, motor system, shutters, *etc.*, and by actually applying periodic disturbances to the motor shaft. These pictures were then submitted to the various observers for their comments. Later the test-films that were of interest were measured throughout their length by a method employing what was essentially a recording densitometer having a relatively slow time response so that the density of each frame was somewhat averaged. Strictly comparative results were obtained by this method and the final answer obtained was, as noted in the paper, 3 per cent difference in transmission for perceptible flicker. More accurate methods of obtaining the data would certainly be of value and would definitely be required in order to separate the various types of flicker.

THE WORK OF THE

PROCESS PROJECTION EQUIPMENT COMMITTEE

OF THE

RESEARCH COUNCIL, ACADEMY OF MOTION PICTURE ARTS AND SCIENCES*

A. FARCIOT EDOUART**
Chairman

Summary.—*A brief account is given of the development of the process projection art, and the difficulties that arose due to its intial haphazard evolution.*

Following this is an account of the work of the Process Projection Equipment Committee of the Research Council of the Academy of Motion Picture Arts and Sciences, leading up to the recommendations of the Committee with regard to the projection equipment used in the process.

The motion picture industry's utilization of the projection background or transparency process of composite cinematography has become more and more important every year. Scarcely a picture is made which does not in some degree utilize this process; some have employed it to such an extent that as much as 50 to 60 per cent of the production's released footage has been produced on the process stage.

When considering this extensive use of process shots, it should be kept in mind that while the process naturally lends itself to the production of out-and-out "trick shots," its routine application is rarely in this category. The transparency process is not used as a means of fooling the public, but simply as the best and often the only method of securing scenes which would be too difficult, too costly, or too dangerous to film by conventional methods. The expense of sending a large company of stellar players, "extras", and technicians to do extensive filming on a distant location would under modern conditions reach a staggering total. But thanks to the present efficiency of

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** Transparency Department, Paramount Pictures, Inc., Hollywood, Calif.

projection background cinematography such scenes can now be photographed in the studio with equal effectiveness, and at a considerably lower cost.

It can be readily seen, therefore, that the application and advancement of this process have assumed not merely a technological importance, but an economic importance vital to the continued financial success of the motion picture industry.

The process developed spontaneously as technicians throughout the industry discovered methods and materials which made it practicable. These key developments were the introduction of sound, which brought the means of electrically synchronizing the composite or foreground camera with the background projector, and the introduction of the first supersensitive panchromatic emulsions, which for the first time afforded the high film sensitivity necessary for rephotographing the projection background image. With these elements available, it was inevitable that cinematographers in practically every major studio should put them together to form in actuality a system which for years many of us had pondered in theory.

From a simple, utilitarian standpoint, this spontaneous evolution was something of an advantage, since it quickly gave the entire industry a valuable new tool, with a minimum of dissention over proprietary patent formalities.

But from an engineering and industrial planning standpoint, it was highly unfortunate, because this haphazard evolution prevented any early standardization of essential methods and equipment.

As it was, each studio's process staff built or assembled their own equipment, often with little or no knowledge of what was being done along similar lines by other studios. Inevitably a great deal of wasteful duplication of effort ensued. Private manufacturers, when called upon to build process equipment for one studio, could seldom plan on selling similar units to other studios, not because of any patent or other restrictions, but because such units in all probability would not coördinate with the other studios' individual systems.

As a result the industry paid the penalty of using custom-made equipment. This was evident not only in the inevitably high cost of equipment, but in the lack of availability of items such as especially designed super-speed lenses and steady, silent, ultra-powered lamp houses, the design and construction of which would entail such extensive research that no major manufacturer could afford to undertake the project knowing that his total sales would be restricted to but one or two units.

Yet the technical problems underlying the design of process equipment were crying for skilled engineering and coördinated research. Since the very inception of the transparency projection process, it had been found that ordinarily available projection equipment for this type of work is principally composed of an assembly of units never originally designed or engineered to be combined and worked together in such a capacity. Basic elements of these assemblages were never intended to meet such strict and exacting requirements as have been imposed by the consistent demand for higher-quality rear projection results, and by the ever-increasing physical scope demanded by the increasing need for the process. We must not merely project our background images on a translucent screen and rephotograph them without subjects in the foreground: we must do it with such mechanical and photographic precision that both the foreground subject and the background projected picture are of such quality as to appear as if they were photographed at one and the same time. The increasing use of the process demands increasingly great physical scope—in other words, the ability to use background screens of increasingly greater size.

These requirements, in a word, mean *Maximum Light Delivery* with the following primary requisites: *Absolute Steadiness* of the projected picture with a *Minimum of Light Variation* on the screen and *Increased Efficiency of the Light and the Optics which Transmit It.*

Over a year ago the Research Council of the Academy of Motion Picture Arts and Sciences realized that it was necessary to take steps to correct this harmful situation, and to coördinate all the various ideas of the different studio Process Departments so that manufacturing companies would not be trying to manufacture a separate type of equipment for each producing studio. To this end, in March, 1938, the Research Council's Process Projection Equipment Committee was appointed. On February 2, 1939, the Committee's Report on Recommendations on Process Projection Equipment was approved by the Research Council for publication and distribution throughout the industry.

In the preparation of this Report, eleven meetings and two demonstrations, consuming approximately one thousand man-hours, were held, and at least an equal amount of time was consumed by the Committee Chairman and members in conferences, in preparing for meetings, tests, and demonstrations, and in preparing the Report itself. The Report therefore represents over two thousand man-hours of technical effort and combines the views of approximately fifty experts on the field of process projection.

It is only fitting to state here that the Research Council and the Committee are greatly indebted to all the many manufacturing firms consulted for their participation in this program. We are particularly appreciative of the coöperation of the National Carbon Company for sending its Development and Control Laboratory Director, Mr. David B. Joy, to Hollywood in connection with the development of carbons for process projection use, and to the Bausch & Lomb Optical Company for sending its representatives, Mr. Haller Belt and Mr. Alan A. Cook to Hollywood in connection with the development and standardization of optical systems for process projection work. All these men remained in Hollywood for several weeks, conferring with the Committee and its members.

The coöperation of such other firms as the International Projector Corporation, the Mitchell Camera Corporation, the Technicolor Motion Picture Corporation, the General Electric Company, the Mole-Richardson Company, Paramount Studios, RKO-Radio Studios, and Selznick-International Studios in the work of this Committee was also cheerfully given to an extent far greater than is ordinarily required of participants in the Council's program.

It is to be regretted that at this meeting we do not have the time to read the name of each member of the Committee and thus to extend the credit that is due. On this Committee there are 37 active members, not only cinematographers and technicians from all the studios participating in the Research Council program, but also experts from the companies which are the leading manufacturers of all the many types of equipment used in process projection work. Their interest and their whole-hearted coöperation made possible the success of this, the first step in the Committee's program.

We believe that the Report presents for the first time the coördinated viewpoint of the majority of Hollywood studios and their experts on this subject. As such, it should be of value to all the studios and to all the manufacturers of process projection equipment. The text of the report was published in the June, 1939, issue of the JOURNAL and should be of interest to every member of the Society.

In studying the report it should be observed that we have stressed the importance of faster lenses, perfect illumination, perfect registration, and increased light. Progress in these factors is the key to progress in the transparency projection process as a whole, and as these have been improved, the scope and utility of process projection has advanced proportionately.

Our great underlying problem is the fact that in our composite shots we are dealing with two photographic irreconcilables: for the image of our foreground action is an original, while that of the background is necessarily a "dupe," being the rephotographed image of a positive print. It is our task to combine these so perfectly as to color values and perspective that both appear as if they were photographed at the same time and place, and so that both maintain a photographic quality comparable to that of the production scenes (necessarily originals) with which they are ultimately intercut.

As the work has progressed, and the usefulness of the process has increased, all of us have striven to increase the general physical scope of the process and to provide a means of increasing the size of back-projection screens we could use. When the process was first introduced, screens six or seven feet in width were about the maximum possible. Two years ago the largest screens that were being used by the various studios ranged between fourteen and sixteen feet in width. Last year, when we began the transparency sequences for *Spawn of the North*, we commenced with a twenty-four-foot screen; we ended the picture using a thirty-six-foot screen, and filling it with ample illumination. I am sure all will agree that this represents progress.

As regards quality we—and by we I do not by any means restrict my meaning to my own Department at Paramount, but I refer to the process experts of all the major Hollywood studios—have very consistently succeeded in turning out process shots so convincingly natural that in the majority of cases the layman is not aware that the scene was made on the process stage. In some instances we have succeeded in producing pictures using really large screens where it is impossible even for many technicians to discern the difference photographically between the quality of the foreground original and the background dupe, or to point definitely to a scene and say, "This is a process shot." In doing this it will be appreciated that any flicker, any fluctuations, or any unsteadiness in the projected background naturally dispels the illusion of reality and reveals the scene as a process shot, lessening its dramatic value. Our aim is to eliminate these flaws, and to extend the scope and usefulness of the process.

The recommendations contained in the Research Council Process Projection Equipment Committee's Report will, we believe, further these aims, to the benefit of the industry and of the engineers and manufacturers who supply its equipment. Although these recommendations have been published but two months, they are already beginning to bear fruit in a concrete and satisfying manner.

The new lamp houses required are being developed. New lenses of two higher speeds are being calculated. There was a very immediate response by the Bausch & Lomb Optical Company when the various studios signified their intention of purchasing seventy-six of the new Super-Cinephors. That, by the way, was within a week or two after the recommendations were released at the studios. The Mitchell Camera Company is working on a new projection head, designed in accordance with these specifications. The Mole-Richardson Company has made notable progress in engineering a new lamp house and a new grid to meet these specifications and has the first equipment practically completed. With these developments, we can anticipate notable progress in the art of process projection cinematography in the near future. The ability to use background screens fifty feet wide seems well within the realm of practical possibility. So, too, do worth-while advances in steadiness, both of picture and of screen illumination, in picture-quality and in operating precision.

In closing, I can think of no better way to summarize than to quote from the preface written for the Report by Major Nathan Levinson, who in addition to being Executive Vice-President of the S.M.P.E. is Acting Chairman of the Research Council:

"Process projection methods continue to become increasingly important: Economically, they offer opportunities for still greater savings in production costs. Technically, developments in equipment and technic continue to expand the possibilities in this field until some day it will be the exception, rather than the rule, to send a cast on a distant location.

"Artistically, as the equipment and technic are further developed, the extent of their use will be limited only by the imagination of the production personnel; whereas up to the present time, the equipment has been the limiting factor, and only the ingenuity and resourcefulness of the technicians have made its wide use possible."

To these ends, the Research Council's Process Projection Equipment Committee is continuing its work. We consider the present recommendations a vital initial step in that work, but further coordinated activity will build upon that foundation. For the present, we hope that the industry will accept these recommendations and profit therefrom.

A CARDIOID DIRECTIONAL MICROPHONE*

R. N. MARSHALL AND W. R. HARRY**

Summary.—*A microphone is described which has uniform directivity over a wide frequency range. This is made possible by placing in a single instrument a dynamic type pressure microphone element and a ribbon type "velocity" element, and electrically equalizing the outputs before combination. The resultant directional pattern is a heart-shaped curve or cardioid, giving a fairly wide pick-up zone in front and a substantial dead zone at the back of the instrument. Because of the unusually rugged ribbon employed, the new microphone is much less susceptible to wind noise than ordinary ribbon types. Housed in an aluminum case, the microphone weighs only $3^1/_4$ lbs. High output level, low impedance, and high quality, together with the excellent directivity, promise to make the cardioid microphone an important tool for the motion picture sound engineer.*

A microphone, in sound motion picture systems, bears the same relationship to sound that a camera does to light. The special lighting technics of motion picture photography have been so widely publicized that everyone is aware of the steps taken to provide a visual illusion. It is also well known[1] that similar technics are required in sound recording to create the illusion of presence of the sound with the screen action. The balancing of these two arts, only just now being introduced to broadcasting through television, has long been practiced in the motion picture business; with the result that a particular set of microphone requirements have been evolved which are peculiar to the picture industry.

There are certain factors to be considered at the microphone which can not be handled at any other spot in the system. It is naturally expected that the microphone shall have a smooth frequency response over a wide frequency range, that the nonlinear distortion shall be at a minimum, and that the phase relationship among the frequency components of a complex sound shall be kept within bounds. Moreover, not only must the microphone be adaptable to use under a variety of acoustic conditions, but all the microphones

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

must produce records which can be intercut so that a continuity of sound quality is preserved throughout the performance.

Still another requirement, and a severe one, is imposed on the microphone by the type of sound system employed. Most sound systems in use today are monaural, which means that all the transmitted sounds come from one source, the loud speaker. In normal listening we are often interested in sounds coming from a particular direction, and our aural senses have the peculiar property of being able to focus our attention on such sounds. In monaural listening, however, we can not use these focusing powers to separate unwanted sounds which are transmitted. Therefore these unwanted sounds must be eliminated at the original location, and this may be done in two ways, either by controlling the sources of these sounds[2] or by making the microphone directional.

Aside from extraneous noises such as camera click, the principal class of sounds it is desired to exclude consists of reflections which render the sound reverberant. Now a certain amount of reverberant sound is necessary to achieve naturalness since we are accustomed to listening in rooms or auditoriums, but in monaural listening, where we lose the focusing powers of our aural senses, reverberation becomes much more noticeable or unnatural. If the reflected sound can be reduced either at the reflecting surfaces or at the microphone, then the reverberant effect may be reduced to the point where the reproduced sound will be natural. Moreover, in sound motion picture systems, control of this reverberant effect helps provide fore and aft presence in the reproduced sound.

The microphone to be described in this paper enables, for the first time, many of these pick-up conditions to be controlled at the microphone itself. This is made possible by providing the choice of three different directional patterns, so that the instrument is truly a "mechanical ear" which can help perform the functions of our normal aural senses in centering our attention on direct sounds. There still remains unexplored, however, the practical applications of this microphone to the operating technics of sound motion pictures.

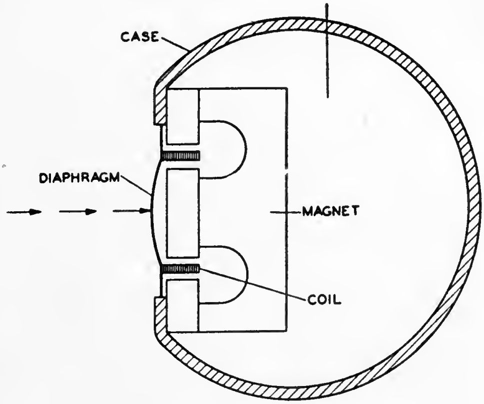
Directivity in a microphone can be of the greatest service only if it is independent of frequency and only if the discrimination in the undesired directions is high. The failure of most commercial directional microphones in the past to meet one or both of these requirements accounts for the fact that the field is virtually unexplored. It is the purpose of this paper to describe a microphone which has uniform directivity over a wide frequency range, responds to sounds coming from the front but is dead to those coming from the back, and yet meets many of the usual specifications of the sound motion picture studios. This new microphone, known as the Western Electric *639-A*, and shown in Fig. 1, combines into one instrument the popular features of both the dynamic pressure and ribbon velocity types. It is well known that by virtue of their fundamentally different principles of operation these two elements yield in proper combination a heart-shaped directional pattern known as a cardioid.[3]

FIG. 1. Western Electric *639-A* cardioid directional microphone.

The principle of operation of the dynamic or moving coil element is illustrated in Fig. 2. It consists essentially of a movable membrane or diaphragm closed off on one side by a hollow case, which should have small impedance compared to that of the diaphragm itself. Excess sound pressure at the diaphragm surface will cause it to move inward against the normal air pressure within the housing. Because sound can flow around corners, this type will respond to sound arriving from any direction, and excess pressure will always cause the diaphragm to move inward regardless of the angle of incidence. This accounts for the label "nondirectional pressure element." A coil attached to the diaphragm and placed in a magnetic field transforms the mechanical vibrations into the desired electrical oscillations. Because the diaphragm and coil assembly permits an efficient magnetic structure and is of high enough impedance to permit the use of a small hollow case, this moving-coil type can be made very small without sacrificing sensitivity—a decided advantage over many other types of pressure elements.

The ribbon unit works on the quite different property of a soundwave, namely, the variation of pressure with respect to distance;

the rate of variation being known as the pressure gradient. Thus, if a ribbon is placed in a sound field as shown in Fig. 3, there will exist a pressure difference between the front and back of the ribbon by virtue of the acoustic path distance L. The ribbon will naturally tend to move in the direction of diminishing pressure. If the ribbon is hung in a magnetic field, its motion will cause an electrical voltage to appear across its length. Observe carefully, for this is the key to the problem, that the motion of the ribbon will reverse with reversal



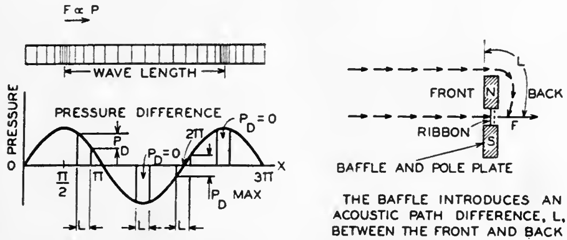


ILLUSTRATION OF THE PRESSURE DIFFERENCE EXISTING BETWEEN TWO POINTS IN A SOUND WAVE. NOTE THAT THIS DIFFERENCE WILL BE ZERO AT MAXIMUM AND MINIMUM PRESSURE, AND LARGEST HALF WAY IN BETWEEN, I.E., P_D IS 90° OUT OF PHASE WITH THE PRESSURE

THE BAFFLE INTRODUCES AN ACOUSTIC PATH DIFFERENCE, L, BETWEEN THE FRONT AND BACK OF THE RIBBON

PRESSURE GRADIENT = RATE OF CHANGE OF PRESSURE WITH DISTANCE = $\frac{P_D}{L}$ APPROXIMATELY IF L IS SMALL COMPARED WITH THE WAVE LENGTH

FIG. 2. (*Upper.*) Principle of dynamic-pressure microphone. Neutral pressure in case can change only by motion of diaphragm. Excess pressure on outside will push diaphragm in regardless of direction of sound wave.

FIG. 3. (*Lower.*) Principal of ribbon type pressure gradient microphone.

of the direction of the incident sound-wave. It can be readily seen that if the wave approaches the ribbon on edge, the pressure will be equal on both sides; the motion will be nil; and the response zero. Actually, the sensitivity is proportional to cos θ, the angle of sound incidence, as shown in the two-looped characteristic Fig. 4 (*B*). The device is "two-faced" or bi-directional since it picks up sound coming from front or back but not from the sides.

The motivating force on the ribbon is in phase with the pressure gradient which is 90 degrees out of phase with the pressure, and increases nearly linearly with respect to frequency. This is offset over the operating frequency range by keeping the ribbon impedance a mass reactance which also increases with frequency and introduces a 90-degree phase-shift. As a result, the motion of the ribbon is actually in phase with the particle velocity of the air which accounts for the term "velocity" microphone. A "velocity" type is merely a special case of the pressure gradient variety.

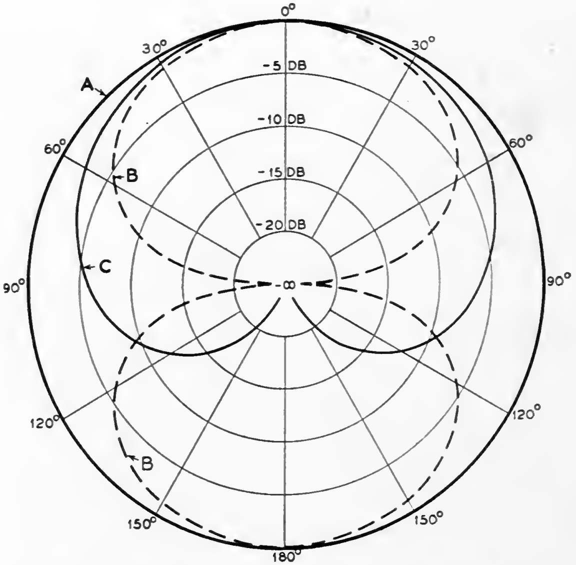
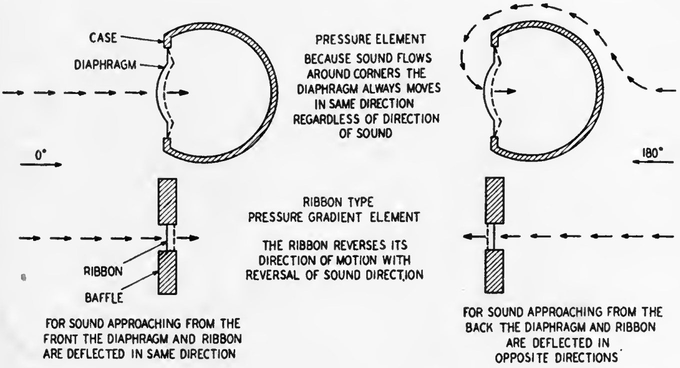


FIG. 4. *A*—Ideal characteristic of a non-directional pressure microphone.
B—Ideal characteristic of a bi-directional pressure gradient microphone.
C—Cardioid directional characteristic resulting from combination of *A* and *B*.

The ribbon pressure gradient element may be thought of as providing the directional ingredient, but in a "two-faced" form which has severe limitations of use. The non-directional dynamic element is added to annul one unwanted loop of the ribbon response and to transmute the directional pattern into the more desirable cardioid type. This is possible, because, as explained above, the ribbon motion reverses with reversal of sound direction so that the unchanging dynamic only annuls one loop and augments the other (Fig. 5). If the maximum sensitivity of both types is represented by the quantity 1, then the output of the series combination will be given by $1 + \cos\theta$ which in polar coördinates has the shape shown in Fig. 4(*C*). Since the word uni-directional implies one direction only, the name "cardioid directional microphone" has been adopted here as more descriptive of the combination of a pressure gradient and pressure type.



BECAUSE SOUND FLOWS AROUND CORNERS THE DIAPHRAGM ALWAYS MOVES IN SAME DIRECTION REGARDLESS OF DIRECTION OF SOUND

THE RIBBON REVERSES ITS DIRECTION OF MOTION WITH REVERSAL OF SOUND DIRECTION

FOR SOUND APPROACHING FROM THE FRONT THE DIAPHRAGM AND RIBBON ARE DEFLECTED IN SAME DIRECTION

FOR SOUND APPROACHING FROM THE BACK THE DIAPHRAGM AND RIBBON ARE DEFLECTED IN OPPOSITE DIRECTIONS

FIG. 5. Principle of the *639-A* cardioid directional microphone.

Although this explanation serves to present the general idea underlying the new microphone, the complete analysis is quite complicated; principally because neither element follows the simple assumptions made above. In the first place, the physical sizes of the elements, for the sake of sufficient output level, are so large that the assumption that the dimensions are small compared with the wavelength is not met. In the second place, the magnitude and phase of the outputs are not the same over the frequency range so that cancellation of one response loop of the ribbon type can not be achieved in simple fashion. The solutions of these problems are so interrelated and tangled together that they can not be considered separately in rigorous fashion, and space prevents the complete unravelling of the story. After all, it is the results that we are principally interested in so we will only glance at the highlights of the design problem.

The dynamic element is the same compact unit used in the Western Electric *630-A*[4] nondirectional microphone. The problem of getting the diaphragm of the dynamic unit in close proximity to the ribbon so as to minimize phase differences caused by the distance of separation, and at the same time prevent serious disturbances of the normal operation of each element due to the presence of the other, is solved by the electromechanical structure shown in Fig. 6. A special ribbon magnet structure has been developed using a highly effective permanent-magnet steel, which permits a fairly open arrangement. The housing of the dynamic unit has been reshaped and streamlined so that its presence does not seriously affect the operation of the ribbon. In addition this housing encloses the ribbon transformer, electrical equalizer, and switch (see Fig. 6); supports the ribbon wind screen housing; and provides the mounting and terminal facilities in the form of a projecting cylindrical plug. It may be noted that the size of the device is dictated largely by the ribbon element which, because of the wide air-gap to accommodate the ribbon, requires heavy permanent magnets. Moreover, the ribbon is susceptible to air currents and must be surrounded by a cloth screen a few inches away, which reduces the flow of air through the instrument and yet has a negligible acoustical effect.

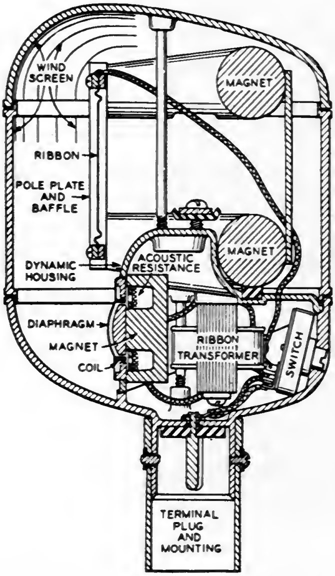


FIG. 6. Cross-section of the *639-A* cardioid directional microphone.

Since the screen, by requirement, has no effect on sound transmission, its shape is not quite as functional as in the case of the dynamic housing where the hard shell forces sound to flow around it. Consequently the screen was styled in such a manner as to convey as much as possible the idea of directionality. For this purpose an aerodynamic motive has been employed in which the bulbous end is the front. At the same time, however, every inch of space has been utilized so that the overall size is the minimum consistent with operating requirements. The housing is fashioned of a cast aluminum alloy, and is finished in aluminum grey with the horizontal lines in polished metal. The overall height of the microphone, including the plug terminal mounting, is $7^1/_2$ inches; and the weight is approximately $3^1/_4$ pounds.

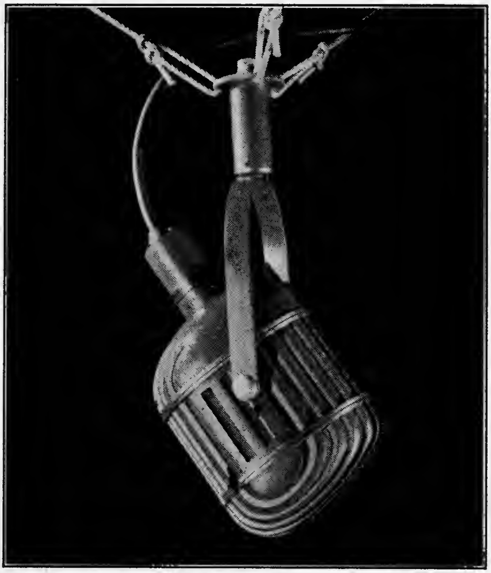
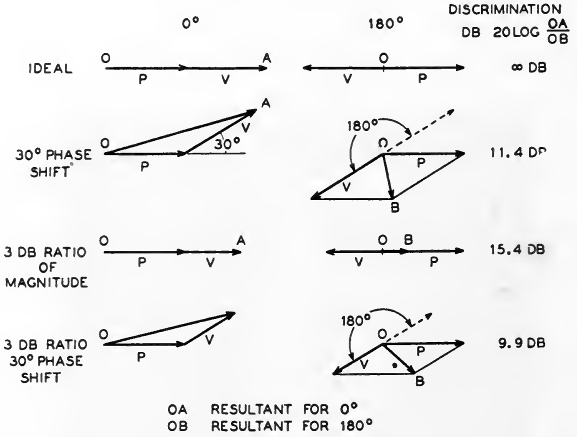


FIG. 7. For stage work where large angles of inclination are required, the universal *11-A* attachment, a combination suspension mounting and swivel holds the microphone at the center of gravity and friction joints permit quick setting of the instrument in any desired direction.

The *639-A* is designed to mount directly on a floor-stand as shown in Fig. 1. No tilting of the microphone is normally necessary since, as will be explained later, because of its broad pick-up angle, sufficient adjustment may be obtained by setting the stand in the right direction. For stage or set use where hanging or other placement requires a tilting feature, a universal swivel mounting is available. This mounting, shown in Fig. 7, suspends the microphone from its center of gravity and friction joints allow setting of the instrument in any direction. The mounting may either be suspended by cords or attached to a floor or desk stand.



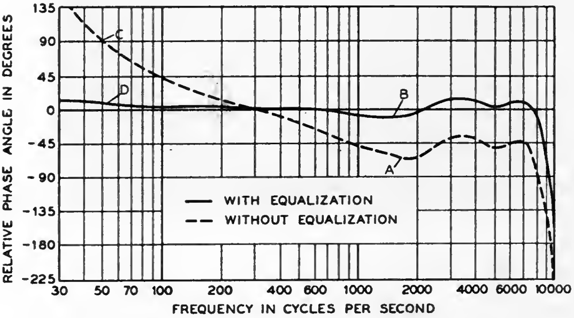


FIG. 8. (*Upper.*) Effect of difference in phase and magnitude on the resultant of the sum and difference of two vectors. This illustrates the necessity of carefully matching the outputs of the two microphone elements in order to obtain good discrimination.

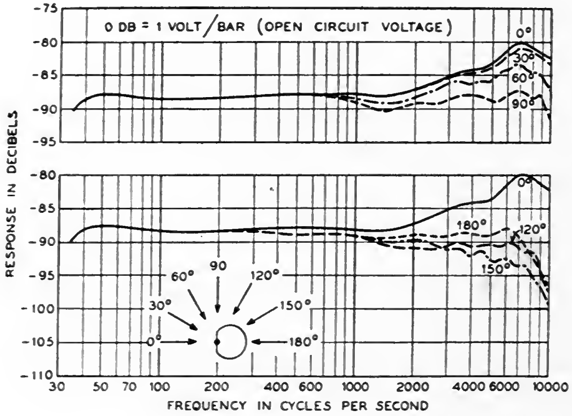
FIG. 9. (*Lower.*) Relative phase-angle between outputs of dynamic-pressure element and ribbon-pressure gradient element.

Another feature of the new microphone is the three-way switch located at the lower rear of the housing. This allows the choice of the dynamic or ribbon units individually as well as the combination which gives the cardioid directional characteristic. Essentially then, the owner of a *639-A* has three microphones in one, non-directional performance from the dynamic, bi-directional from the ribbon, and cardioid-directional from the two together. The responses of the bi-directional and non-directional elements, however, have been adjusted to permit the best results in the cardioid combination, and therefore may require slight equalization, at high frequencies, if takes, using the three different types of performance, are to be intercut.

With the physical size and construction of the pressure and pressure gradient elements set, there still remains the question of whether their electrical outputs are sufficiently alike in magnitude and phase. To understand the significance of this problem, let us examine for a moment the diagrams of Fig. 8, which illustrate, the effect of relative differences in the output voltages. Note that whereas the addition resultant of the two vectors is not very critical, the subtraction resultant is very sensitive to variations. A difference in magnitude of 3 db and phase of 30 degrees permits a discrimination between front and back of only 10 db. Complete cancellation is evidently a very difficult thing to achieve.

For the present case Fig. 9 represents the relative phase between the pressure and pressure gradient elements for sound incidence of 180 degrees which is the direction for which we desire complete cancellation. It is obvious from Fig. 9 then, that aside from magnitude differences, the phase characteristics will permit good results only in the middle frequency range, and some corrective steps are necessary. Now it so happens that most of the phase differences are attributable to the pressure element, and are difficult to avoid unless we sacrifice ruggedness and size. The question naturally arises as to whether this phase shift has a serious bearing on the quality of the transmitted sound and should be avoided. Fortunately, this question has been studied in some detail by research physicists, and it has been found that the human ear has difficulty in distinguishing between a system with considerable phase distortion and one without.[5] In other words wave-form is of little significance physiologically, and it may be assumed that other factors are considerably more important from a quality standpoint. Therefore, in the present problem, emphasis has been placed on reducing the relative phase-angle to a minimum without reference to the absolute phase. Moreover the problem naturally divides itself into two parts, high frequency and low frequency equalization.

From Fig. 9 it is apparent that considerable equalization is necessary to bring the phase exactly in line, and means for doing this are rather complicated. Consider for a moment the response characteristics for a dynamic type microphone alone given in Fig. 10, and note that at high frequencies this type is directional already. Hence, as a



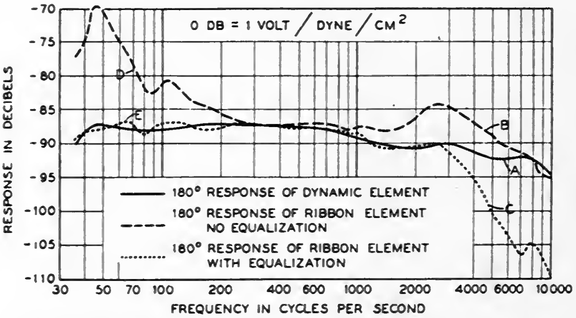


FIG. 10. (*Upper.*) Field response of a dynamic-type microphone for several angles of sound incidence.

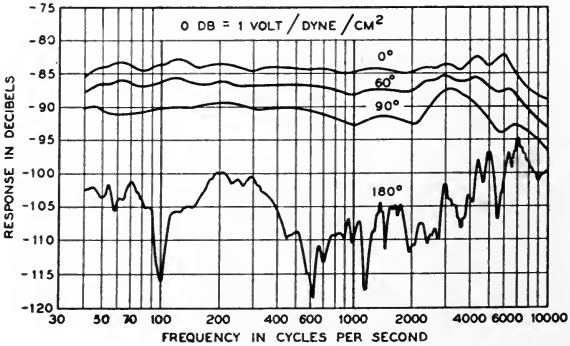
FIG. 11. (*Lower.*) Field responses of ribbon and dynamic elements, illlustrating the manner of equalizing and matching the outputs up to 3000 cycles, where the ribbon element is then filtered out.

solution to the problem, the ribbon element is used to provide directivity at the lower frequencies and is filtered out at high frequencies leaving the dynamic element do the work alone. The filter network chosen acts also as a phase equalizer, and Fig. 11 shows just how the transition is accomplished. Curve *A* is the 180-degree response of the dynamic element and is the curve to be matched by the ribbon since it is for 180 degrees that we desire complete cancellation. Curve *B* is the response of the ribbon and has been made of such a shape that the loss in the filter matches the two outputs very closely up to about 3000 cycles, and then spreads them rather sharply, as shown by curve *C*. The relative phase between the dynamic element and the ribbon element with the corrective network is given by curve *B* of Fig. 9.

The results are now clear. Good cancellation may be expected up to 3000 cycles since the responses agree closely both in magnitude and phase. From 3000 to 8000 the ribbon element stays in phase but drops off in magnitude so that the directivity resulting from cancellation gradually diminishes with increasing frequency, but this has been made to coincide with the increasing directivity of the dynamic element. Consequently, there is no loss of directivity in the transition region and at 8000 cycles where control of the ribbon phase is lost, it is contributing so little to the output that it doesn't matter. Still another bit of matching occurs in the zero incidence response where the falling off of the equalized ribbon response is offset by the rising characteristic of the moving coil unit. The actual performance of the microphone is shown by the response curves of Fig. 12.

The problem of equalizing the low end of the two elements to achieve the discrimination shown in Fig. 12 is so closely associated with that of reducing wind noise caused by fluttering of the ribbon that the two may be discussed simultaneously. From the standpoint of wind noise, the thicker the ribbon material, the stiffer the ribbon, and the greater the stability. Offhand, since the sensitivity is proportional to the mass of the ribbon, it would seem that a thicker ribbon would result in too high a loss but this is partly offset by the reduction in electrical resistance. A compromise was selected in the form of a ribbon 10 to 15 times as stiff as those normally employed in ribbon microphones, and yet causing a loss of only 1 db. Such a ribbon, however, resonates at approximately 45 cycles causing a large peak in the low end response, unless provision is made to suppress it. Placing a shunt inductance and resistance, however, across the ribbon terminals not only introduces damping of the ribbon through electromagnetic coupling, but also shifts the phase to correspond to that of the moving coil element. This is illustrated by curves *C* and *D* of Fig. 9 and *D* and *E* of Fig. 11.

A thick ribbon formed with corrugations over its whole length, a form commonly used for thinner ribbons, has harmonic modes of vibration within the useful frequency range. This problem is solved by a unique ribbon form. The ribbon is given a cylindrical curvature over most of its length and is corrugated at each end so that the action is more like a bar hinged at each end. By this means the fundamental mode of vibration is affected very little but other modes are effectively suppressed. The curves of Fig. 13 make clear the extent to which the microphone response is smoothed out by the action of this new type ribbon.



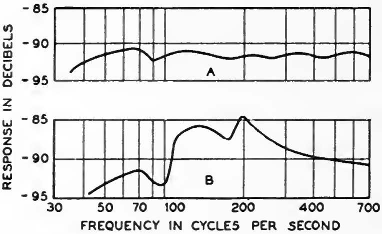


FIG. 12. (*Center.*) Field response of a representative model of the *639-A* cardioid directional microphone.
FIG. 13. (*Lower.*) Low-frequency response of ribbon elements.
A—new type thick ribbon with longitudinal stiffening.
B—Thick ribbon with lateral corrugations.

Besides achieving a smooth response that matches that of the dynamic both in magnitude and phase, the stiff ribbon reduces wind noise to a level approximately 10 db lower than that encountered with usual ribbon microphones. This is of considerable importance since it permits the microphone to be used more freely outdoors where breezes are often unavoidable, and for the first time makes "panning" of a ribbon type from a boom practicable. Also there is less likelihood of damaging the ribbon by exposure to a sudden gust of wind, especially since mechanical stops are provided which prevent motion of the ribbon beyond the elastic limit of the material. This does not mean that the ruggedness of the dynamic type has been matched, but it does assure a wider field of application for a ribbon element than has been possible heretofore.

The network required to accomplish these results is quite simple electrically, but the physical size of the condenser required is quite inconvenient if the circuit is to be included in the microphone. An obvious way around this would be to transform the condenser circuit up to a higher impedance where a smaller capacity could be used and then transform down again to the microphone impedance. Offhand, it might seem that the transformers required would offset the saving in condenser size, but a transformer is normally required anyway to bring the very low impedance of the ribbon up to a useful value. A third winding has been added to the transformer, so coupled to the primary and secondary that a condenser $^1/_{20}$th the size could be used and without any increase in the transformer size. Fig. 14 illustrates the reduction in size of the equalizing network made possible by the three winding transformer. Thus it is entirely feasible to include all of the circuit elements inside the housing of the moving coil element, resulting in a compact instrument.

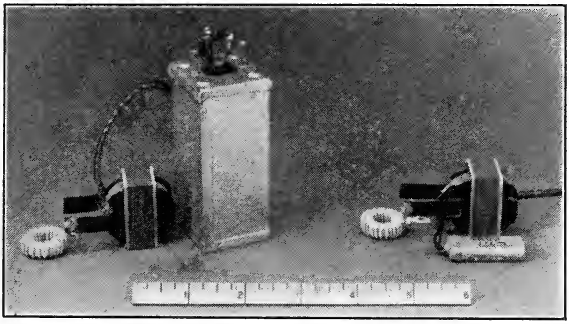


FIG. 14. A special 3-winding transformer makes possible the reduction, illustrated in the size of the elements required in the electrical equalizer.

We are now in a position to appraise the overall performance of the new *639-A* cardioid directional microphone. The output level is quite high, 84 db below 1 volt/dyne/cm^2 or 64 db below 1 volt/10 volt/dyne/cm^2 open-circuit voltage across its terminal impedance of approximately 40 ohms. This is a level 4 to 5 db higher than that of the Western Electric *630-A* or *633-A* dynamic types already mentioned and only 2 db lower than that of the Western Electric highly efficient *618-A* dynamic. The normal incidence response of the cardioid combination is smooth over the frequency range from 35 to 10,000 cycles (Fig. 12), and there is hardly any perceptible quality change for any angle of incidence up to 120 degrees. Provided the discrimination is good, the quality of the response at the angles greater than 120 degrees is of little importance because of the very low sensitivity in this region.

For the switch in the *D* (dynamic) position, the microphone performance is similar to that of the Western Electric *630-A* with the acoustic screen removed, both with respect to quality and output level, as shown in Fig. 10. While there is a change in quality with angle the performance of the dynamic is essentially nondirectional as far as problems of reverberation and feedback are concerned. Since this type is so well known in the field, there is no need to elaborate here the pick-up technic. Likewise the performance of the ribbon element alone, switch in *R* position, is similar to that of well known studio ribbon microphones as far as its bidirectional characteristics and quality are concerned. The output level is the same as that of the dynamic alone, 90 db below 1 volt/dyne/cm^2, a level which is recognized as being sufficient for general use.

In order to demonstrate how closely the new microphone follows the cardioid directional characteristic at all frequencies, polar curves have been plotted in Fig. 15 on a decibel scale. Percentage scales are often used for this purpose but are likely to be misleading since 50-per cent reduction looks like a lot more than the 6 db it actually is to the ear. Since the agreement with the theoretical characteristic is so good, the cardioid curve may be used for all practical purposes.

For ready reference, therefore, the chart of Fig. 16, has been prepared. The figure has been shaded from light to dark to give a visual indication of the variation of sensitivity with angle. Also several zones have been designated as an aid to remembering how to utilize the performance of the microphone to best advantage. A "wide pick-up" zone of 120 degrees represents the region in front of the microphone where there is practically no variation in quality or sensitivity. The "fading" zone from 60 to 150 degrees on either side

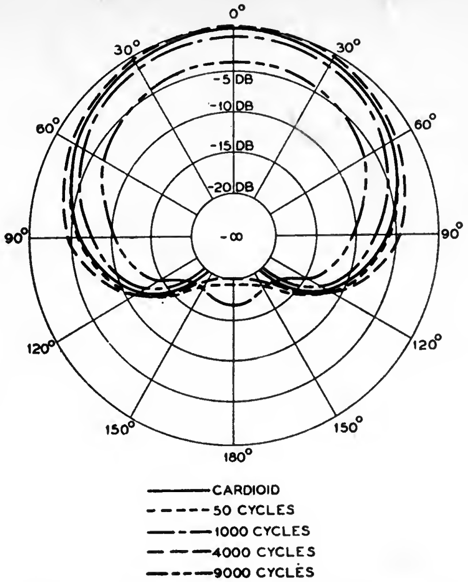


FIG. 15. These polar curves demonstrate how closely the *639-A* approaches cardioid directivity over a wide frequency range.

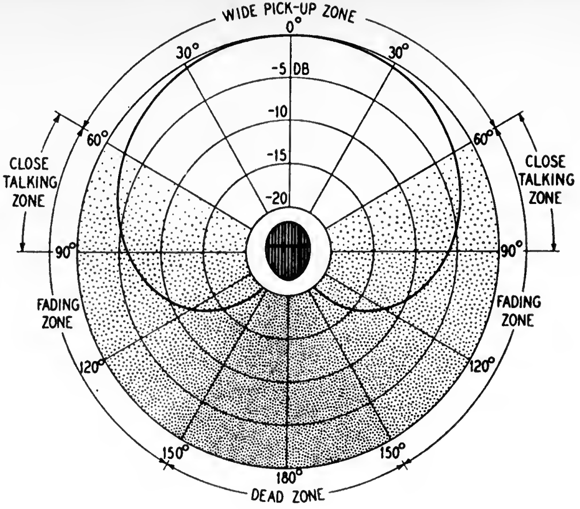


FIG. 16. Reference chart for interpreting the performance of the *639-A* cardioid directional microphone.

indicates that here the sensitivity changes rapidly with angle and care must be exercised to keep within range of the microphone. The dead zone of 60 degrees at the back of the microphone is that for which sounds are discriminated against by approximately 20 db. In addition to these three principal zones, the sector from 60 to 90 degrees on either side has been selected as a close talking zone.

To understand the reason behind this close talking zone requires a little explanation. The human voice is radiated as a spherical sound-wave, for low frequencies at least. Now it is a property of a sperhical wave that, whereas the pressure is independent of the wavelength, the pressure gradient is not, and becomes proportionately very large for points close to the source compared with the wavelength. As a result, a microphone of the ribbon type, which responds to the pressure gradient, will, when placed close to a spherical sound source such as a person talking, favor the lower frequencies of long wavelength. This is why ribbon microphones in general use are provided with speech "straps" which equalize for low-frequency boom on close talking. The necessity for this can be avoided, however, in the new microphone by talking at 90 degrees, for in this position the ribbon element is contributing practically nothing, leaving the pick-up to the dynamic element which is not affected by the spherical character of the sound field. Although this zone is recommended for close talking, it should be recognized that since the ribbon element contributes only part of the output, the accentuation of its low-end response by a spherical wave, is only partly reflected in the response of the combination microphone. Consequently, even at full front the new microphone does not accentuate lows in closely delivered speech nearly as much as the ordinary ribbon microphone.

Exploring of the possibilities of this cardioid microphone in improving the technic of sound motion picture recording has only just begun, and the results are being awaited with interest. Trials in other fields, however, have been so fruitful that three representative set-ups will be described here as typical of the results that can be expected from the new microphone.

A small symphonic orchestra of around 30 members was selected for one of the studio experiments. The studio selected was one in which considerable pick-up difficulty had been experienced, and the microphone and orchestra placements are shown in Fig. 17. Note that the microphone was set with its dead zone backed near a wall leaving plenty of room for arrangement of the orchestra within the

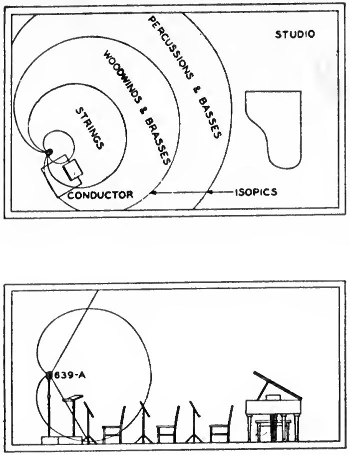


FIG. 17. Studio arrangement of small symphonic orchestra for pick-up with the cardioid directional microphone.

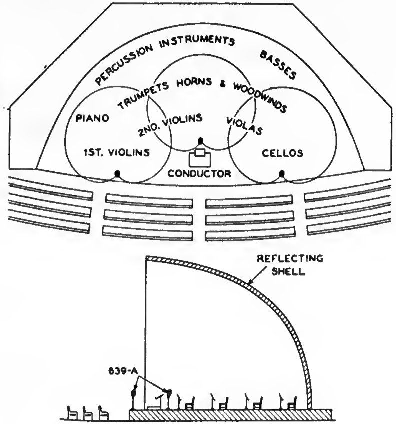


FIG. 18. Placement of three cardioid microphones to cover large symphony orchestra at open-air concert.

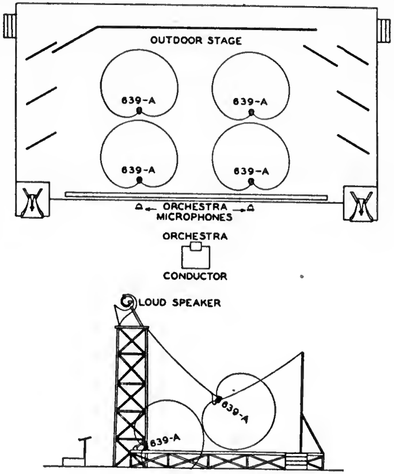


FIG. 19. Placement of four cardioid microphones to allow opera singers full freedom of the stage.

wide pick-up zone. Because of the directional characteristic, reflections from the back wall were prevented from interfering with the direct sound without having to resort to an acoustic screen or special damping of the wall surfaces. Without particular care being paid to its exact position, the new microphone handled the situation perfectly although the studio was quite "live" in character. The quality of the reproducing sound was characterized by unusual definition and sense of space; the brasses, the woodwinds, and the strings particularly standing out in full naturalness. Also the bass was very rich and clear without being "boomy." This result was directly attributable to the true cardioid directional characteristics of the microphone.

The reason for the unusual quality obtained may be attributed to three principal features of the new microphone. First, the directionality gave a control of the balance between the direct and reverberant sound so that the individuality of the instruments was not lost in a meaningless jumble of reflections. Second, because of true cardioid directional response for bass as well as treble tones, indirect sound or reflections that were picked up were transmitted with high fidelity. Just as a room finished entirely in red would offend our eyes, so would pick-up from a microphone which discriminates against all reflected sounds except the bass seem boomy; or as a predominant purple *motif* might offend our taste, so would the result from a directional microphone which failed to suppress high-frequency reflections grate on our nerves. In other words, the quality of the microphone is good in the fading zone as well as the wide pick-up zone, so that the total pick-up was evenly balanced.

Furthermore, since the microphone is made up of a pressure and pressure gradient element each responding to different properties of the sound, the effect of "dead spots" in a studio are practically eliminated by the use of this instrument. Every room has characteristic tones resulting from standing waves which are set up at certain frequencies by reflections from the walls. Now in a standing wave there are nodes at which the pressure is a maximum and the pressure gradient zero and vice versa. As a result, these nodes are "dead spots" for one type or the other, but in combination both can not be "dead" at once. This important feature, no doubt, contributes to the "clear bass" observed in the pick-up.

For another trial, the pick-up of a large symphony orchestra in an open air ampitheater was selected. The general layout of orchestra, audience, and microphone placement is shown in Fig. 18. Because of the large stage and necessity of separating the audience, three *639-A* cardioids were used, two on each side of the front of the stage, and a third directly in front of the conductor. This third microphone covered especially the string instruments and "heard" very closely, the same thing as the conductor himself, but the dead zone discriminated against accidental noise caused by the conductor. All instruments of the orchestra were within the wide pick-up zone of one microphone or another without tilting. Furthermore the effect of the overhead shell, designed for the benefit of the audience and not pick-up, was minimized by the cardioid directional characteristic. With this set up it was possible to secure a balance and fidelity of pick-up which had not been possible to achieve previously with other types of microphones. The enthusiasm expressed by the conductor was an indication of the appreciation that fine musicians have for a device that enables them to put across their art to the vast unseen radio public, without losing the fine details they have worked so hard to put into their playing.

Perhaps the most interesting of the trials, in that it illustrates the versatility of the microphone, was in a sound reinforcement system for an opera staged in an open-air theater. The stage layout and microphone placements are shown in Fig. 19. Four *639-A*'s were employed, two in the footlights pointing 30 degrees up and two hanging overhead half way back and pointing degrees 30 down. With this arrangement it was found that with fixed levels on the mixer, very little variation in quality or level could be observed when a singer walked across stage or from front to back. Thus the director was informed that he need not instruct the singers to play to the microphone. To the best of our knowledge this was the first time it has been found possible to cover a stage so completely; and it is suggested that this method might be considered for application to certain scoring problems. The true cardioid directional characteristic obviously made this result possible, the performer moving into the pick-up zone of one microphone after another as he walked about the stage. Furthermore, the orchestra was in the dead zone of the microphone so that there was normally plenty of leeway to balance the singing with the orchestra pick-up, and feedback conditions were improved by approximately 5 db over that obtainable with other types. Throughout the performance the engineer, operating the mixing controls, was able to operate the four stage microphones together as if only one; and thus could concentrate on balancing the singing with the orchestra.

The results from the audience viewpoint were startling, some people saying that they did not believe the public address system was operating when actually reinforcement was practically all they did hear. The freedom permitted the performers aided this illustion greatly, besides allowing them to act in their accustomed manner. Again the enthusiasm of artists and engineers alike, were a tribute to the unusual possibilities in this new microphone.

These actual trials here described, as well as many others which space prevents relating, all testify that pick-up control at the microphone, a long cherished dream has at last been actually accomplished. The key to this control is the directionality for all ranges of the musical scale from the lowest bass to the highest overtone. The range of this control is from non-directional to bi-directional to cardioid-directional performance, but of the three, it is expected that the cardioid characteristic may prove to be the most useful form of directivity.

The secret behind the success of the Western Electric *639-A* in achieving this true cardioid directional performance lies in the choice of the type of pressure and pressure gradient units and the method of electrically equalizing and combining the outputs. These also are responsible for the high output level of the combination, the ability to choose the dynamic, or ribbon units individually, the convenient size, and the sturdiness. In addition to its ability to handle any situation, to provide control at the microphone, the new *639-A* cardioid simplifies the technic of pick-up because of its indifference to "dead spots" in the room while at the same time its "dead zone" of sensitivity minimizes unwanted slap-back reflections.

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DISCUSSION

MR. KELLOGG: I would like to ask three questions: You have stiffened up the ribbon. It is my impression that although this gives you lower resistance it does not make up for the reduced amplitude. How much sensitivity did you have to sacrifice in stiffening the ribbon? What are the separation and relative positions of the pressure and velocity units? Will not the curve be somewhat altered if the source of the sound is not in the equatorial plane of the ribbon, or is the wavelength below 3000 cycles long enough to make the effect negligible? You spoke of damping the ribbon by shunt inductance: I can imagine how shunt inductance could affect the velocity and phase of the voltage but as a damping agent it seems to me that any inductance would be prejudicial. Am I correct about that?

MR. MARSHALL: Regarding the first question, how much loss is obtained by stiffening the ribbon, the loss is of the order of 1 db. The curve of sensitivity *vs.* ribbon thickness has a sufficiently broad peak that considerable departure may be made from the optimum without taking a serious loss.

The response of the ribbon unit, since it is essentially a mass-controlled unit, is proportional to the weight of the ribbon plus the mass loading of the air. Therefore increasing the ribbon alone two and one-half times does not increase the effective mass that much, and at the same time the electrical resistance is also reduced. There are also other factors that have to be taken into account, such as the leakage path around the edges of the ribbon and the width of the baffle path and so forth. I would say that the formula we used for calculation shows a theoretical loss of about 0.9 db and we have checked that pretty closely.

As to your second question—"How did the directivity vary in the vertical plane"—it is well known that the separation of the microphone units will cause a phase shift between them at high frequencies. In this particular microphone the separation is approximately $1^1/_2$ inches, I believe. As you yourself intimated, the fact that we are filtering out the ribbon unit at 3000 cycles enables us to retain directivity that is more uniform than one might expect. The directivity in the horizontal plane does not vary seriously. With respect to the vertical plane it does vary a little. The phase shift we do get will either be helpful at some point and give better directivity, or be harmful and give less. The average is about the same in this particular unit.

As to how the ribbon becomes damped by the use of shunt inductance, the shunt inductance does two things. Not only does it introduce electrical loss but at the same time allows current to flow back through the ribbon. It is a sort of feed-back principle in which the current that goes through the inductance regulates the motion of the ribbon. There is also some electrical resistance which is reflected back, through the electromagnetic coupling, into the mechanical side.

MR. KELLOGG: Is not the presence of the inductance prejudicial to the damping of the amplitude of the ribbon?

MR. MARSHALL: No; as can be shown theoretically and practically. One may call it prejudicial, but it does perform in a uniform manner. I have not observed anything undesirable from shunting.

I tried to outline a moment ago that we have a way of regulating some of the output. The equations show that the magnetic coupling factor is sufficient to bring down the response to a point where it is satisfactory and can be controlled. As a matter of fact, the size of the inductance has to be controlled to take care of variations in flux density, and we get a proper coupling factor which reflects back the right amount of this so-called feedback current and resistance. It is quite complicated. There is actually a resistance in this inductance circuit as well as feedback current. There is also electrical loss and all three factors are concerned in the problem.

MR. STEVENS: Is it impossible to obtain at high frequencies better directivity than shown by your curves?

MR. MARSHALL: No, but this was the best we were able to do with this particular microphone at this time.

MR. STEVENS: In your opinion is it possible to provide more?

MR. MARSHALL: It is possible, but we run into factors at high frequencies that make it very difficult, such as diffraction effects and phase-shift caused by separation of the units.

MR. WILLIAMS: I assume that the curves you show were taken in a plane wave?

MR. MARSHALL: There is no such thing, practically. Field calibrations have been standardized in terms of plane waves and, of course, we approximate a plane wave the best we can.

MR. WILLIAMS: I believe I am right in saying that there is considerable difference between a plane wave and a spherical wave near the source. You have corrected for the two and added cancellation from the back in the plane wave.

MR. MARSHALL: That is correct.

MR. WILLIAMS: You have demonstrated what part the spherical wave plays. Do you get equally good cancellation in the plane wave?

MR. MARSHALL: We get better.

MR. KIMBALL: What is the variation in output level in the three switch positions?

MR. MARSHALL: A ratio of two to one. Naturally, with one unit we get half as much voltage.

MR. STANCIL: When the switch is on the cardioid position, a low-pass filter cuts in above 3000 cycles attenuating the ribbon element. Now, if this switch is turned to the ribbon position, would the filter still be in the circuit, attenuating much of the high-frequency response?

MR. MARSHALL: No. The switch when turned to ribbon position also removes the filter or equalizer circuit.

MR. HILLIARD: What is the characteristic of the non-directional unit compared with that of the *630* mike.

MR. MARSHALL: It is similar to the *630* without the screen. The same dynamic unit that is used in the *630*, is used in the *639-A* without alteration or change.

MR. THAYER: Does the difference in the front of the moving-coil housing of the *630* and *639* have any effect on the response?

MR. MARSHALL: Yes. If you will recall, the curve I showed of the dynamic action was the curve of the *630* microphone without screen. The acoustic screen of the *630* keeps out the residual directional effect at high frequencies and if you remove it, the microphone becomes semi-directional.

MR. THAYER: The diaphragm housing of the *639* mike is different from that of the *630?*

MR. MARSHALL: There is a difference but the difference is not such as to affect the directional pattern seriously. The major portion of the directional effect in this microphone is due to the physical size of the diaphragm, which is about $1^1/_4$ inches in diameter.

DR. DAILY: On account of the physical separation between the velocity and pressure elements of this type of microphone, there will be peaks and valleys in the response characteristic, their amplitude depending to some extent on the angle of incidence of the sound-wave. Is there an appreciable increase in the differential amplitude of these peaks and valleys as the angle of incidence changes from normal to 35 or 40 degrees?

MR. MARSHALL: There will not be much effect until you get around to the back. Up to 90 degrees it might be about ±2 db. At the back the variation may be as much as ±4 db.

CHARACTERISTICS OF MODERN MICROPHONES FOR SOUND RECORDING *

F. L. HOPPER**

Summary.—*Factors influencing the choice of a microphone for sound recording are considered. The characteristics of a new miniature condenser transmitter and amplifier, as well as a number of other types of microphones now in use, are included.*

One of the most interesting problems with which the sound engineer has to contend in the communication, broadcasting, and sound recording fields, is the provision of a suitable instrument to translate the acoustic variations in speech and music to corresponding electrical variations. The microphone performs this function, and the purpose of this paper is to consider its application to sound recording for motion pictures.

Requirements for microphone performance in sound recording are somewhat more critical than in other fields. This is due to the variety of pick-up conditions encountered, and to the necessity of listening to the recorded material many times during the course of production. In dialog recording, the microphone position is changed almost continuously to allow wide scope of action on the set. Set construction, lighting, and camera angles necessarily limit a choice of microphone position and often make it difficult to secure an optimum position. These restrictions become less severe if the microphone is sufficiently small so that it may be easily kept out of the field of view of the camera. It should be light in weight so that it may be used interchangeably on a microphone boom or upon a fishpole when space requirements restrict the use of a boom. A light-weight microphone is more easily handled for action shots where rapid movements of the microphone are required to cover action properly. Its use for this latter type of pick-up predicates freedom from wind noise and mechanical shock. Dialog recording on location or for newsreel

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** Electrical Research Products, Inc., Hollywood, Calif.

service requires the instrument to be sufficiently rugged to withstand mechanical shock, and to be relatively unaffected by wind, altitude changes, temperature variations, or moisture.

Program material in sound recording is not transitory in character. One scene may be repeated a dozen times for the benefit of action or photography, and the subsequent reproduced recordings must of a necessity be judged for acceptable sound quality in the review room. By having an opportunity to become familiar with the quality of the actor's voice, both by direct listening on the set and from the reproduced recordings, a fairly critical estimate can be made of this quality throughout the picture. If different microphones, or different types, are used from day to day, any variation in quality due to microphones is easily perceived. This, of course, places a premium on similarity of response characteristics of various microphones of the same type, and upon their ability to maintain such a characteristic in service.

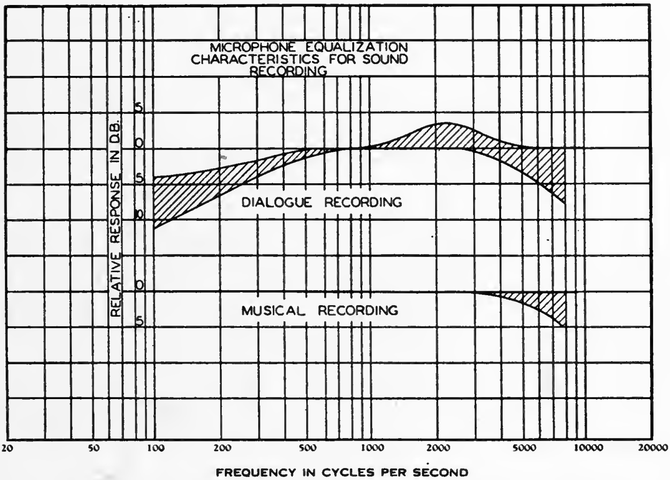

FIG. 1. Equalization characteristic for sound recording.

Another limitation is the present-day use of monaural sound systems.[1] Listening with both ears, binaurally, the sound-sources can be localized, and the interfering effects of background noises and reverberation minimized. The microphone inherently can do neither. To compensate for these deficiencies, present technic requires that the microphone be placed close to the sound-source to minimize these disturbances, or the use of an instrument having marked directional properties.

With some of these factors in mind, consideration may be given to the requirements for an ideal microphone. In the first place, the output should contain all the frequency components present in the original with comparable amplitudes, and within certain limits bear the same phase relationship to each other. It is essential that the microphone's electrical output be sufficiently high so that the noise-level of the system to which it is connected does not become a limiting factor. Its directional characteristics are not as easily defined since various degrees of directivity may be required. Size and weight play an important part in its ease of handling on the stage, and susceptibility to such interferences as wind, movement, and power exposure, must be considered.

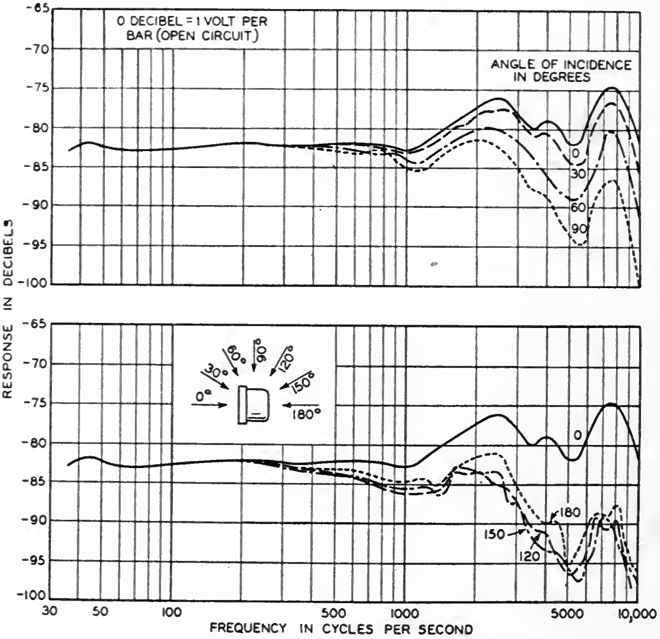

FIG. 2. *618-A* microphone characteristics.

Present-day designs approach these fundamental requirements, and offer instruments which may be successfully adapted to sound recording. It might appear that with such devices it would be necessary only to connect them to a recording channel and proceed. We find, however, that due to factors such as set acoustics, differences in the actor's speech volumes as originally heard and subsequently reproduced, and certain considerations of the recording and reproducing system characteristics, some modification of the microphone response characteristic is required. This is usually accomplished by electrical equalization in the recording system, or sometimes by the addition of devices to the microphone for acoustically altering its response. While such equalization necessarily varies with the type of microphone used, and class of recorded material, it usually falls within the limits indicated in Fig. 1. The two sets of limits correspond to those employed for dialog and musical recording, and differ principally in the amount of attenuation used at low frequencies. The attenuation of low frequencies in dialog recording is occasioned by set acoustics and volume differences in the original and reproduced material. By set acoustics is meant reverberation, the possibility of first-order reflections from walls or objects on the set, and vibration of insecurely braced walls or set materials. Volume differences in original and reproduced dialog are occasioned by the higher volumes required in the theater for satisfactory reproduction, and due to the non-linear characteristic of the ear, represent an increase in low-frequency response which is compensated for by equalization in recording. The indicated increase in response in the region of 2500 cycles is sometimes employed to increase "presence." "Presence" refers to the completeness of illusion that the voice from the theater screen is emanating from the pictured actor. This results in a feeling that the sound is being reproduced intimately at the screen, and not at some location remote to it.

Microphones now in use generally belong to one of two groups: the electrodynamic, including the various pressure-operated moving-coil types, and pressure gradient ribbons; or the electrostatic devices, represented by the condenser transmitter. The salient properties of those in common use, as well as some of the more recent types are given in Table I.

Extensive descriptive material has been published covering the *618* and *630* type microphones.[2,3] The *639* type has been described fully by Marshall and Harry.[1] The *640-A* transmitter is an improved miniature condenser.[4] Its use, with the *RA-1095* transmitter amplifier, has not been previously described and will now be considered. Condenser microphones have been used in one form or another since

TABLE I

Microphone Code	Principle of Operation	Frequency Response	Directional Characteristic	1000 Cycle Output*	Output Impedance	Weight
618-A	Dynamic moving coil	Fig. 2	Semi-directional at high frequencies	−83 db	30 ohms	2 1/2 lbs
630-A	Dynamic moving coil with acoustic screen	Fig. 3	Non-directional	−89 db	20 ohms	1 lb
630-A	Dynamic moving coil with flat baffle	Fig. 4	Semi-directional at high frequencies	−89 db	20 ohms	1 lb
639-A "C"	Combined moving coil and ribbon	Fig. 5	Uni-directional Cardioid	−84 db	35 ohms	3 1/4 lbs
639-A "*R*"	Ribbon		Bi-directional	−90 db	30 ohms	3 1/4 lbs
640-A *RA-1095* Amplifier	Condenser	Fig. 6	Semi-directional at high frequencies	−61 db	50 ohms	1 1/4 lbs

*0 decibel = 1 volt per bar (open circuit).

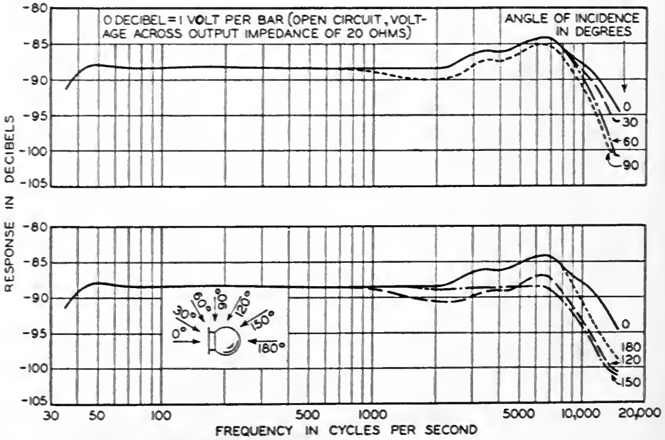

FIG. 3. *630-A* microphone with screen.

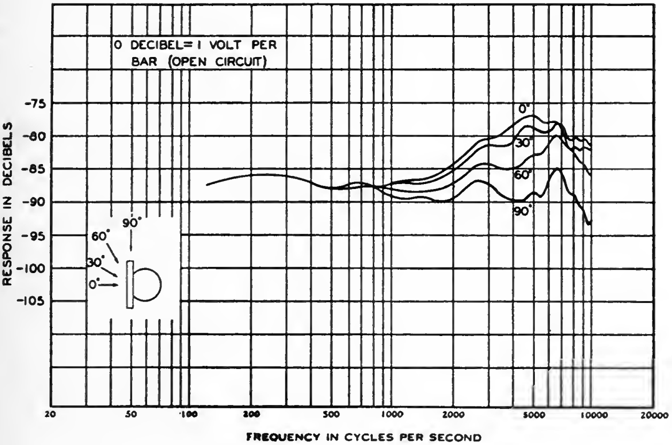

FIG. 4. *630-A* microphone with a $3^1/_4$ baffle.

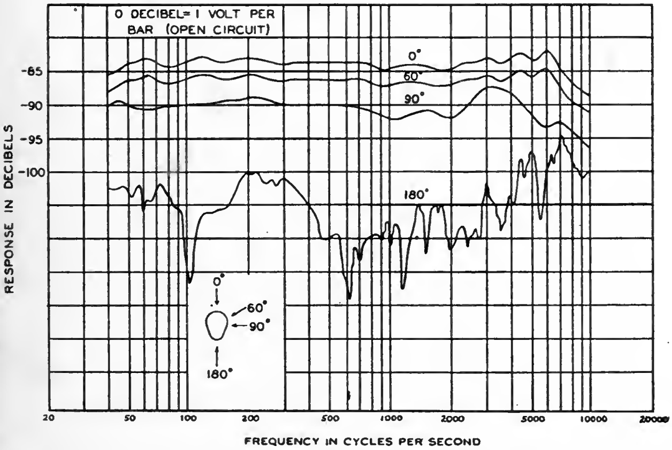

FIG. 5. Laboratory model of *639-A* cardioid directional microphone.

the inception of sound recording and, prior to that, in communication systems. With the development of the smaller and lighte moving-coil microphones, their use has gradually diminished. Now, due to recent developments of the Bell Telephone Laboratories i providing a miniature transmitter, vacuum tube, and output transformer, a design becomes possible that can compete with the moving-coil type with respect to size and weight. The condenser transmitte has an inherent advantage over the moving-coil microphone in tha its mechanical structure is relatively simple. As a result, it possesse a smoother response characteristic than has been practicable in the moving-coil type. For the same reason it has been possible to maintain a much greater degree of uniformity among various individual condenser transmitters, than between various moving-coil microphones of the same type. The high quality of performance of whic this microphone is capable, together with its convenient physic form, promises to re-establish as a recording tool.

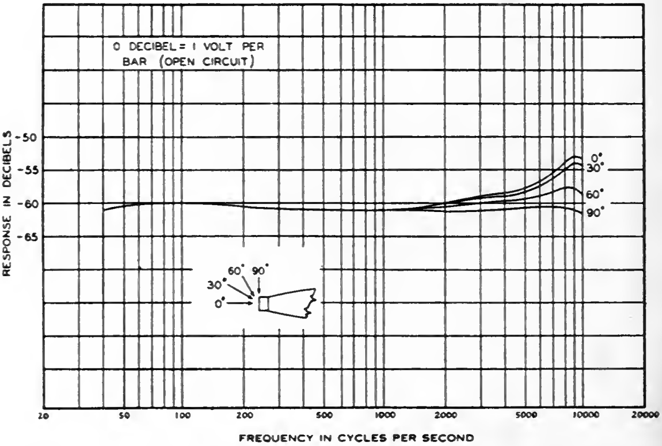

FIG. 6. *RA-1095* amplifier with *640-A* condenser transmitter.

The appearance of the amplifier and associated condenser tran mitter is shown in Fig. 7. The microphone amplifier is about 7 inche long, with a maximum diameter of $2^1/_2$ inches, and weighs 1^1 pounds. The tapered shell housing is easily removed from the chass by loosening two screws at the base, and sliding it from the chassi The chassis consists of a metal frame carrying all equipment. Th vacuum tube and transmitter coupling mesh are mounted on mat rial possessing high insulation resistance, and a number of precautio have been taken both to establish and maintain it. The vacuum tube is of the heater type designed for long service, and is soldered into its socket, which reduces contact troubles and helps to maintain a high degree of insulation. These soldered connections represent no hardship in use, as it is usual studio practice to replace defective microphones on the stage with others, and to repair them elsewhere. A terminal strip on the base of the chassis permits changing output impedance, and ground connections to operate under varying studio conditions.

The combined acoustical and electrical characteristics of the *640-A* transmitter and *RA-1095* amplifier are shown in Fig. 6. This characteristic is a combination of the acoustic response of the transmitter, any effect that the amplifier housing may have upon the transmitter's response due to its modification of the sound field, and the amplifier's electrical characteristic. Since the amplifier frequency response is essentially uniform over the range of recorded frequencies, it may be considered as a means of coupling the transmitter to its associated recording circuits. Previous laboratory data indicate that the characteristic illustrated is essentially that of the transmitter; hence we may conclude that the amplifier housing does not appreciably effect the transmitter response. The rise at high frequencies in the normal incidence response is caused by the diffraction of sound by the microphone. Diffraction effects, however, are fairly small for angles of incidence greater than 60 degrees, and it is the usual practice to use the microphone in such a manner that most of the desired sound is incident at these angles. Referring again to Fig. 6, the response characteristics for angles of incidence of 120, 150, and 180 degrees, are essentially those shown for 90-degree incidence. The output of the amplifier is approximately −61 db/one volt per bar,

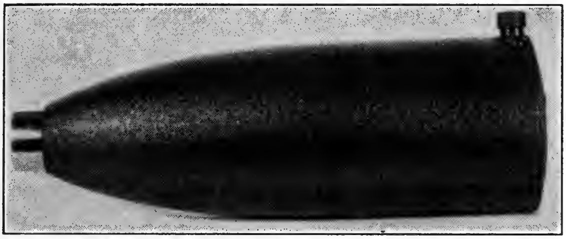

FIG. 7. *640-A* transmitter and associated amplifier.

open circuit. It is about 24 db greater than the output of the *630-A* microphone. The noise output compares favorably with that of similar amplifiers employing large tubes especially selected for low-level circuit application. Numerous recording and listening tests have indicated that this instrument provides improved overall quality, greater naturalness, and intelligibility, compared with older types of microphones.

For stage pick-up microphones are usually supported by means of fishpoles or microphone booms to permit rapid movement of the microphone about the set to cover the action properly. As a result the microphone is subject to considerable mechanical vibration, and some form of insulating mounting is required to prevent these vibrations from being transmitted to the microphone and thus recorded. Two types in common use are the double-ring and the double-plate forms. In the first a double-ring mounting is used, the inner ring being fastened to the outer by means of elastic bands. The microphone is then clamped in the inner ring, the outer being fastened to the boom head or fishpole.[5] This form of mounting is applicable to microphones having cylindrical housings, such as the *618* or *RA-1095* condenser transmitter amplifier, or with an adapter to the *630* type microphone. The plate type of mounting adapted to a *630* microphone is shown in Fig. 8. In this type two plates are isolated from one another by means of Lord rubber mountings. The microphone is carried by one plate, the other being attached to the boom.

Fig. 8. Plate type of mounting, adapted to *630* microphone.

When microphones are used in the presence of wind, slight changes in wind velocity cause corresponding changes in pressure at the face of the microphone, resulting in a low-frequency disturbance in the microphone output. The amplitude of the disturbance is often sufficiently high to interfere seriously with the recording. A windscreen or bag affords a method of minimizing this pressure change, and is quite effective in increasing the microphone's usefulness under such adverse pick-up conditions. The wind-bag in its simplest form consists of a wire screen cage surrounding the microphone. It is usually covered with two layers of porous silk separated by a small air space. It effectively forms a high-pass acoustic filter and attenuates the very low-frequency wind-pressure variations. Over the recording range, it has little effect upon the microphone response characteristic. A typical wind-bag for use with the *630-A* microphone is illustrated in Fig. 9.

Maintenance of microphone equipment in a studio includes a periodic check of the response characteristic and volume output. This is usually accomplished by comparing a standard calibrated microphone of the same type, with the one under test. The measurement is sometimes made as a listening test, with both instruments being alternately connected to a monitoring system, or, more frequently, some sort of acoustic measurement employing a sweep oscillator, and level recorder, from whose charts comparison is made between the calibrated microphone and the one under test. Another common problem where microphones having magnetic structures are used, is that of removing iron particles picked up by the unit. By the use of a brush and some form of sticky tape, it is usually possible to remove them.

FIG. 9. Wind-bag used with *630-A* microphone.

It has been the object of this paper to indicate a number of factors that materially influence the choice and operating conditions for a microphone for sound recording. The characteristics of a number of commercial types in use have been shown, and a brief description has been given of a new miniature condenser transmitter and amplifier giving improved performance.

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THE CLASS A–B PUSH-PULL RECORDING SYSTEM*

C. HAWLEY CARTWRIGHT** AND W. S. THOMPSON†

Summary.—*After an explanation of the term Class A–B and a brief specification of such a recording system, the general requirements for the operation of any Class A–B system are given and illustrated.*

Differences between the operation of push-pull photocells and push-pull vacuum tubes are pointed out and explained, and a discussion of the relative advantages of Class A, Class A–B, and Class B push-pull tracks is given.

A push-pull sound-track consists of two simultaneously recorded tracks that are mutually related so that the original sound can be reproduced by means of a push-pull reproducing system.

A push-pull reproducing system consists of essentially two photocells for detecting the signals recorded on the two component parts of a push-pull track. The two photocells are both connected to a sound producing system and are mutually 180 degrees out of phase.

For a push-pull Class-A sound-track each of the two component tracks are complete records which are recorded 180 degrees out of phase. When the detecting system is in perfect balance, all even-harmonic distortions produced by processing of the two component tracks are automatically eliminated. When the detecting system is not in perfect balance, even-harmonic distortions are still partially compensated and since both component tracks are complete records no additional distortion is introduced due to the unbalance; simply an attenuation of the signal strength occurs. (This attenuation may be selective depending on the nature of the unbalance.) As with standard recording, the ground-noise reduction is accomplished by means of automatically operated shutters. Ideally any modulation produced by movements of the shutter vanes should be automatically eliminated in the push-pull reproducer. Actually at present it is possible only about to double the shutter speed over that of a stand-

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ard recording before noticeable distortion occurs. Due to this gain in shutter speed the clearance lines are reduced to half the width of that used for standard recording and hence the ratio of signal to ground noise is increased by about six decibels.

For a push-pull Class *B* sound-track, only deflections of the recording galvanometer in one direction from its nul position are recorded on one of the component sound-tracks; deflections in the other direction from the galvanometer's nul position are recorded on the other component sound track. Since the two component records must be combined perfectly to make a complete record, any unbalance in the reproducing system creates distortion. The main feature of the push-pull Class *B* sound-track is its inherent noise reduction. No shutters are required for noise-reduction and the ratio of signal to ground-noise is higher than for any other system of recording. The disadvantages of Class *B* recording are: (*1*) the necessity of a well balanced reproducing system, (*2*) the extreme sensitivity of the azimuth adjustment for the recording and reproducing slits, and (*3*) the critical requirements for processing the film and the dependence of the correct azimuth setting of the recording aperture on the film processing.

A push-pull Class A–B sound-track consists of a pure Class *A* record for low modulations up to a predetermined level and a combination of Class *A* and Class *B* records for higher modulations. The features of this type of recording are:

(*1*) Ground-noise reduction is inherent in the record;

(*2*) Azimuth adjustments in recording and reproducing are less critical than for Class *B* recordings;

(*3*) Film processing is less critical than for Class *B* recordings;

(*4*) Balance in the reproducing system is less important than for Class *B* recordings.

In the following description and analysis of Class *A–B* recording, only variable-area sound-tracks will be treated explicitly; however, there is an intimate correspondence to Class *A–B* variable-density sound recording which should be apparent.

General Requirements for a Class A–B Recording Aperture.—Due to the general familiarity with vacuum tube amplification, it may be well to point out the differences which exist between Class *A–B* vacuum tube amplification and Class *A–B* sound detection by the use of photocells. Fig. 1 illustrates the relationship between input and output voltages to be fulfilled by any push-pull Class *A–B* system.

For the pure Class *A* amplification both vacuum tubes or photocells are equally effective in producing an output voltage. Beyond the pure Class *A* portion only one device is operative and, hence, must yield twice the output per input ratio as it did for pure Class *A*. Efficiency considerations make it desirable to match impedances and in the case of the vacuum tubes this impedance matching can be attained and it automatically yields the ideal relation between input and output as shown in Fig. 1, except for a small distortion due to the toe characteristic of the vacuum tubes. That is, when one vacuum tube becomes inoperative, as is the case beyond the pure Class *A* amplification, the efficiency of the other is automatically doubled.

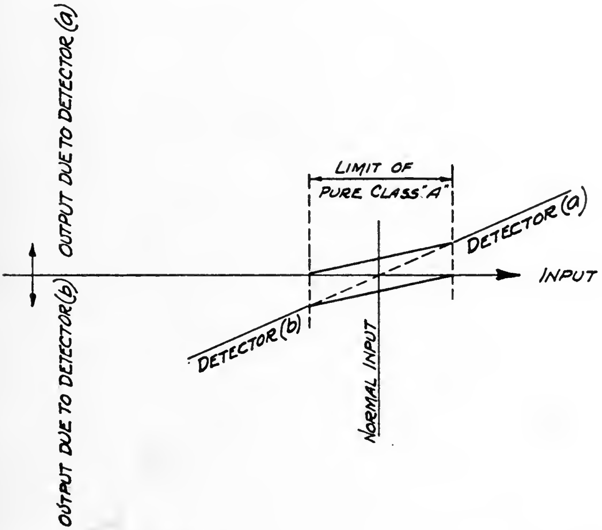

FIG. 1. Input *versus* output relation to be fulfilled by any push-pull Class *A–B* detecting and amplifying system.

In the case of photocells, the desired impedance matching is not attained and the efficiencies of the two photocells are practically independent. This means that beyond the pure Class *A* region the effective output per input ratio of each photocell acting alone must be doubled by some means. The means for doubling the effective output per input ratio which we have employed has been the use of a special recording aperture such that the change in the track width per change in the input to the recording galvanometer is half as great for the pure Class A record as for the region beyond the pure Class A record. Thereby the desired relation in Fig. 1 is fulfilled between the input to the galvanometer and the output of the push-pull reproducing system. Fig. 2 shows the relationship to be fulfilled between the deflection of the recording light-beam (which is proportional to the input to the galvanometer) and the width of the two component sound-tracks produced. Fig. 3 illustrates a Class A–B recording system. The requirements described in Fig. 2 can be fulfilled by several different apertures. The Class A–B shown in Fig. 4 could be produced by the aperture shown in Fig. 5.

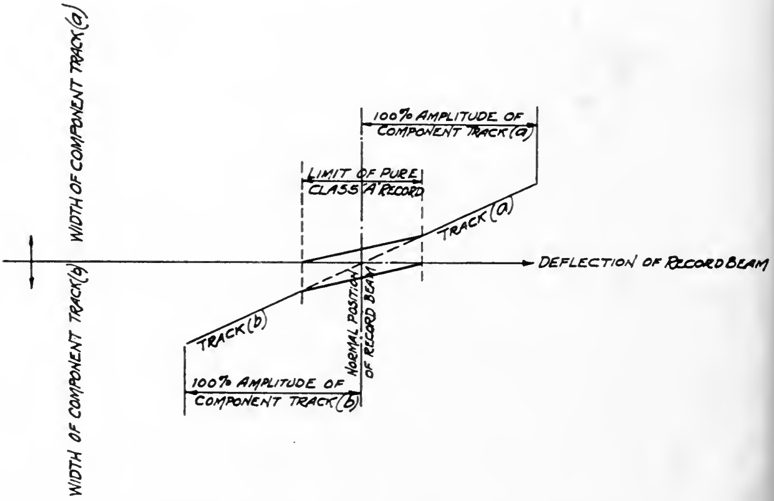

FIG. 2. Relation to be fulfilled between width of sound tracks and the deflections of the recording light-beam by a Class A–B recording aperture.

Detailed Description of Class A–B Recording Apertures.—Fig. 5 shows a Class A–B recording aperture which at full modulation gives two 35-mil component sound-tracks on the film with a minimum separation of 6 mils between the two component tracks. The sensitivity of this aperture is such that for full modulation the galvanometer deflection is the same as now being used in all standard equipment. The choice of dimension a or b depends on the proportion of pure Class A recording desired which, in turn, is proportional to the amount of ground-noise reduction inherent in the track produced.

Tails each 2 mils wide (about $^1/_4$ mil on film) are provided to lessen distortion due to processing. In Table I are data which show different values of a, the corresponding value of b, the inherent amount of ground-noise reduction expressed in decibels over a standard system used without any ground-noise reduction, the proportion of full modulation that is a pure Class A expressed in decibels, and the width of the zero lines produced on the sound-track film.

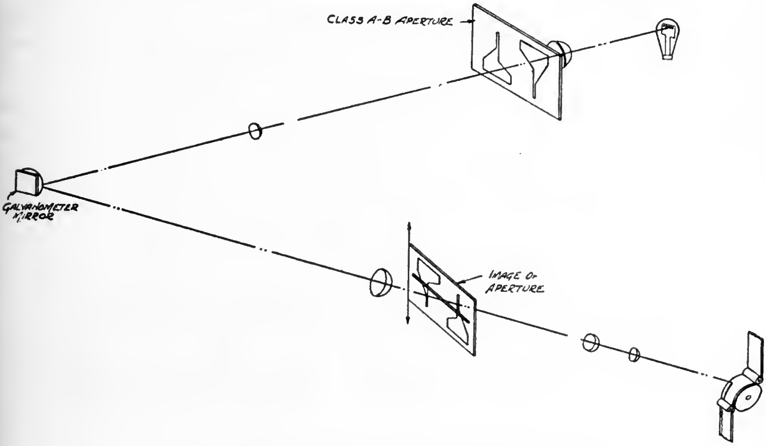

FIG. 3. Class A–B recording optical system.

TABLE I

Class A–B Recording Apertures

Noise Reduction (db)	End of Class A (db below 100%)	Width of Track with No Modulation (Mils)
12.5	−28	0.94
11.5	−25	1.25
10.5	−22	1.56
9.5	−21	1.87
9.0	−19	2.20
8.0	−16.8	2.80
7.0	−14.8	3.44
6.3	−13.2	4.07
5.5	−12.0	4.70

Azimuth, Modulation, and Distortion Tests of Class A–B Records.—An aperture as shown in Fig. 5 with the dimensions a equal to 15 mils was constructed and used for the tests to be described. For this aperture all modulations of less than about 15 db from full modulation produced pure Class A records.

Using a 400-cycle pure sine-wave signal a series of records was made for various azimuth settings and for various amplitudes. The harmonic distortion for these settings was measured by a distortion-factor meter connected to the output of a reproducing system.

The results of these tests show that the azimuth settings for Class *A–B* recording are much less critical than for Class *B* and that they are most critical for those levels corresponding to the level at which the Class *B* portion of the track is just starting. The limits of azimuth setting were such that azimuth could be set by visual inspection to yield a satisfactory recording from a distortion standpoint.

With the correct azimuth setting, harmonic distortion was measured for various signal levels. These tests showed very low harmonic content for both the Class *A* and Class *A–B* positions of the track and an increase of only 0.15 per cent in harmonics at the transition point.

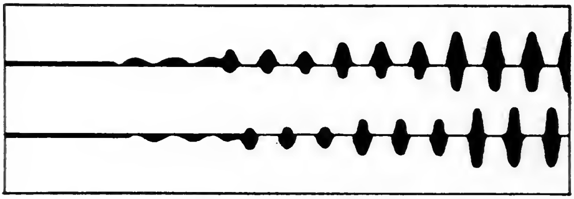

FIG. 4. Class *A–B* recording sound-track.

Conclusion.—The inherent advantages of a push-pull reproducing system can be gained by means of a Class *A–B* sound-track; it has the advantage over pure Class *A* recording in that the ground-noise reduction is inherent in the track and does not require the use of automatically operated shutters and it has the advantage over pure Class *B* recording in that low-level modulations are not distorted as much by film processing or a faulty azimuth setting of the recording aperture, the recording slit, or the reproducing slit.

The amount of ground-noise reduction inherent in a Class *A–B* record is inversely proportional to the ratio of pure Class *A* record to the full track record.

The dimensions of Class *A–B* aperture giving as much inherent ground-noise reduction as is now obtained by the use of shutters for standard bilateral recording or Class *A* push-pull recording are such that the construction of the aperture is practical and the resulting proportion of the track that yields a pure Class *A* record is sufficient to remove the excessive distortion of low-level modulations sometimes found in a Class *B* record due to film processing and azimuth settings.

An analytical treatment of the distortions introduced by faulty azimuth settings for sine waves reveals the distortions of high-level modulations to be practically the same as for a pure Class *B* record. However, the low-level modulations of the Class *A–B* record that are pure Class *A* records are not distorted by a faulty azimuth setting, while the percentage distortion of a Class *B* record increases as the intensity of modulation decreases. An unbalance in a reproducing system distorts all modulations of a Class *B* record equally, but in a Class *A–B* record there is no distortion in the Class *A* portion of the record and the distortion for larger modulations is less than for a Class *B* record.

As far as inherent noise-reduction is concerned the Class *B* track is the quietest known to date and is the ultimate toward which we should progress. However, under certain adverse conditions there are phases of Class *B* recording which become critical, such as film processing, reproducer balance, *etc.* The Class *A–B* record is not as free from these conditions as the Class *A* track but is less critical than the Class *B* record and *has the advantage of inherent noise-reduction without the use of shutters and noise-reduction amplifiers.* It is possible at the present time to obtain noise-reduction equal to that of our standard and Class *A* tracks and we see the possibility of progressively using less and less Class *A* portion as conditions stabilize until straight Class *B* tracks can be used.

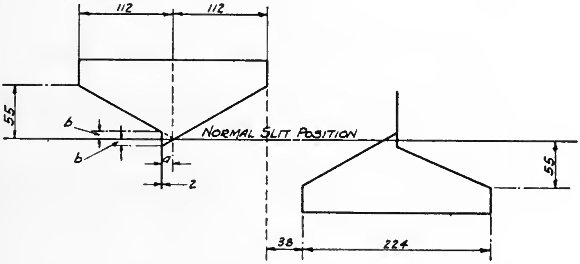

FIG. 5. Class *A–B* recording aperture for standard modulation efficiency. All dimensions in thousandths of inch on aperture.

While we have treated only a variable-area type of sound-track, the same considerations are obviously applicable to a variable-density type of sound-track. Several methods immediately suggest themselves for producing a variable-density push-pull Class *A–B* sound-track—such as the use of a special light-valve, a special penumbra system, or a pair of special filters for the recording aperture.

RCA ALUMINATE DEVELOPERS*

J. R. ALBURGER**

Summary.—*A fundamentally new principle in desgn of photographic developers has been investigated and found to afford many worthwhile characteristics, chief of which is the effective self-replenishing property of the developer solutions. Application of the new principle to developer solution makes it possible to develop about eight times the quantity of film as would be possible under ordinary conditions. The principle may be applied to any developer.*

As a brief preface to these remarks on the subject of aluminate developers, the following paragraph by J. I. Crabtree and C. E. Ives will be appropriate.

> The successful operation of a motion picture laboratory depends very largely upon its ability to produce prints of uniformly good quality. Such prints can be produced only by maintaining constant the various factors which control the exposure and degree of development of the image, and of these the developing power of the developing solution is perhaps the most difficult to control.

The RCA Manufacturing Co. has spent considerable time and research in an effort to improve the sound quality of final release prints. First attempts were made in coöperation with film manufacturers to reduce the image spread of a given film emulsion and thereby increase the tolerances of a negative-print density combination. Research on the part of film manufacturers has in the past few years resulted in the availability of sound recording emulsions having greater speed without sacrifice of resolution or increase of image spread, and of emulsions for other purposes which represent great improvement over previous emulsions. On our part a study has been made of developing solutions with a view of obtaining the desired increased processing tolerances. Although the study of developers and characteristics of developing solutions was entered upon primarily for the purpose of improving the quality of sound-on-film

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received March 31, 1939.

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

recording, it became increasingly evident during the course of investigations that there existed little-known and little-realized principles of chemical behavior which broadened the problem from the restricted application to sound recording to a general overall improvement in developer performance. The developing power of any ordinary developer begins to diminish the moment film is introduced into the developer, due to the release of reaction products which exert restraining action, along with the fact that a certain amount of the developing agent is used up. In order to overcome this difficulty with processing, laboratories have various methods for adding a replenisher to the developer as film is being developed, in an attempt to maintain constant density for a given exposure at a given developing time and temperature. To understand the problems involved in an endeavor to improve developer characteristics, the general theory of development should be considered.

Ordinarily there are four essential ingredients in a developer:

(*a*) The organic reducing agent
(*b*) The ionizing agent or the energizer
(*c*) The preservative
(*d*) The restrainer

The function of these ingredients is evident. The effect of varying their concentration is, in general, as follows: Increasing the concentration of the reducing agent shortens the development time. Increasing the concentration of the ionizing agent may have a number of consequences. First, it increases the energy of the developer, not only shortening the developing time but also increasing the tendency toward fog. Another effect is the physical effect on the gelatin of the film by the ionizing agent, which is usually an alkali, causing the gelatin to swell. Altering the concentration of the preservative also may have a number of consequences. At high concentration of sodium sulfite, which is used as a preservative, there arises an effect on the silver halide grain in the emulsion whereby the silver salts tend to go into solution. The effect of such solvent action is to decrease the contrast and to lower the effective emulsion speed of the film. The reason for this is evident inasmuch as during the course of development portions of the silver halide crystals are dissolved away before they can be developed to metallic silver.

The restrainer is generally potassium bromide. Its presence in the solution has an effect of inhibiting the fog and lowering the toe densities. Increasing the concentration up to a certain point gradually increases the restraining action. When this point is reached corresponding to a point of about 0.08 mol, any further increase of the concentration of potassium bromide will have little effect on the characteristics of the developer.

It is true without doubt there are few things that are perfect, and few things the improvement of which would not be greatly desired. In the case of developers a number of desirable improvements can be enumerated as follows:

(*a*) Increased stability
(*b*) Increased life of developer
(*c*) Higher possible contrast
(*d*) Improved control of developed contrast and emulsion speed
(*e*) High resolution
(*f*) Higher emulsion speed
(*g*) Lower fog
(*h*) Lower cost

To increase stability a number of possibilities present themselves. First of all, the bromide effect should be noted. During the course of development, bromide is released from the silver salts in the emulsion. The presence of the bromide thus released tends to inhibit or slow down subsequent development. A practical way to meet this difficulty and to improve stability so far as bromide effect is concerned, was found in simply starting with sufficient bromide already in solution so that the slight increment of bromide added during development would not cause an appreciable progressive slowing down of the developer. Fortunately it was found possible to formulate a developer the energy of which was sufficiently great so that the presence of large quantities of potassium bromide would not decrease its developing energy below a useful point. It was found that a concentration of potassium bromide of between 6 and 10 grams per liter was optimum. The life of a developer might be improved by increasing the concentrations of essential ingredients but there would still be present instability represented by exhaustion. If the concentration of the developing agent were to be doubled, we should expect the developer to last about twice as long, but the exhaustion characteristic has not been changed by this change in concentration, and instability from this source would still be present.

THEORY OF "PEPTIZED SOL" BUFFER DEVELOPER

Now we enter upon what is believed to be a fundamentally new function as applied to developing solutions. The chemistry of this function is not new but its application to photography seems to have distinct novelty.

Certain metals when treated with sodium hydroxide behave in the following manner: First, the insoluble hydroxide of the metal is precipitated and further addition of sodium hydroxide will re-dissolve this precipitate. The metals that behave in this manner are few. They are aluminum, lead, tin, zinc, and chromium, and the rarer metals, indium, gallium, and germanium.

With aluminum as an example, the reaction would be as follows:

$$\begin{gathered} Al_2(SO_4)_3 + 6\ NaOH \rightarrow 3Na_2SO_4 + 2Al(OH)_3 \downarrow \\ [+6NaOH \leftrightarrows 2Na_3AlO_3 + 6H_2O + 3Na_2SO_4] \end{gathered} \qquad (1)$$

The theory set forth in chemistry textbooks for the re-solution of these metallic hydroxides is that a polypeptized sol is produced. The terms *peptize* and *peptization* are generally used in reference to organic chemistry where the chemical function thus designated is the building up of large molecules from a number of smaller molecular groups. We are most familiar with peptization in its occurrence in the human body where the catalyst "pepsin" present in the digestive system serves to synthesize large complex molecular structures from the component chemicals of the foods we eat. In applying the idea of peptization to the aluminate developer a somewhat related action takes place. A large number of sodium aluminate molecules become grouped together in such a way that a large complex molecule is formed. This complex molecule is found to be soluble. The mechanism of this peptization is believed to be as follows: Aluminum hydroxide exists in equilibrium with acid aluminate. The aluminum hydroxide is an insoluble gelatinous material. The theory is that in the presence of an excess of hydroxyl ions a number of acid aluminate molecules become grouped together and peptized in combination with a molecule of sodium aluminate. To illustrate, the formula for aluminum hydroxide is

$$\downarrow Al(OH)_3 \leftrightarrows H_3AlO_3 \qquad (2)$$

This equation represents an equilibrium wherein an alkali is balanced against an acid. The presence of additional alkali will shift the equilibrium point to the right.

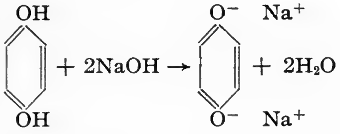
It should be remembered that there is at all times a reaction equilibrium existing in the developing solution. In such a reaction equilibrium, any change in the concentration in any of the reaction products will shift the balance point of the equilibrium. Thus, if the metallic hydroxide is dissolved in the sodium hydroxide in such a manner that there is just sufficient hydroxide to hold it in solution, and no more, a critical balance is obtained. For example, if for any reason some of the sodium hydroxide, or more exactly, the hydroxyl ions in the solution, are removed from the sphere of action, some of the metallic hydroxide will be precipitated from the solution. To illustrate, assume for the moment that we have produced a solution of metallic hydroxide critically balanced with sodium hydroxide, using aluminate as an example. The reaction is given by

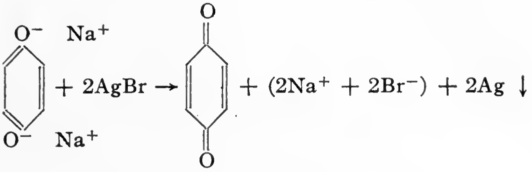
$$Al(OH)_3 + 3NaOH \leftrightarrows H_3AlO_3 + 3NaOH \leftrightarrows Na_3AlO_3 + 3H_2O \qquad (3)$$

A critical point is reached when there is sufficient *OH*-ion concentration to prevent the reaction from reversing. When the sodium hydroxide concentration is increased up to a certain point, the reaction equilibrium is shifted to make available sodium aluminate molecules upon which acid aluminate can become peptized to form an agglomeration of molecules or peptized group. The fact that the re-solution of the aluminum hydroxide occurs rather suddenly, or, in other words, the reaction equilibrium is rather critical, indicates that a large number of acid aluminate molecules may be peptized on a single molecule of sodium aluminate. Thus, a slight shift in the reaction equilibrium may produce a large change in the solution of the aluminum hydroxide.

Consider now what would happen if we were to add a solution of pure developer to this critically balanced solution.

The common property of developers is that they have very much less developing power when in a neutral or non-alkaline solution. The reason for this is the alkali acts as an energizer to ionize the developing agent. The simplest example is hydroquinone. The structure of this component is a benzene ring with two hydroxide groups attached at opposite ends. The presence of sodium hydroxide in a solution of this developing agent acts to split off the hydrogen atoms, leaving an ionized hydroquinone. The hydrogen atoms, thus split off, combine with the hydroxide group from the sodium hydroxide to form water. The developing agent is now chemically in a condition in which it is capable of reducing the silver bromide to metallic silver.


(4)


(5)

It is evident from the foregoing that a certain amount of sodium hydroxide will be used in the reaction with the developer. Thus, if we add a developing agent to a balanced solution of metallic hydroxide, some of the hydroxide will be used up throwing the reaction equilibrium out of balance. Less hydroxyl ion concentration remains than is necessary to hold the metallic hydroxide in solution, so a precipitate is formed. This can again be re-dissolved by increasing the *OH*-ion concentration beyond the critical point.

The function of the balanced solution may be stated to act as a buffer to hold the alkalinity of the solution relatively low, while at the same time the ionization balance of the organic reduction agent is shifted in such a manner to produce increased energy of the developer. The reaction of the organic reducing agent with the exposed silver bromide in the film produces a shift in ion concentration through a long chain of reactions. When the developer is oxidized by silver bromide, Br^- ions are released. The reaction of a developer with silver bromide is an oxidation reduction reaction, wherein the silver is reduced to the metallic state and the developer is oxidized to a less negative state. Aluminate ions exist from the reaction.

$$Al(OH)_3 + 3NaOH \leftrightarrows Na_3AlO_3 + 3H_2O \leftrightarrows 3Na^+ + AlO_3^{\equiv} + 3H_2O \qquad (6)$$

The only thing that keeps the aluminum hydroxide in solution is an excess of sodium hydroxide. The presence of Br^- ions would shift the balance of the reaction slightly to the left. Aluminum hydroxide is now better able to combine with the gelatin of the film to harden it as in any tanning action. Thus, the film in the near neighborhood of the developed image undergoes a pronounced hardening which is evidenced by a distinct lack of swelling. Furthermore, a general hardening effect over the entire surface of the film is obtained. The aluminum hydroxide precipitated during the course of development is not entirely absorbed by the gelatin of the film. The major portion of it forms a sludge-like precipitate which behaves as a clarifying agent, carrying down with it undesirable impurities such as oxidized developer and certain other undesirable reaction products which would interfere with the course of further development. This precipitate can easily be filtered from the solution.

The presence of the aluminate in a developing solution becomes useful beyond the point of stabilization of the developer energy. It behaves as a very effective inhibitor of swelling of the gelatin film. It was found possible to use a developer containing aluminate in temperatures well above 110°F. To be sure, such extreme conditions would not be encountered in commercial laboratory practice. However, it is seen by this that certain new characteristics arise which may prove useful for certain specific purposes. For example, the incorporation of the aluminate principle in developers for amateur use would have a certain advantage inasmuch as processing could be carried out in tropical climates or extremely warm weather without fear that the emulsion would melt.

EXHAUSTION CHARACTERISTICS

Comparative tests and measurements were made showing the relative exhaustion characteristics of the aluminate developer and a representative positive developer. The formulas for the two developers used in the comparative tests are as follows:

Al-Q-101

Sodium sulfite	50 grams
Hydroquinone	15 grams
Sodium Hydroxide	30 grams
Potassium Alum	40 grams
Potassium Bromide	7 grams
Water	1000 cc

	RCA Original	RCA Replenisher
Elon	0.9	0.9
Sodium Sulfite	63	63
Hydroquinone	16	20
Sodium Carbonate	23.5	23.5
Potassium Bromide	2.1	1
Water	1000 cc	1000 cc

In the tests made between the RCA and the *Al-Q* developer it was the object to have as nearly an equivalent amount of developing agent as possible in each of the two developers. The first test was carried out by exhausting the two developers without replenishment. The procedure was as follows: H & D measurements were made with a given amount of fresh developer after which a quantity of fully exposed film was fully developed in the solution to be tested. Further H & D measurements were made during the course of this exhaustion.

Fig. 1 shows the result of this comparative test. In this graph the density for a given step on the developed II*b* strip is plotted against the footage of developed film. Although the test was carried out with fully exposed, fully developed film, the measurements of footage have been converted to footage of normally exposed, normally developed film where the average density of the developed film is taken to be 1.25. To facilitate measurements of exhaustion rate it was found necessary to use fully exposed film and develop it fully. Subsequent tests were made with film exposed in a printer and developed to an average density of 1.25. The results of these measurements were in accordance with the first test.

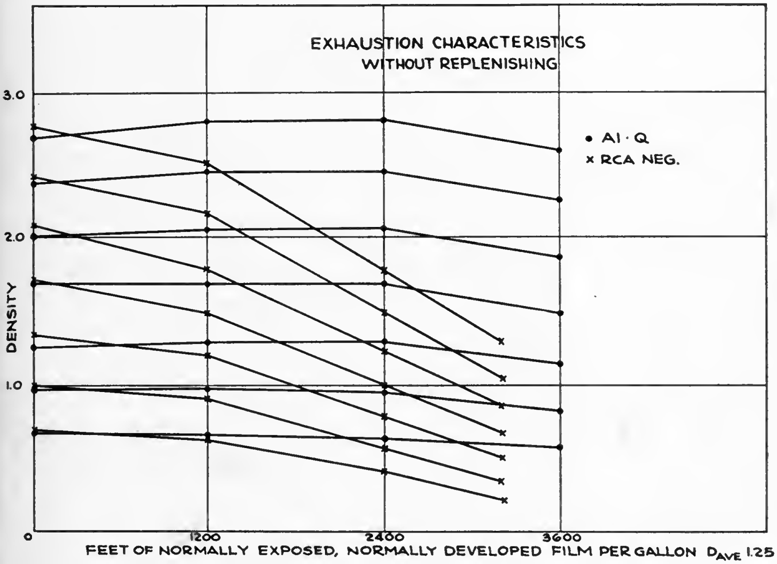


FIG. 1. Comparative test of *Al-Q* and RCA developers.

The problem of replenishment has long been one of interest to the motion picture industry. It was found possible by use of the aluminate formulas to replenish partially exhausted developer with the original developer formula. Evidently the stability of the developer is sufficiently great to obviate the necessity for special booster formulas. Fig. 2 shows the test carried out on the RCA developer where replenishment was made at the rate of 200 cc. of replenisher for each 10 feet of fully exposed, fully developed film.

A II*b* strip was developed in the fresh developer, after which 10 feet of fully exposed film was developed fully in the developer. A second II*b* strip was then put through the developer; 200 cc. of the developer was discarded, being replaced by replenisher; and a third II*b* strip was developed. This procedure was repeated until 50 feet of fully exposed film had been developed. As can be noted, there is a slight general falling off of the developed density during the course of this process of exhaustion.

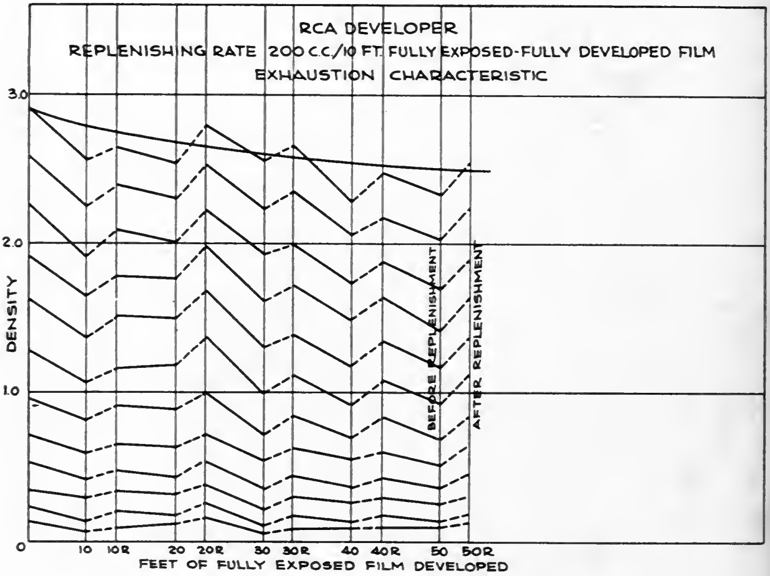


FIG. 2. Replenishment test of RCA developer.

A similar procedure was carried out in testing the *Al-Q-101* developer, although in this case the replenishing rate was 125 cc for 50 feet of fully exposed, fully developed film, as compared to 200 cc for 10 feet for the RCA developer. It was found that this replenishing rate was sufficient to maintain the energy constant. The results of this test are shown in Fig. 3.

Fig. 4 shows the characteristic curves obtained during exhaustion of the two developers under test. From these curves, speed and gamma have been plotted against footage of developed film per gallon, as shown in Fig. 5.

As shown by the data obtained in the tests, the new developer apparently has a life such that constant developing conditions can be maintained by replenishing with the original formula only for that amount of developer which is carried away by the film in the emulsion. In fact, if our understanding is correct, considerably more developer is carried away by the film in commercial laboratories than would be necessary for maintaining constant activity of the solution.

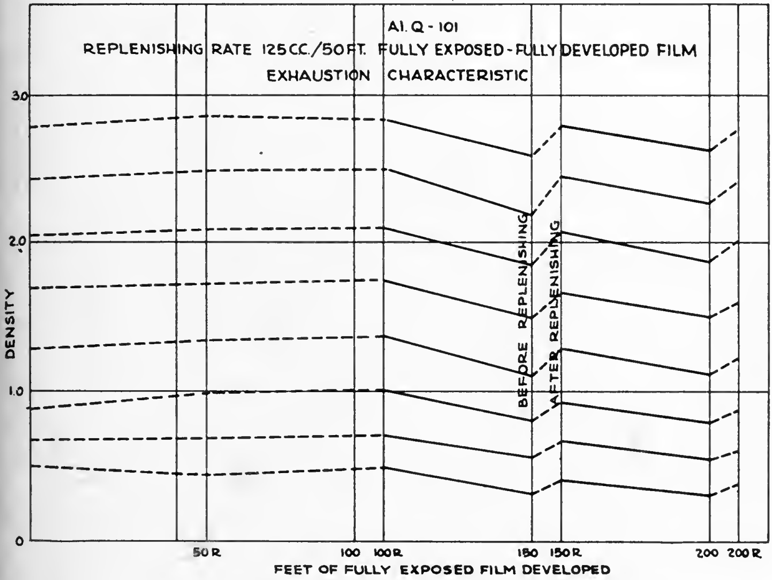


FIG. 3. Replenishment test of *Al-Q-101* developer.

Some laboratories do not maintain a closed system for developer circulation, in which case the developer is exposed to a considerable amount of air. Due to the high energy of the new developer the oxidation is greater than with present developers. Tests made by bubbling air through small quantities of the developer show that the oxidation properties are not too serious. Fig. 6 shows the results of this test.

A test made in Camden showed that while a deep tank of the developer solution (30 gallons with 100 square-inches of surface exposed) would keep indefinitely, a shallow tank of 10 gallons with 4 square-feet of exposed surface would oxidize within a period of four to six weeks. Actual storage tanks, however, are so designed as to present a comparatively small free surface, and in a reasonably active laboratory exhaustion, and not oxidation while standing, would be the determining factor with respect to deterioration.

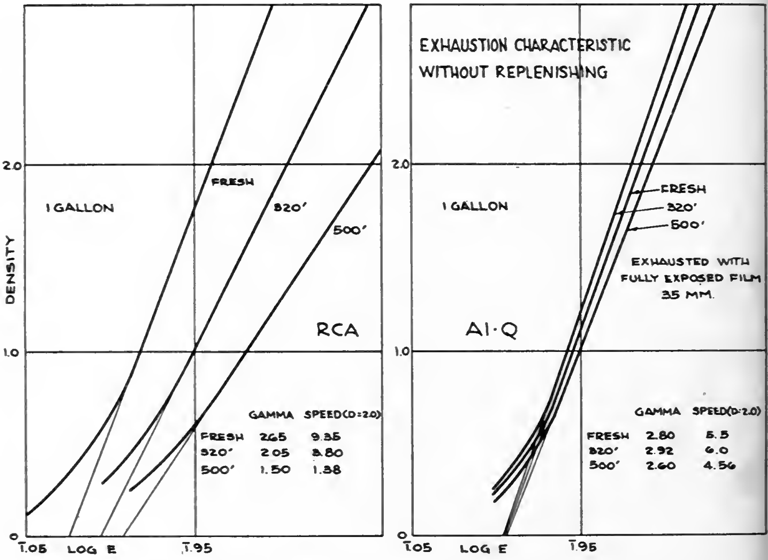


FIG. 4. Exhaustion characteristics of RCA and *Al-Q* developers.

HYPO CONTAMINATION

Early in the course of investigations of the new developer the question arose whether any special handling consideration was necessary in respect to neutralization of the acidity in the hypo. The *Al-Q* developer is considerably more alkaline than ordinary developers. It should be expected that due to the carry-over of alkali to the hypo the acidity of the hypo would be neutralized somewhat more rapidly than in standard developers, thus possibly requiring some acid replenishment. A test was carried out to satisfy this question where the hardness of the film, fixed in fresh and partially contaminated hypo, was measured. The degree of hardness was determined by the procedure specified by the Eastman Kodak Company. Quoting from p. 109 of *Motion Picture Laboratory Practice:*

> The degree of hardening produced by an acid fixer and hardening bath may be determined as follows: Develop, fix (for normal time used in practice), and wash a piece of motion picture film using the solutions to be tested. Place in a beaker of water and heat the water so that the temperature rises about 10 °F each minute. Agitate the film gently at intervals by lifting it out and reimmersing it in the water and note the temperature at which the gelatin begins to melt or flow away from the film base. This melting point is a measure of the degree of hardening, and for normal processing conditions should be between 130° and 170 °F (54° and 76 °C).

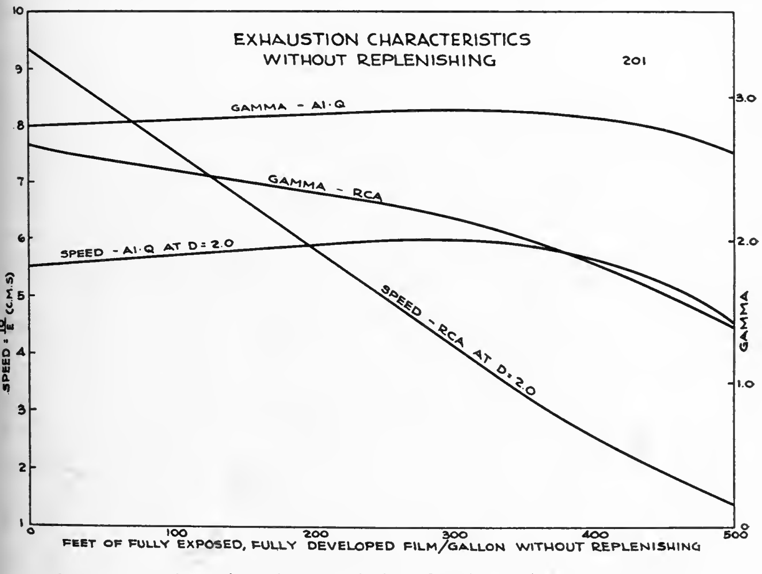


FIG. 5. Exhaustion characteristics of RCA and *Al-Q* developer.

Results of the hardness measurements on film developed in the RCA developer and the *Al-Q-101* developer are shown in Fig. 7.

It should be noticed that there is one important difference in the hardness of films processed in the two developers. Film processed in the RCA developer has the same degree of hardness for both the clear gelatin and gelatin with the silver image. Film processed in the *Al-Q-101* developer has a hardness characteristic for the clear gelatin similar to the RCA, but the hardness of the gelatin in the neighborhood of the silver image is extremely high. In the few tests which were made the silver image was found to have a relative hardness above 200°F. The reason for this can be traced back to the previous statements regarding the chemical equilibrium between sodium aluminate and aluminum hydroxide present in the solution. In the near neighborhood of the development reaction there is a shift in alkalinity in such a way as to liberate aluminum hydroxide which combines with the gelatin of the film to harden it. In machine processing of motion picture film, developer is continually carrie over through the rinse water into the acid hardening fixing bath The presence of alkaline developer in the film emulsion acts to neutralize the acid in the acid hardener. As shown in Fig. 7 the effec of contamination of the fixing bath by developer solution is more pronounced with the *Al-Q* developer than with the RCA developer, although this contamination may reach $3^1/_2$ to 4 per cent by volum before the hardening effect is appreciably diminished. An optimu rinsing time was found to be slightly less than one minute.

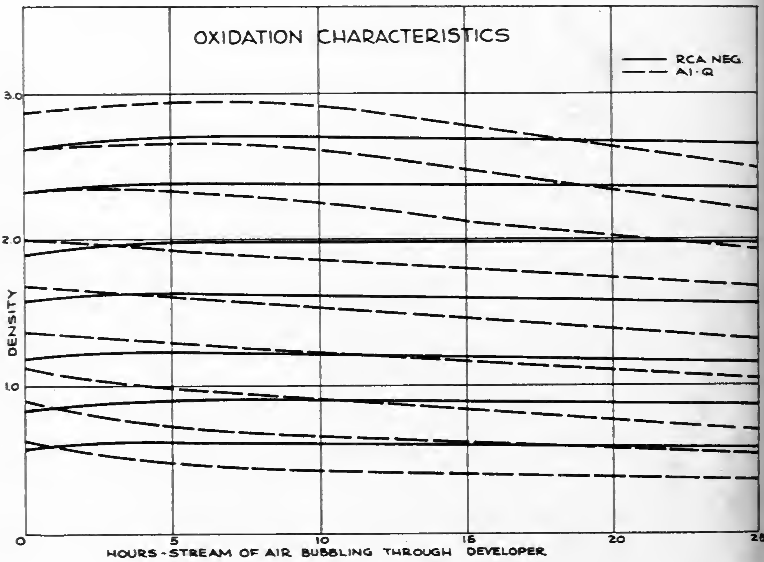


FIG. 6. Oxidation characteristics.

TOLERANCE CHARACTERISTICS

It was found that variations in developer characteristics with respect to temperature were diminished 50 per cent in the *Al-Q* developer. Fig. 8 shows the result of a test plotting temperature and degrees Fahrenheit against developed density and gamma for a typical sound-recording emulsion.

Another interesting characteristic of the *Al-Q* developer, with regard to temperatures, is the fact that development may be carried out at temperatures as high as 115°F. As was stated before, such extreme conditions of temperature would not be encountered in laboratory practice, but the fact that this can be done serves to illustrate that there is a pronounced inhibition of swelling of the gelatin in the film. The inhibition of swelling obtained along with the hardening of the developed image serves to decrease the turbidity in the emulsion, producing improved resolving power. The image portions are hardened in such a way as to diminish the tendency for the silver grains to shift their positions.

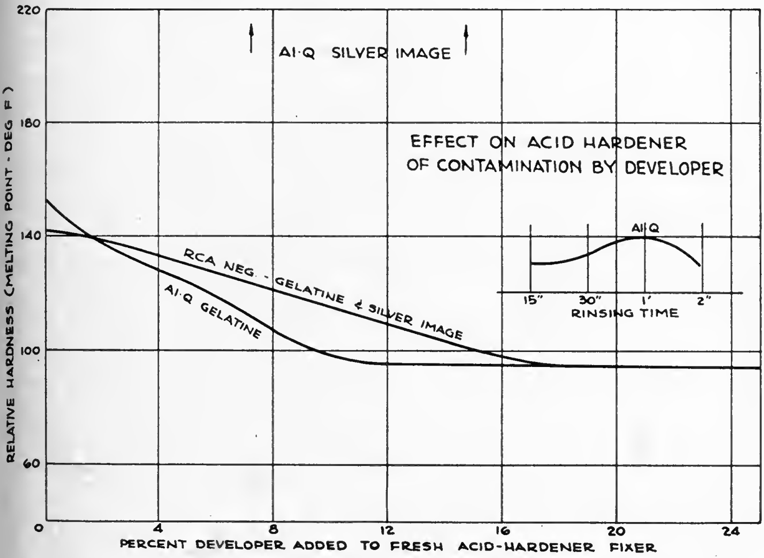


FIG. 7. Results of hardness measurements on film developed in RCA and *Al-Q-101* developers.

For certain purposes (for example, for variable-area sound recording) high contrast is desirable. Using certain modifications of the *Al-Q* formula it is possible to develop a film to a contrast beyond the characteristic gamma-infinity of the emulsion itself. Generally speaking, the definition of the practical gamma-infinity for a particular emulsion and developer is the gamma obtained under prolonged development. If development of the low densities is inhibited, the effective gamma is increased. It was found possible to develop films in such a way that up to a given time of development toe densities were inhibited so as to produce a greater gamma than would be obtained upon full development. A time-gamma curve in this case would appear as shown in Fig. 9.

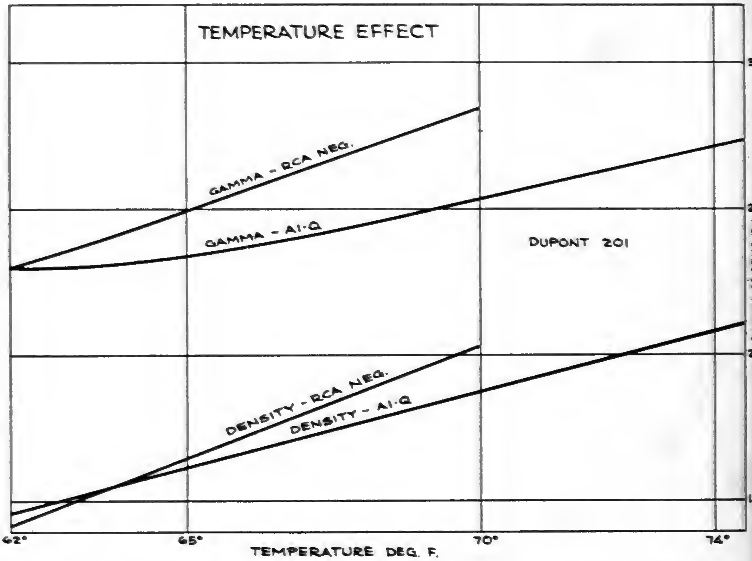


FIG. 8. Variations of developer characteristics with temperature.

Although extreme conditions can be obtained by suitable modification of the developer, normal characteristics may be had for soun negatives and positive prints. Fig. 10 shows curves plotted for sound recording negative material and ordinary print positive film.

These two characteristic curves were made at the same time a test recordings analyzing the cross-modulation characteristics obtained in the new developer. The method of cross-modulation fo use in determining optimum print density for variable-width soun recording has been discussed previously in the JOURNAL. Briefl the method is to record a 9000-cycle signal modulated with 400 cycles. Image spread in the film can be detected as a distortion of the 9000-cycle frequency. If the recorded track has no distortion it will be impossible to detect any 400-cycle signal when the film is played in a film phonograph. Cross-modulation or image spread will produce a 400-cycle note, the amplitude of which can be measured and plotted as densitometric level. In Fig. 10 are shown cross-modulation curves for the new developer *Al-Q-101.*

The RCA curve in Fig. 11 shows the characteristic cross-modulation for a series of prints from a negative of density 2.1. In this case the films were developed in standard developers, modifications of *D-16.*

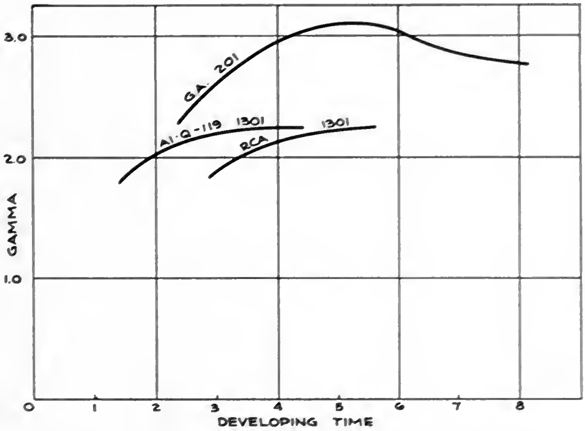


FIG. 9. Time-gamma curves showing increase of effective gamma.

Here we have print density plotted against densitometric level in decibels. If a distortion level of −36 db is taken to be suitable sound quality, it will be noted that the range of densities suitable in the print lies between 1.6 and 1.82. The density drop from the negative density is 0.42. Accordingly, if the negative density is 2.1 the optimum print density for this developer film combination turns out to be 1.67. There are two possible improvements on a set-up of this sort. For example, if the curve could be broadened out in such a way as to give a greater range of suitable print densities, we would thus have a greater tolerance available in processing technic. Furthermore, if the negative-print density drop could be diminished we could, for the

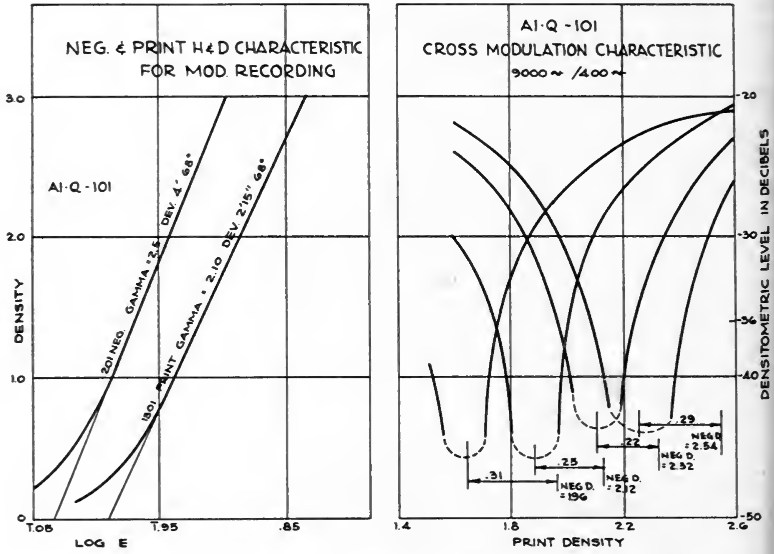


FIG. 10. Curves of sound negative and print positive film.

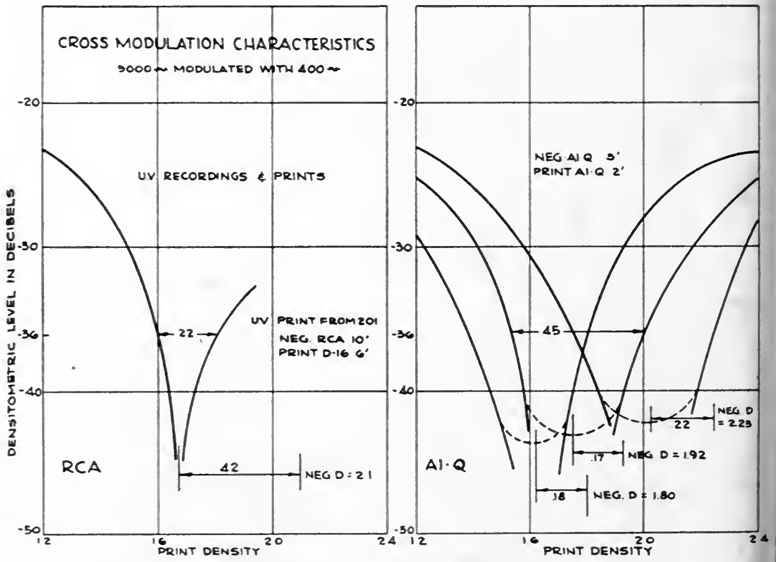


FIG. 11. Cross-modulation characteristics.

same negative density, have a higher print density which would produce somewhat less background noise. In Fig. 11 the curves *Al-Q* show cross-modulation characteristics where the film was developed in one of the *Al-Q* formulas. The negative-print density difference is diminished considerably and the curves are broadened so that at a densitometric level of −36 db there is considerably greater print density tolerance. It was found that slight modifications of the developer formula could be made to broaden this density tolerance.

It should be stated specifically that all the cross-modulation tests were made on a special continuous, non-slip, non-synchronous printer in order that variations due to printer behavior might be minimized. Accordingly, the amount of improvement in cross-modulation characteristics in commercial work by use of the new developer would depend chiefly on printer quality.

SUMMARY

In many of the formulas used in the field it is necessary to dissolve the chemicals in a certain specified order. Furthermore, the mixing sometimes requires a procedure which is somewhat cumbersome and inconvenient. The new developer can be mixed in any fashion whatsoever and, if desired, the ingredients may be poured as rapidly as convenient into a tank of cold water which is being thoroughly agitated. Chemicals may even be mixed dry and dumped in bodily, although, of course, thorough agitation must also be maintained. The laboratory tests conducted thus far have indicated many desirable characteristics. Briefly, they are as follows:

(*1*) Long, useful life which, it is hoped, will result in substantial savings to the motion picture industry.

(*2*) Higher possible contrast and improved resolution for both variable-area recordings and release prints.

(*3*) Developing conditions with respect to effective emulsion speed, gamma, and density hold reasonably constant throughout the life of the developer.

(*4*) Temperature effect is reduced by 40 to 50 per cent.

(*5*) Density tolerances with modulated high-frequency recording are increased by approximately 100 per cent.

(*6*) The developer is entirely satisfactory for both sound negatives and picture positives.

(*7*) The developed image is hardened in the developer.

(*8*) The developing time of the formula as at present constituted is of the order of two minutes for picture prints and sound positives, and three minutes for variable-area sound negative. If for any reason somewhat greater optimum developing time is warranted, this can be maintained.

(*9*) Mixing is simple.

In closing, recognition should be given to J. O. Baker of the RCA Laboratories at Camden for his assistance in the work; to Dr. Solomen of RCA for his counsel; and to the management of the RCA Research and Engineering Department for carrying this work through its long period of incubation.

REFERENCE

[1] CRABTREE, J. I., AND IVES, C. E.: "A Replenishing Solution for a Motion Picture Positive Film Developer," *J. Soc. Mot. Pict. Eng.*, **XV** (Nov., 1930), p. 627.

[2] BAKER, J. O., AND ROBINSON, D. H.: "Modulated High-Frequency Recording as a Means of Determining Conditions for Optimel Processing," *J. Soc. Mot. Pict. Eng.*, XXX (Jan., 1938), p. 3.

DISCUSSION

MR. CRABTREE: Have you made tests with the same formula omitting the aluminum salt and simply buffering the solution with sodium bisulfite?

MR. ALBURGER: We have tried that combination. The properties were not much superior to those with ordinary carbonate but the characteristics were similar.

MR. CRABTREE: It is probable that the properties of this developer are peculiar to the formula type rather than to any specific effect of the aluminum ions. Admittedly, the presence of aluminum ions will tend to tan the gelatin but any developer which has sufficient salt content will permit development at 90°F or higher.

MR. ALBURGER: We have been working on this problem for the last year and a half, and have endeavored to cover the situation as completely as possible. We have satisfied ourselves, at least, that the problem has been as stated.

THE PRESENT TECHNICAL STATUS OF 16-MM. SOUND-FILM*

J. A. MAURER**

Summary.—*Improvements in the technic of recording and printing during the past few years have made possible the production of 16-mm. sound-films, either by optical reduction or by direct recording, having considerably better quality than is being obtained in general commercial practice. By the use of a moderate degree of equalization in recording, it it practicable to obtain from 16-mm. negatives prints giving a flat frequency response to 6000 cycles, with useful response to 7500 cycles, when reproduced through a flat amplifying system. Harmonic and envelope distortion and speed variations can be kept within acceptable limits for high-quality reproduction. The principal remaining defect is background noise. Some general agreement upon commercial 16-mm. reproducing system characteristics is needed, however, before this improved quality can be made generally available.*

The optical reduction equipment that is in general commercial use today for producing 16-mm. sound-films was developed during the years 1933, 1934, and 1935. This equipment was described and the results obtained were discussed in papers by Baker;[1] Dimmick, Batsel, and Sachtleben;[2] Kellogg;[3] Batsel and Sachtleben;[4] and Sandvick and Streiffert,[5] in the JOURNAL of this Society.

All these authors are in close agreement in reporting that the 16-mm. prints showed high-frequency losses of the order of 12 decibels at 5000 cycles and 16 decibels at 6000 cycles, on the basis of constant modulation in the 35-mm. recording.

Several papers relating to 16-mm. sound have appeared in the JOURNAL since the time of the Sandvick and Streiffert paper, but none of these has contained direct information on the frequency characteristics being obtained from 16-mm. film. The purpose of the present communication is to bring the record up to date.

Since 1935 considerable improvements have been made in 35-mm. recording technic, but these have had little effect upon the quality of 16-mm. sound-prints commercially available. A good idea of the

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quality that is being obtained in practice may be gained by a study of the SMPE 16-mm. Sound Test-Film.[6]

Fig. 1 shows the result of measurement on a print of this test-film obtained from the New York office of the Society in March, 1939. The curve marked *A* was obtained by running the film on a reproducer employing a scanning beam 0.0004 inch wide, the measuring amplifier having been adjusted to give a flat output when the photocell was illuminated with constant modulated light at frequencies covering the range in which we are interested. The curve marked *B* is obtained by measuring the amplitude of the recorded frequencies with a micrometer microscope. The curve marked *C* is the difference between the first two curves. It will be observed that this curve repeats rather closely the loss measurements of the authors previously cited. Evidently the use of ultraviolet light in recording the more recent 35-mm. test-film negative has not materially affected the response of the 16-mm. print.

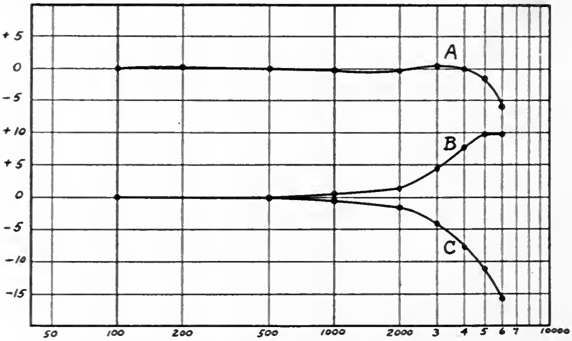

FIG. 1. Characteristics of S.M.P.E. 16-mm. Sound Test-Reel. (*A*) Reproduced characteristic using 0.0004-inch scanning beam; (*B*) Measured amplitude; (*C*) Loss characteristic in terms of constant amplitude recording.

The amount of equalization shown in curve *B* of Fig. 1 is greater than is commonly used in 35-mm. recording. In practice most 16-mm. optically reduced sound-films sound considerably less "bright" than would be indicated by curve *A* of that figure. The practice of recording film with special equalization for reduction to 16-mm. is rarely employed, though the possibilities are obvious from the results shown in Fig. 1.

Most of the authors of this series of papers on optical reduction printing condemned direct 16-mm. recording as an inferior method. This, however, was on the basis of recording image widths in the range from 0.0005 inch (Batsel and Sachtleben) to 0.00025 inch (Kellogg). The results are very different when the recording image is reduced to a width of 0.00015 inch.

The method of measuring the width of the recording image is important if valid comparisons are to be made. A figure for image width arrived at by dividing the width of a physical slit by the ratio of reduction of the lens used to image it on the film is not correct unless allowance is made for the diffraction pattern and the aberrations of the lens. The image widths stated in this paper are arrived at by looking directly at the aerial image formed by the recording optical system, using a 4-mm. apochromatic microscope objective of the type that is corrected to work without a cover glass. A micrometer ocular calibrated in combination with this objective reads with fair reproducibility to 0.00002 inch. The aberrations and diffraction pattern of this apochromat lens are small in comparison with those of the image being measured.

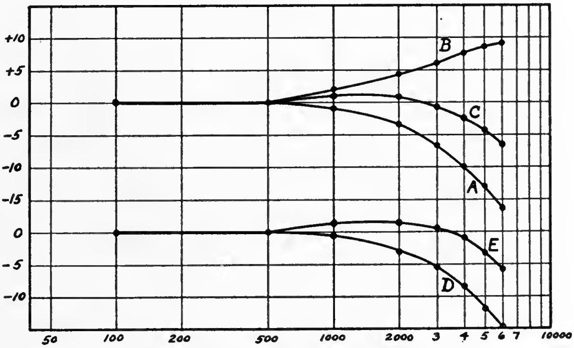

FIG. 2. Characteristics of white-light recording on 16-mm. positive film. (*A*) Response with constant-amplitude negative, non-slip white-light print; (*B*) Equalization employed in practice; (*C*) Overall reproduced characteristic of non-slip print; (*D*) Response of optical white-light print from same negative as *A*; (*E*) Overall reproduced characteristic of optical white-light print.

The results of white-light recording on 16-mm. positive film stock with an image width of 0.00015 inch are shown in Fig. 2. Curve *A* shows the measured losses of non-slip white-light prints from several constant-amplitude 16-mm. negatives having densities in the range from 1.0 to 1.7, the print densities covering the same range. The variation of high-frequency output with negative and print densities is too small to be shown on these graphs.

Curve *B* of Fig. 2 shows the equalization commonly employed in recording 16-mm. sound negatives with white light, while curve *C* shows the resulting overall characteristic. It has been our experience that films made according to Curve *C* are more often criticized as "too bright" than as being deficient in high-frequency response in comparison with optically reduced prints. The reason for this will be apparent when we come to consider the characteristics of commercial 16-mm. reproducers.

No curve is given for the response obtained by running the 16-mm. sound negative on a reproducer because it has been found that the relationship between negative and print is not one that can usefully be represented by plotting their individual frequency response curves. Thus, at certain densities the print gives a better frequency response than the negative from which it was made. It is not the light-modulating ability but the contrast of the high-frequency portions of the negative that is important. For this reason "printer loss" can not usefully be expressed in decibels.

Optical printing of 16-mm. negatives appeared likely to offer the advantage of increased effective contrast of the negative, resulting from the collimated nature of the light, together with the possibility of providing for negative shrinkage without encountering the synchronization difficulties of the non-slip type of printer. In order to find out whether or not these advantages could be realized in practice, a printer was built, using a recorder movement at each end of a one-to-one optical system made up of the best available microscope lenses. White-light prints made with this printer gave $1^1/_2$ decibels higher response at 6000 cycles than non-slip prints from the same negatives.

Curves *D* and *E* of Fig. 2 show the effect of optical printing from the negatives that gave the non-slip prints represented by Curves *A* and *C*.

As may be seen from Fig. 2, films made by direct 16-mm. recording, using standard positive film and white light, and printed by white light, are at least as good from the standpoint of frequency response as prints made by optical reduction. But this is by no means the best that can be done.

When we have improved optical definition to the point where we encounter the law of diminishing returns (and it has been found that a recording image narrower than 0.00015, while attainable, gives practically no improvement in results) we must perforce turn to methods of increasing the resolving power of the film used for recording.

One of the methods that has proved practicable for securing better resolution is the use of ultraviolet light,[7] which confines the image to the surface of the emulsion. This method has the disadvantage of requiring extremely high light-source temperature if sufficient exposure is to be obtained. Trials showed, however, that it is not necessary to use an actual ultraviolet filter in order to obtain substantially the same improvement. Any filter that absorbs the band of wavelengths from 560 to 450 millimicrons will serve the purpose. Such a filter, which is purple or lavender in color, used in combination with a fast type of sound-recording film such as Eastman Type *5359*, requires very little increase of exposure over that required for white-light recording with ordinary positive (Type *5301*), while it gives a response curve only one decibel lower at 6000 cycles than is obtained by true ultraviolet recording. A print made optically from a constant-amplitude 16-mm. negative recorded in this manner, using in the printer a filter of the same type as that used in the recorder, shows

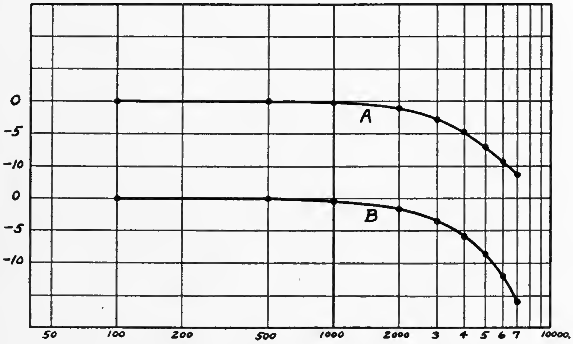

FIG. 3. Results of high-resolution recording technics. (*A*) Measured response of 16-mm. optical print from constant-amplitude 16-mm. negative recorded with yellow-dyed stock (Eastman *5504*) and Jena *BG-12* filter. Jena *UG-3* filter used in printer; (*B*) Measured response of 16-mm. optical print from constant-amplitude 16-mm. negative recorded on Eastman *5359* stock with Jena *UG-3* filter. Print through Jena *UG-3* filter.

a loss of 12 decibels at 6000 cycles and of 16 decibels at 7000 cycles. The curve is shown in *B* of Fig. 3.

Another method of improving resolution is the use of yellow-dyed film stock in combination with a blue filter having a transmission that does not overlap the transmission of the yellow dye. This means, in general, a filter that absorbs wavelengths greater than 480 millimicrons. The exposure required for this method of recording is as great, with films now available, as is required for ultraviolet recording, but the method has the advantage that the increased light can be obtained by redesigning the optical system, without the necessity of operating the lamp filament at a high temperature in order to get ultraviolet radiation. Furthermore, the results are superior to the results of ultraviolet. A negative made by this yellow-dyed-stock-plus-blue-filter technic, printed on ordinary positive stock with the lavender filter previously referred to in the optical printer, gives a print having a loss of only $9^1/_2$ decibels at 6000 cycles and $11^1/_2$ decibels at 7000 cycles. The complete curve is shown by *A* in Fig. 3. A print on the yellow-dyed stock would be still better, but this is not practical because pictures can not be printed satisfactorily on yellow-dyed stock.

A third method of improving high-frequency response is the use of slow, fine-grained, high-resolution film stocks such as Eastman Type *1360*. Unfortunately this type of stock was not available in 16-mm. size at the time these measurements were made, so that no comparative results can be given.

Fig. 4 shows an equalization characteristic suitable for use with either of the two methods of improving high-frequency response represented in curves *A* and *B* of Fig. 3. The two lower curves, *B* and *C* of Fig. 4, show the resulting overall frequency characteristics. Experience has shown that this amount of equalization, sufficient to give flat reproduction up to 6000 cycles, may be employed without danger of causing high-frequency waves to overshoot before those of lower frequency.

Wide frequency ranges in reproduction give satisfactory performance only when distortion is kept within suitable limits. Measurements have been made of the harmonic distortion present in 16-mm. prints of 400 and 2000 cycles, produced by both white-light recording and by the technics corresponding to Fig. 3. These measurements show that for proper combinations of negative and print densities the total harmonic distortion is less than 5 per cent. The results check in general the findings of Sandvick, Hall, and Streiffert,[8] who reported in 1923 that the condition for best wave-form (with white-light recording and printing) was equality of negative and print densities. If this condition is satisfied, envelope distortion[9] is also reduced to a satisfactory degree. The requirement of accuracy in the control of printing is rather exacting, but by no means impossible to meet.

It is hoped that the work on distortion summarized in the preceding paragraph may form the subject of another communication to the Society at a future meeting.

One of the principal difficulties encountered in early attempts to build 16-mm. recorders, before the development of optical-reduction printing, was the control of speed variations. But, like many of the other difficulties of sound-on-film recording, this is mainly a matter of mechanical accuracy. The degree of freedom from speed variation that has been achieved can best be judged from the reproduction of critical musical instruments in the selections that are to be demonstrated.

The principal remaining defect is background noise. In this respect prints from direct 16-mm. recordings have a distinct advantage over optical reduction prints. The conditions for freedom from envelope distortion lead to higher densities in prints from 16-mm negatives. Most optical reduction prints have densities in the range from 0.9 to 1.2. If they are made denser, they exhibit noticeable envelope distortion. Prints from direct recordings, on the other hand, may be made as dense as 1.5 with excellent results. The higher print densities give noticeable reductions in the noise level of quiet passages.

At the present time, when reproducing a 7500-cycle frequency range, the background noise is about equally divided between film noise and photocell hiss. Any development that would make it possible to concentrate more light into the scanning beam of the reproducer would bring a distinct improvement in the hiss level. From the standpoint of film noise the need is for finer-grained printing stocks. Both these problems will doubtless be solved in the course of time.

In its commercial aspects, however, the noise problem is very different. Sixteen-mm. sound projectors in general have been designed to reproduce optical-reduction prints. As has been mentioned, these prints are generally made from standard 35-mm. recordings, which means that the amount of equalization employed is altogether insufficient to offset the high-frequency losses. Many of the prints, if played on a flat reproducing system, give the impression that the frequency characteristic is much nearer to Curve *C* than to Curve *A* of Fig. 1. To offset this loss of high frequencies, most 16-mm. reproducing amplifiers are peaked at the higher end of their ranges. This peak accentuates the background noise, both from the film and from the photocell.

Today it is impossible to employ, commercially, 16-mm. films having the improved high-frequency response discussed in this paper. On the better reproducers now on the market such films sound objectionably shrill. In many cases there is considerable attenuation of low frequencies, which adds to the unsatisfactory nature of the result.

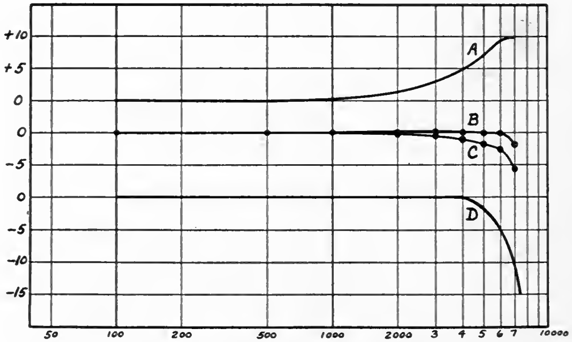

FIG. 4. Practical utilization of high-resolution 16-mm. recording: (*A*) Suitable equalization characteristic; (*B*) Overall response with yellow-dyed negative, optical print through Jena *UG-3* filter; (*C*) Overall response with negative recorded through Jena *UG-3* filter, optical print through Jena *UG-3* filter; (*D*) Suggested reproducer characteristic for most pleasing final result.

If it could be done by general agreement, the author feels that it would be desirable to reproduce high-quality 16-mm. films with an amplifier characteristic somewhat similar to that shown in *D* of Fig. 4. This procedure would be equivalent to what has been done by the adoption of the standard 35-mm. theater reproducing characteristic. Noise would be greatly reduced, while the proportion of high frequencies would still compare satisfactorily with that of 35-mm. theater reproduction. Optical-reduction prints having the necessary high-frequency content could be produced either by reducing from suitably equalized 35-mm. negatives or, more simply, by the use of ultraviolet filters in the reduction printing. But unless such a program can be generally agreed upon, higher-quality 16-mm. sound-films must be restricted to special applications.

This, of course, does not mean that these improved methods of recording are of no immediate value. If they are not used to increase the frequency range, they can be employed to increase processing latitude or to reduce distortion. In both these directions progress is desirable.

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DISCUSSION

DR. MILLER: Some years ago we should have thought this an excellent performance from 35-mm. film. As a matter of fact, from the appearance of these 16-mm. frequency characteristics, it seems as if we may have to look to our laurels on 35-mm. film before long. Will Mr. Maurer give an estimate of the volume range that is available in the 16 mm. film we have just heard?

MR. MAURER: With a reproduced frequency range of 7000 cycles, the background noise, as read on an ordinary copper-oxide rectifier type of meter, is about 40 decibels below maximum signal. I say "about" 40 decibels because the noise varies several decibels with different degrees of cleanliness in processing. In practice a volume range of about 30 decibels in the recorded signal may be used without annoyance from background noise during periods when the modulation is at a low level.

DR. FRAYNE: Will Mr. Maurer please tell us about this special film, and whether it is commercially available?

MR. MAURER: I do not know whether or not it is available in 35-mm. It is a yellow-dyed stock, Type *5504*, which has been used for some time for reversal picture duplication in 16-mm. It is not very suitable for recording because it requires quite high exposure, but I hope that before long yellow-dyed film will be available that will overcome this difficulty.

MR. HAWKINS: What amount of noise-reduction was used, in terms of the standard 35-mm. noise-reduction?

MR. MAURER: Very nearly the same practice was followed as is generally followed in 35-mm. The width of the biased track is about the same as is found on optically reduced 16-mm. prints.

DR. MILLER: Can you give me any information regarding the optical system employed in the original recording?

MR. MAURER: The optical system forms a line image on the film, which is a reduced image of the filament of the recording lamp. The filament is 8 mils in diameter, and is reduced to 0.15 mil on the film.

MR. LAMBERT: Have you made any records available on reversible type film suitable for photographing and recording.

MR. MAURER: I do not have any records here that I can play. Reversible film has characteristics that are favorable in one respect and unfavorable in other respects. It gives a better frequency characteristic than is obtained by recording and printing with a given color of light, but reversible film requires an accurately controlled exposure in variable-area recording; otherwise it gives a considerable amount of envelope distortion. However, once the exposure has been determined for a given type of film it can be maintained in practice within close enough limits. The improvement in frequency characteristic is about half as great as is obtained by the yellow-dyed stock technic.

MR. BURCHETT: What results do you get by using that method with Kodachrome?

MR. MAURER: In direct recording, that is, using a newsreel type of camera, very good results are obtained. Kodachrome duplicates are still in the experimental stage so far as sound is concerned.

MR. PALMER: Have you done any work in determining what the maximum cut-off would be in recording and printing on Kodachrome? My experience has been that it is impossible to print beyond 4000 cycles instead of 6000 or 7000 cycles, as demonstrated here.

MR. MAURER: My experience with Kodachrome does not indicate any fundamental limit as to the frequency range that can be recorded. The difficulty I have experienced is in getting adequate volume in reproduction.

MR. PALMER: That has been my experience. However, I have noticed a definitely lower resolving power of the Kodachrome emulsion as compared with reversible black-and-white emulsion we ordinarily use.

MR. MAURER: That does not run parallel with my experience with Kodachrome. However, I believe that any statements regarding Kodachrome duplicates at the present time are premature, because it is quite evident that a great deal of experimental work is still being done toward improving the process.

MR. GRIFFIN: I presume that your equipment runs at 36 feet a minute; what type of scanning system is being used? Is it the type of scanning system such as we call the rotary stabilizer?

MR. MAURER: The film was run at the standard 16-mm. sound speed of 36 feet per minute. In referring to the scanning system I take it you mean the method of film transport. It is a system that we have developed ourselves, and differs rather radically, I believe, from any of those that are in commercial use for 35-mm.

THE FLUORESCENT LAMP AND ITS APPLICATION TO MOTION PICTURE STUDIO LIGHTING*

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Summary.—*Fluorescent lamps provide a new tool for solving some of the lighting problems encountered in the motion picture industry. A low-pressure glow discharge in mercury vapor and an efficient fluorescing powder are the chief features of such lamps. The differences between them and the ordinary filament lamps are many—not only with regard to design but with respect to their operating characteristics. These differences are discussed and many characteristics are shown for both the lamps and the necessary auxiliary equipment. The daylight quality of light which may be produced at high efficiencies and the relative lack of radiant heat make the new lamps attractive for several applications in studios.*

The new fluorescent lamps announced to the trade about a year ago are receiving more and more attention and offer greater possibilities for lighting, for decoration, for use with air-conditioning, and as a duplication of daylight, than they did at the beginning. They are apparently destined to play an important part in the scheme of illumination and decoration in many industries as well as in homes, shops, *etc.* The attraction that they have comes somewhat from their newness, of course, but is chiefly the result of their high efficiencies, their relatively low brightness, their many attractive colors, their shape which is so suitable from an architectural standpoint, and their ability to product light of daylight quality. Characteristics of these fluorescent lamps for low voltage circuits have been previously described,[1,2,3] but new information is constantly being made available. An approach to the unusual features and a better understanding of the characteristics of the new fluorescent lamps may be had by a comparison with the well known tungsten-filament lamps. Such comparisons are made in the first part of this paper.

Design.—In the ordinary filament lamp the source of light is a filament of tungsten wire, either coiled or straight, which is mounted on a stem in a bulb, either in vacuum or in an inert gas at nearly

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atmospheric pressure. The source of light in a fluorescent lamp is a special and carefully controlled synthetically produced powder which adheres to the inner bulb surface. Five different powders or "phosphors" are in general use which when used alone give the following colors: calcium tungstate—blue; magnesium tungstate—blue-white; zinc silicate—green; zinc beryllium silicate—yellow-white; cadmium borate—pink.* Theoretically, fluorescent light is caused by the movement of electrons of some of the atoms of the powder under the influence of ultraviolet radiation. The bulb contains a drop of mercury, to produce a vapor at low pressure, and argon gas at low pressure for starting purposes. A tungsten filament becomes incandescent due to heat from the watts consumed in accordance with the I^2R law, while the fluorescent powder becomes luminous because of its ability to transform the short ultraviolet radiation, to which the fluorescent powders are particularly sensitive, into visible light. This is done by an electric discharge at low current-density between the electrodes (the electrodes act alternately as cathodes and anodes, depending on the current flow) which are placed in the two ends of the bulb (Fig. 1). The cathodes are heated by the discharge during lamp operation, and with the selection of proper bulb dimensions, lamps low enough in voltage to operate on standard line voltages without a step-up are possible. The mercury-vapor must be at low pressure for best results, because as the pressure increases there is a shift in energy from the λ2537 Ångström line to the longer and less effective mercury lines. The low current and vapor-pressure are therefore two reasons for not making lamps of the present design in higher-wattage sizes.

The best form for a filament in most cases is one that is concentrated in order to conserve heat, but with fluorescence there is an advantage in long lengths. This is due to the fact that there is a constant loss at the electrodes, as evidenced by a voltage drop in their vicinity, and since the lamp voltage increases with lamp length this loss drops to a lower percentage, the greater the lamp length. Long tubular sources of light are the result. Four lamps are now available, in lengths from 18 to 48 inches, the electrical ratings for which are shown in Table I.

Different colors may be produced in fluorescent lamps at uniformly

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* The chemical names are only partially descriptive of the phosphors which, for the most part, are covered by patents and patent applications, as are also certain processes for obtaining special color and efficiency characteristics.

high conversion efficiencies by merely changing the powders on the bulb wall, while filaments produce essentially one kind of light and changes in color are obtained by the filter method which throws away those colors that are not wanted. Blue, green, gold, pink, red, white, and daylight are available in fluorescent lamps, although special color coats for the gold and red are required in order to obtain the desired hues. The lumen output and brightness values are shown in Table II.

TABLE I

Dimensions and Electrical Data

	15-watt 18-inch T-8	15-watt 18-inch T-12	20-watt 24-inch T-12	30-watt 36-inch T-8	40-watt 48-inchT-12
Lamp Watts	15	15	20	30	40
Diameter (Inches)	1	1½	1½	1	1½
Line Volts	110–125	110–125	110–125	208–250* 110–125*	208–250*
Lamp Amperes	0.30–0.32	0.32–0.35	0.34–0.37	0.32–0.37	0.40–0.44
Lamp Volts	54–58	46–50	60–64	100–106	105–111
Rated Life (Hours)	2000	2000	2000	2000	2000

* Depending on Auxiliary.

Efficiencies are limited in filament lamps because of the evaporation and melting of tungsten at the high temperatures, where most light is given off. Fluorescent lamps are limited by their ability to produce ultraviolet and by the efficiency of conversion of ultraviolet into visible. Fig. 2 shows the distribution of energy in the 15-watt daylight fluorescent lamp; for other wattages the proportions remain about the same. Skillful lamp design results in about half of the energy going directly into the λ2537 line, to which the fluorescent powders are particularly sensitive. A little less than two per cent of the energy is represented in the four visible mercury lines, which produce a total of about 45 lumens or three lumens per watt independently of the powders. The rest of the input (along with the λ2537 conversion loss) is emitted as long infrared radiation or dissi-

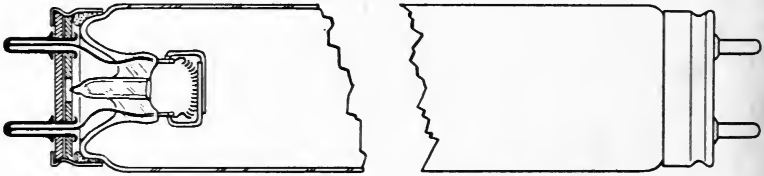


FIG. 1. Internal construction of a fluorescent lamp.

TABLE II

*Lumen Output and Brightness**
(Approx. Initial Values)

	15-watt T-8		15-watt T-12		20-watt T-12		30-watt T-8		40-watt T-12	
	Lumens	Foot Lamberts	Lumens	Foot Lamberts	Lumens	Foo Lamberts	Lumens	Foot Lamberts	Lumens	Foot Lamberts
Daylight	450	1800	450	1200	660	1300	1110	2000	1600	1400
White**	530	2100	530	1400	760	1500	1320	2300	1880	1700
Blue	310	1260	310	830	460	870	780	1400		
Green	900	3600	900	2400	1300	2500	2250	4000		
Pink	300	1200	300	800	440	850	750	1350		
Gold	380	1500	380	1000	540	1050	930	1650		
Red	45	180	45	120	60	120	120	200		

* Maximum values measured at center of lamp normal to the axis. At 75 degrees from the normal at the center or normal to the axis at the ends the brightness will be about half the values shown.

** New Type (3500°K).

pated by convection and conduction. Part of this unavoidable loss keeps the electrodes heated—an essential condition for the free emission of electrons at practical operating voltages. An average-size filament lamp (40-watt) gives 12 lumens of white light per watt while the 15-watt fluorescent (exclusive of loss in auxiliary) gives 30 lumens per watt, or approximately the same amount of light. The luminous efficiencies for the lamps alone vary from 3 lumens per watt for the red lamp to 75 lumens per watt for the long green lamp. Overall efficiencies are 10 to 25 per cent lower, depending upon the

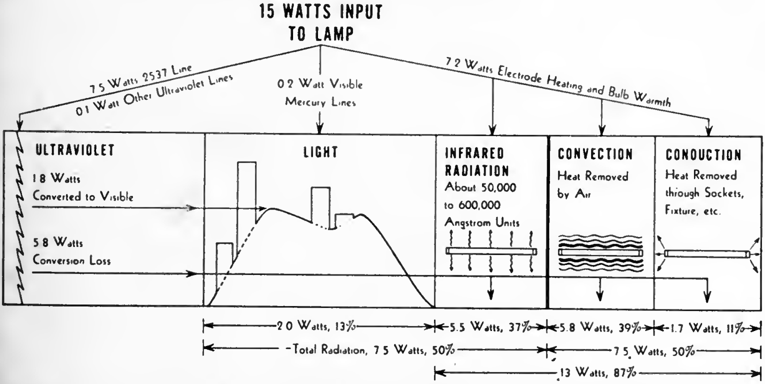


FIG. 2. Disposition of total energy delivered to a 15-watt daylight fluorescent lamp.

type of auxiliary used. Efficiency comparisons with filament lamps depend not only upon the size and color of the fluorescent lamp but also upon the size, design, and color of the filament lamp.

Light of daylight quality is produced by combining three fluorescent powders in the same bulb. The spectral curves of the three overlap and cover the entire visible spectrum. The resultant light is close to that of natural daylight both by measurement and observation, and is something that has not been produced by the so-called daylight filament lamps except when additional highly absorbing filters are used (Fig. 3).

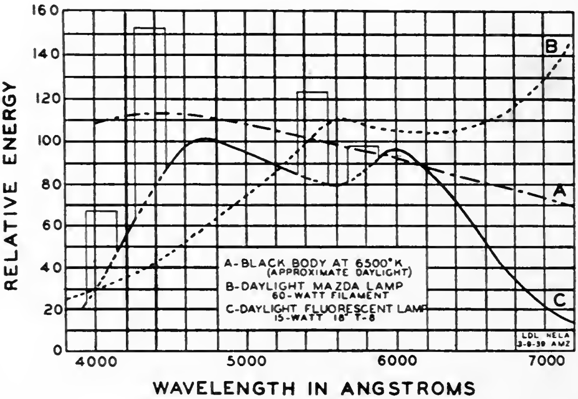


FIG. 3. Distribution curves comparing three daylight sources.

Lamp Characteristics.—A useful by-product of fluorescent lighting is a smaller amount of radiated energy with respect to the total watts consumed than is encountered with filament lamps. Most of the wattage used by filament lamps is given off as infrared radiation. This is to be expected because of the characteristics of a hot tungsten filament. The fluorescent lamp, however, not dependent upon the same principle of light production, does not radiate much heat from its relatively cool light-giving substance. The energy that is lost is chiefly conducted and convected away from the lamp (Fig. 2), so that for equal lumens there is approximately one-fourth as much heat radiated from daylight fluorescent lamps as from ordinary low-wattage filament lamps. This is a factor in connection with use in air-conditioned interiors.

There is an effect noticeable in the colder climates, due to the temperature sensitivity of lamps, that should be mentioned and guarded against. At low temperatures the mercury-vapor inside the fluorescent lamp has a tendency to condense (especially when exposed to draft and wind) and reduce the lumen output unless the lamp is protected by its fixture or a special shield. The curves shown in Fig. 4 indicate the effect produced by various air conditions upon a 15-watt *T-8* lamp with and without a $1^3/_4$-inch glass tube, which represents about the ideal size enclosure. The draft conditions were obtained by placing a 12-inch fan near the lamps. While it is to be expected that variations from these specific conditions would result in somewhat different curves, these data represent a range that will apply to most conditions. For example, an idea of the performance of lamps used in an inclosed cavity could be obtained by taking into account the cavity size, shape, exposure, and other conditions that determine the departure of the installation from the test represented here. Effective protection even at 0°F is provided by the enclosing shield.

Every lamp, no matter what kind, when burned in the usual manner on alternating current has a non-uniform light output due to the cyclic variation of current, which is increased at lower frequencies. Whether or not this non-uniformity results in an objectionable flicker depends upon other things as well as upon the frequency. In filament lamps a small wire-size is conducive to variations because of its more rapid cooling between half-cycles. In electric discharge lamps, where practically no energy is stored up in the light-giving medium, the light drops almost to zero along with the current between each half-cycle. Fluorescent powder, however, except for the blue-fluorescing variety has a persistence of glow, or phosphorescence, which helps to reduce cyclic light fluctuation, and this characteristic is affected by the kind of phosphor being used. Ordinarily the slight fluctuations from fluorescent lamps are not noticed on 60-cycle current; and with lamps burned on two or more phases or with the use of the new two-lamp power-factor-corrected auxiliaries, the fluctuation in light output is further reduced and is brought to a level comparable with that from the ordinary low-wattage filament lamp (Fig. 5).

Auxiliaries.—Because of negative volt-ampere characteristics every fluorescent lamp requires some sort of ballast, and for the sake of starting at a low voltage a simple starting device is attached. These are adequately provided by means of a simple reactor and switch—the latter being momentarily in the closed position, connecting the cathodes in series with the choke across the line, for preheating purposes; then opening to allow the arc to strike. A very small low-cost choke, although it may be adequate for ballasting purposes, has a higher loss and does not provide as good regulation as a larger choke of higher quality. In practice an automatic thermal type of switch has been used with the former, while an automatic magnetic switch has been sold with the latter. Both types of switches are somewhat fragile and, consequently, the complete auxiliaries must be handled with care. To be satisfactory an auxiliary must not only deliver the correct wattage to the lamp but always preheat the cathodes to the proper value and then provide a wave-shape during operation that does not show an excessive peak current. Power-factors usually run between 50 and 60 per cent, but condensers of the proper size to fit in wiring channels are available that largely correct them. A new two-lamp auxiliary promises to provide practically unity power-factor.

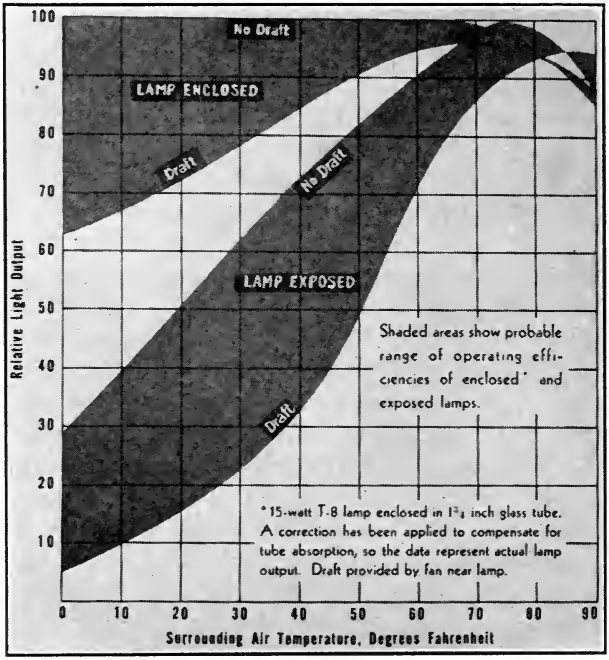


FIG. 4. Effect of various surrounding conditions on the light output of 18-inch *T-8* fluorescent lamps.

With changes in line voltage, fluorescent lamp characteristics are decidedly different from those of filament lamps. As the line voltage increases, the lumen output increases, the wattage increases, and the current increases, but the lamp voltage and the efficiency decrease. Greater changes take place with a small type of choke: a one-per cent increase in line volts may mean a four or five-per cent increase in current in this case, while with a large choke only a two-per cent change in current may be found. The lumens, although affected to a lesser degree show the same trend, the change with a small choke being about the same as for a filament lamp. Figs. 6(*A*) and (*B*) show the characteristic curves. Too low a line voltage (less than 85 to 90 per cent of normal) may result in uncertain starting and may cause a decrease in lamp life, as will operation at excessively high voltage. It is desirable to use line voltages close to the center values of 118, 208, and 236 volts for the various listed auxiliaries, in order to obtain best results.

FLICKER OF 15-WATT FLUORESCENT LAMPS
Operated with Reactors on 115V-60 Cycle-A.C.

Lamp	% Deviation from Mean	Lamp	% Deviation from Mean
Blue	95	White	35
Green	20	Daylight	70
Pink	20	Daylight (2 lamps operated out of phase)	25
Gold	30		
Red	10	15-Watt Filament	18

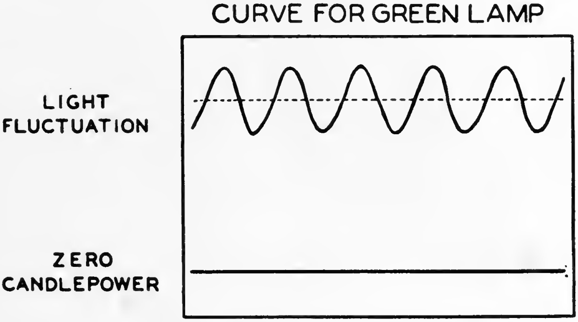
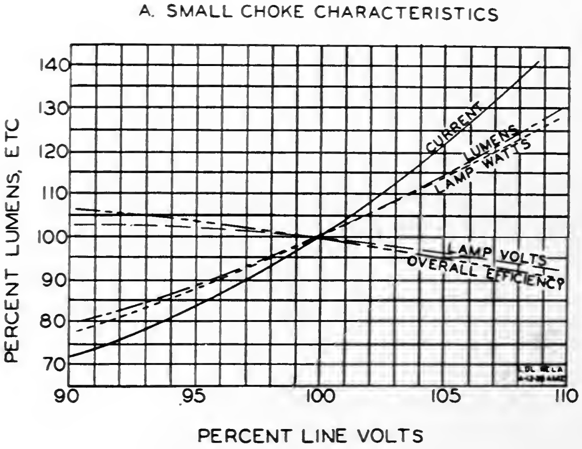


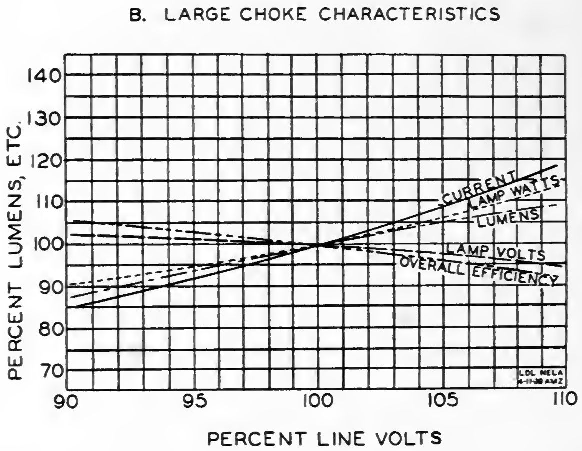
FIG. 5. Cyclic flicker chart for 15-watt fluorescent lamps.

Fluorescent lamps may be operated on direct current by combining a suitable resistance with the regular auxiliary. Losses in this case are higher resulting in lower overall efficiencies.

As some of the applications of the fluorescent lamps of particular



A. SMALL CHOKE CHARACTERISTICS



B. LARGE CHOKE CHARACTERISTICS

FIG. 6. Changes in fluorescent lamp characteristics at varying line voltages.
(*A*) Using a small, low-cost auxiliary.
(*B*) Using a high-quality auxiliary.

interest in the motion picture field may be mentioned the use of daylight fluorescent lamps for make-up work; sketching of costumes and sets; for mixing paint in colors called for in sketches; matte painting; for illumination in close-up motion picture shots; and for general interior lighting of offices, commissaries, and the like. These are but a few of the many possible applications, and doubtless many more will arise with experience and familiarity with the lamps.

FIG. 7. Use of fluorescent lamps for close-up in scene from Warner Bros. *The Old Maid.*

Fig. 7 illustrates an application of fluorescent lighting for close-ups, showing Tony Gaudio of Warner Bros. First National Studio, photographing a scene from *The Old Maid,* starring Bette Davis, Miriam Hopkins, and Cissie Loftus, who is shielded by the fluorescent lamp in the foreground. A *Y-1* straw gelatin was used to filter the daylight fluorescent lamps to give the best rendition of Miss Davis' blue eyes.

REFERENCES

[1] INMAN, G. E., AND THAYER, R. N.: "Low-Voltage Fluorescent Lamps," *Electrical Engineering,* **57** (1938), p. 245.

[2] INMAN, G. E.: "Characteristics of Fluorescent Lamps," *Trans. Illum. Eng. Soc.,* **34** (1939), p. 65.

[3] THAYER, R. N., AND BARNES, B. T.: "The Basis for High Efficiency in Fluorescent Lamps," *J .Opt. Soc. Amer.,* **29** (1939), p. 131.

PRESIDENTIAL ADDRESS*

E. ALLAN WILLIFORD

Fellow Members of the Society of Motion Picture Engineers: By tradition and custom, the President of this Society is charged with the obligation of making an address to you upon the convening of each of your Semi-Annual Meetings. Formerly, you were regaled, enlightened, and entertained with a second Presidential address at the Semi-Annual Banquet. But with the progress of time, the insistent demand for this second speech has diminished so that now, it would take a very brave and irrepressible President even to attempt a banquet oration.

For the next few minutes, however, I will briefly review the aims of our Society and its accomplishments since we last convened here in Hollywood. But before proceeding with that portion of this address, may I pause to express to our officers, members, and other good friends here, our delight at being again in this Capitol of picture entertainment. It is always a pleasure to forsake the rigors of our Eastern winter and bask in the sunshine of lovely Southern California, but it becomes doubly delightful when one is here surrounded by the forces of practical creation in that field in which we all labor, and where we can commune and exchange ideas and experiences with those of you who are responsible for so much that is technically fine and artistically beautiful in the motion picture of today.

The Society of Motion Picture Engineers was organized by Mr. C. Francis Jenkins in October, 1916. It grew out of an urgent need for just such an organization whose functions were not being and could not be performed by any other organization then in existence. The subsequent growth and usefulness of our Society is fairly common knowledge to all of you. From a membership of nine persons at the start, we have grown to a membership of 1319 as of December 31, 1938.

The Society of Motion Picture Engineers is exactly what its name

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* Presented at the 1939 Spring Meeting at Hollywood, Calif., April 16, 1939.

implies. It is not a commercial or trade association, it has no axe to grind, no work to perform other than to serve as a clearing house for orderly progress in the development of the science and art of motion picture production, processing, and projection. It is recognized by the United States Bureau of Standards and by all other leading engineering and scientific societies as the engineering center of our industry. It numbers among its members the leading technicians in the motion picture field whether they be in Hollywood, or New York, in production or projection, on university staffs or associated with commercial organizations, in research work or as executives of the companies they represent. This society exists to serve our industry, not to compel it. It believes in whole-hearted and generous coöperation among our various members and with sister societies. In its principal task of standardization, it keeps in mind at all times the axiomatic definition of a law as being "the statement of the recurrence of a phenomenon." The standard *follows* approved practice—it does not precede it.

How is it that a society so large as the SMPE can work efficiently? The answer is "through committees." The organization of our society is the result of practical experimentation, just as the design of a piece of technical apparatus is perfected through experimentation. Our vice-presidents all have specific functions to perform and each is responsible for the work of the comittees they appoint and who serve under their guidance. The excellent arrangements for this particular Convention are the result of the planning of our Executive Vice-President, Mr. Nathan Levinson, and his various local committees. The general framework of this, as with other conventions for a number of years past, has been the work of our genial Convention Vice-President, Mr. William C. Kunzmann. The various technical committees, such as the "Laboratory Practice," the "Preservation of Film" and the "Projection Practice" committees carry on this work of coördination and standardization under our Engineering Vice-President, Dr. L. A. Jones. The planning and solicitation of papers for this, and many other Conventions of our society in the past, and the supervision of the editing of our monthly Journal has been under the untiring guidance of our Editorial Vice-President, Mr. John I. Crabtree. And last but by no means least from a practical point of view, the building of membership and supervision of finances comes under the watchful eye of our Financial Vice-President, Mr. Arthur S. Dickinson. Your Secretary and

Treasurer perform the usual duties of those offices while your President supplies the general planning and, we hope, the urge and inspiration to accomplishment and harmony.

Our Society, like our government, functions under a Constitution. What we can do for the industry or for any individual company or person is limited by the powers granted us in this Constitution, and the By-Laws which supplement it. Provision has been wisely made, however, for amendment to this charter and the number of such changes which have been made from time to time by action of the society, has enabled us to keep abreast of changing times and changing needs.

No organization, no matter how perfect on paper, is any better than the men who occupy the responsible positions in it. New men come along to fill vacancies as they are open and some of the old-timers are reëlected to their former offices because no new man has shown up who has the ability, the time, and the willingness to take this job. The more active members of our Society are constantly looking for new blood to fill places as officers, members of the Board of Governors, committee chairmen, and even members of committees themselves. It is my belief that in the near future, no one will be permitted to succeed himself in office indefinitely, thereby compelling new men to come in to take their places.

With this word picture of our Society in action, let us review for a moment the progress which has been made during the past year in the motion picture industry. Not since 1931, have so many nor so radical innovations in film emulsions been introduced to the world. First came films with increased speed and finer grain as compared with the former emulsions available. Then came a special, fine-grained film with twice the former speed for background projection. And finally, for black-and-white photography, there was introduced a film with four times the speed of last year's speediest emulsions. For color photography a similar high-speed emulsion is available.

The introduction of these faster films has made possible an improvement in the quality of the photographic image through stopping down the lens opening at present levels of lighting. Or, if money savings seem more important, the amount of light used can be reduced while using present lens openings. Or perhaps a better balance can be arrived at by using some of each of these methods.

And while on the subject of set lighting, there has continued a movement toward smaller units of higher light output made possible by improved incandescent bulbs and silent, steady-burning, high-intensity arcs.

Great progress has been made in the art and science of background projection. A committee of the Research Council of the Academy has developed recommended standards for projectors, lamps, carbons, lenses, and other necessary equipment which has greatly advanced the precision and availability of this medium. Triple-projector units have been used successfully in superimposing three images from keyed prints with satisfactory registration on the background screen and greatly increased volume of light.

This past year has seen much greater use of light and exposure-meters on sets. While these have not fully solved some of the problems inherent in the use of the faster films and in making color pictures, they have been of considerable assistance and have pointed the way toward further development of such meters.

In the theater field, new projection machines and new sound systems have improved the quality of exhibition. A greater use of the high-intensity arc, particularly of the non-rotating positive carbon type, has added to the enjoyment of theater patrons, especially when color pictures are shown.

During 1938, the use of 16-mm film was greatly expanded. Some producers are making feature pictures available on 16-mm acetate film for theatrical as well as for non-theatrical use. New 16-mm projectors and cameras with sound have been developed and placed on the market. A small, compact carbon arc projection lamp has been developed in conjunction with 16-mm projectors giving several times the light and definition previously available for 16-mm film.

Several new 8-mm cameras and projectors have appeared on the market during the past year. One of these is adaptable for 8-mm, 9.5-mm, or 16-mm film, while another is capable of showing either 8-mm or 16-mm pictures.

Last, but far from least in the amount of interest engendered, is the commercial introduction of television. While direct telecasting of sports and news events and perhaps a few dramatic productions seem in the offing, by far the greatest use of television will probably be in the telecasting of sound-films. For this purpose, both intermittent and non-intermittent projectors have been used successfully. In England, recently, a prize fight was televised directly from the ringside to two theaters. Two systems of telecasting and reception were used, one employing a cathode-ray tube for projection onto the theater screen and the other using a carbon arc lamp for projecting the televised image. Both screens were small but the images were reported as fairly distinct and flickerless. The reporter who witnessed both experiments stated however, that much was yet to be done before televised theater pictures would be satisfactory to the patrons.

During the next few days, you will see and hear demonstrated some of the improved materials, apparatus, and methods referred to in this brief comment. We hope you will attend as many of our sessions as your time permits and that you will participate freely in the discussion of the various papers. This is your Society and you will benefit from it in proportion as you give of your time and effort. In closing, may I wish for all of you, much pleasure and profit during the balance of our convention.

E. A. W.

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, 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

86 (June 9, 1939), No. 4127

Foveal Circle Scan, A Basically New Method of Moving Picture Presentation (pp. 362–363)	L. H. Huitt

86 (June 23, 1939), No. 4129

Progress in Colour (p. 387)	

Communications

19 (May, 1939), No. 5

New High Fidelity Receiver (pp. 14–15, 35–36)	L. G. Pacent and H. C. Likel
Television Lighting, Pt. I (pp. 17–19)	W. C. Eddy
Films in Television (pp. 28, 30, 32–34)	J. A. Maurer

19 (June, 1939), No. 6

Sound Motion Picture Films in Television, Pt. II (pp. 17, 27, 30)	J. A. Maurer
The Fundamentals of Television Engineering, Pt. III (pp. 18, 20, 24)	F. A. Everest

Educational Screen

18 (June, 1939), No. 6

Motion Pictures—Not for Theatres, Pt. 10 (pp. 191–194, 208)	A. E. Krows

International Photographer

11 (June, 1939), No. 5

Direct Color Still Methods Compared (pp. 5–6)	D. Hooper
Projection Symposium, Pt. 7 (pp. 7–9)	J. Hilliard
New Shift Modernizes B & H Camera (pp. 16, 18)	

Kinematograph Weekly

268 (June 8, 1939), No. 1677

Television by Scophony's Newest Model (p. 31)	

268 (June 1, 1939), No. 1676

Title Cards by Typewriting Process (p. 36)

A Puzzle in Photometry, Solar Mirror Increases Actinic Light (pp. 36, 35)

Philips Technical Review

4 (April, 1939), No. 4

A Simple Apparatus for Sound Recording (pp. 106–113) K. de Boer and A. Th. van Urk.

1939 FALL CONVENTION

SOCIETY OF MOTION PICTURE ENGINEERS

HOTEL PENNSYLVANIA, NEW YORK, N. Y.
OCTOBER 16th–19th, INCLUSIVE

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J. Haber, *Chairman, Publicity Committee*
S. Harris, *Chairman, Papers Committee*
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Headquarters

Headquarters.—The headquarters of the Convention will be the Hotel Pennsylvania, where excellent accommodations have been assured, and a reception suite will be provided for the Ladies' Committee.

Reservations.—Early in September room reservation cards will be mailed to members of the Society. These cards should be returned as promptly as possible in order to be assured of satisfactory accommodations. The great influx of visitors to New York, because of the New York World's Fair, makes it necessary to act promptly.

Hotel rates.—Special *per diem* rates have been guaranteed by the Hotel Pennsylvania to SMPE delegates and their guests. These rates, European plan, will be as follows:

Room for one person	\$ 3.50 to \$ 8.00
Room for two persons, double bed	\$ 5.00 to \$ 8.00
Room for two persons, twin beds	\$ 6.00 to \$10.00
Parlor suites: living room, bedroom, and bath for one or two persons	\$12.00, \$14.00, and \$15.00

Parking.—Parking accommodations will be available to those who motor to the Convention at the Hotel Fire Proof Garage, at the rate of \$1.25 for 24 hours, and \$1.00 for 12 hours, including pick-up and delivery at the door of the Hotel.

Registration.—The registration desk will be located at the entrance of the *Banquet Room* on the ballroom floor where the technical sessions will be held. All members and guests attending the Convention are expected to register and receive their badges and identification cards required for admission to all the sessions of the Convention, as well as to several *de luxe* motion picture theaters in the vicinity of the Hotel.

Technical Sessions

The technical sessions of the Convention will be held in the *Banquet Room* on the ballroom floor of the Hotel Pennsylvania. The Papers Committee plans to have a very attractive program of papers and presentations, the details of which will be published in a later issue of the JOURNAL.

Luncheon and Banquet

The usual informal get-together luncheon will be held in the Grand Ballroom of the Hotel on Monday, October 16th. The Semi-Annual Banquet and Dance will be held in the Grand Ballroom of the Hotel Pennsylvania on Wednesday, October 18th, at 8:30 P. M. At the banquet the annual presentation of the SMPE Progress Medal and the Journal Award will be made, and the officers-elect for 1940 will be introduced.

Entertainment

Motion Pictures.—At the time of registering, passes will be issued to the delegates of the Convention admitting them to several *de luxe* motion picture theaters in the vicinity of the Hotel. The names of the theaters will be announced later.

Golf.—Golfing privileges at country clubs in the New York area may be arranged at the Convention headquarters. In the Lobby of the Hotel Pennsylvania will be a General Information Desk where information may be obtained regarding transportation to various points of interest.

Miscellaneous.—Many entertainment attractions are available in New York to the out-of-town visitor, information concerning which may be obtained at the General Information Desk in the Lobby of the Hotel. Other details of the entertainment program of the Convention will be announced in a later issue of the JOURNAL.

Ladies' Program

A specially attractive program for the ladies attending the Convention is being arranged by Mrs. O. F. Neu, *Hostess*, and the Ladies' Committee. A suite will be provided in the Hotel where the ladies will register and meet for the various events upon their program. Further details will be published in a succeeding issue of the JOURNAL.

New York World's Fair

Members are urged to take advantage of the opportunity of combining the Society's Convention and the New York World's Fair on a single trip. Information on special round-trip railroad rates may be obtained at local railroad ticket

offices. Trains directly to the Fair may be taken from the Pennsylvania Station, opposite the Hotel: time, 10 minutes; fare, 10¢. Among the exhibits at the Fair are a great many technical features of interest to motion picture engineers.

Points of Interest

Headquarters and branch offices of practically all the important firms engaged in producing, processing, and exhibiting motion pictures and in manufacturing equipment therefor, are located in metropolitan New York. Although no special trips or tours have been arranged to any of these plants, the Convention provides opportunity for delegates to visit those establishments to which they have entree. Among the points of interest to the general sightseer in New York may be listed the following:

Metropolitan Museum of Art.—Fifth Ave. at 82nd St.; open 10 A. M. to 5 P. M. One of the finest museums in the world, embracing practically all the arts.

New York Museum of Science and Industry.—RCA Building, Rockefeller Center; 10 A. M. to 5 P. M. Exhibits illustrate the development of basic industries, arranged in divisions under the headings food, industries, clothing, transportation, communications, *etc.*

Hayden Planetarium.—Central Park West at 77th St. Performances at 11 A. M., 2 P. M., 3 P. M., 4 P. M., 8 P. M., and 9 P. M. Each presentation lasts about 45 minutes and is accompanied by a lecture on astronomy.

Rockefeller Center.—49th to 51st Sts., between 5th and 6th Aves. A group of buildings including Radio City Music Hall, the Center Theater, the RCA Building, and the headquarters of the National Broadcasting Company, in addition to other interesting general and architectural features.

Empire State Building.—The tallest building in the world, 102 stories or 1250 feet high. Fifth Ave. at 34th St. A visit to the tower at the top of the building affords a magnificent view of the entire metropolitan area.

Greenwich Village.—New York's Bohemia; a study in contrasts. Here are located artists and artisans, some of the finest homes and apartments, and some of the poorest tenements.

Foreign Districts.—Certain sections of the city are inhabited by large groups of foreign-born peoples. There is the Spanish section, north of Central Park; the Italian district near Greenwich Village; Harlem, practically a city in itself, numbering 300,000 negroes; Chinatown, in downtown Manhattan; the Ghetto, the Jewish district; and several other such sections.

Miscellaneous.—Many other points of interest might be cited, but space permits only mentioning their names. Directions for visiting these places may be obtained at the Convention registration desk: Pennsylvania Station, Madison Square, Union Square, City Hall, Aquarium and Bowling Green, Battery Park, Washington Square, Riverside Drive, Park Avenue, Fifth Avenue shopping district, Grand Central Station, Bronx Zoo, St. Patrick's Cathedral, St. Paul's Chapel, Cathedral of St. John the Divine, Trinity Church, Little Church Around the Corner, Wall St. and the financial district, Museum of Natural History, Columbia University, New York University, George Washington Bridge, Brooklyn Bridge, Triborough Bridge, Statue of Liberty, American Museum of Natural History, Central Park, Metropolitan Museum of Art, and Holland Tunnel.

SOCIETY ANNOUNCEMENTS

OFFICERS AND GOVERNORS FOR 1940

At the meeting of the Board of Governors, held at the Hotel Pennsylvania, New York, N. Y., on July 13th, the following nominations for officers and governors for 1940 were made:

Engineering Vice-President	D. E. Hyndman
Financial Vice-President	A. S. Dickinson
Secretary	J. Frank, Jr.
Treasurer	R. O. Strock
Governors	H. Griffin
	A. N. Goldsmith
	A. C. Hardy
	L. W. Davee
	F. E. Carlson
	N. F. Oakley

Nominating ballots have been mailed to the voting membership of the Society, and announcement of the results will be made on the first day of the Fall Convention at New York on October 16th.

The Engineering Vice-President, Financial Vice-President, and the Governors are elected for two-year terms; the Secretary and Treasurer for one-year terms. Of the six nominees for Governors, three will be elected. The elected officers and governors will assume office on January 1, 1940.

AMENDMENTS TO THE BY-LAWS

At the meeting of the Board of Governors on July 13th, the following amendments to the By-Laws were proposed for submission to the Society at the Fall Convention. These proposed amendments are published herein in accordance with the requirements of By-Law XI, specifying the method of amending the By-Laws, and will be acted upon at the Business Session of the Fall Convention scheduled for Monday, October 16th.

BY-LAW IV

Committees

Sec. 1.—All committees, except as otherwise specified, shall be appointed by the President.

Sec. 2.—All committees shall be appointed to act for the term served by the officer who shall appoint the committees, unless their appointment is sooner terminated by the appointing officer.

Sec. 3.—Chairman of the committees shall not be eligible to serve in such capacity for more than two consecutive terms.

It is intended that this By-Law, if and when adopted, will be known as By-Law IV, the present By-Law IV and all subsequent By-Laws being re-numbered accordingly.

BY-LAW VI

Elections

(In the following proposed amendment, the new portions are printed in Italics, the unchanged portions in Roman type.)

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 shall nominate for each vacancy several suitable candidates. Nominations shall first be presented by a Nominating Committee appointed by the President, consisting of nine members, including a chairman. The committee will be made up of two Past Presidents, three members of the Board of Governors not up for election, and four other Active, Fellow, or Honorary members, not currently an officer or Governor of the Society. Nominations shall be made by three-quarters affirmative vote of the total Nominating Committee. Such nominations shall be final unless any nominee is rejected by a three-quarters vote of the Board of Governors present and voting.

The secretary shall then notify these candidates of their nomination, 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 *Active,* Fellow, or Honorary members other than those suggested by the Board of Governors may be voted for. The balloting shall then take place.

The ballot shall be enclosed in a blank envelope which is enclosed in an outer envelope bearing the secretary's address and a space for the member's name and address. One of these shall be mailed to each Active, Fellow, and Honorary member of the Society, not less than forty days in advance of the annual fall convention.

The voter shall then indicate on the ballot one choice for each office, seal the ballot in the blank envelope, place this in the envelope addressed to the secretary, sign his name and address on the latter, and mail it in accordance with the instructions printed on the ballot. No marks of any kind except those above prescribed shall be placed upon the ballots or envelopes.

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 following is the original paragraph which the italicized paragraph given above is intended to supersede:

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.

FALL CONVENTION

As announced in the previous issues of the JOURNAL, the Fall Convention of the Society will be held at the Hotel Pennsylvania, New York, N. Y., October 16th–19th, inclusive. Details pertaining to the Convention will be found on page 343.

ADMISSIONS COMMITTEE

The following applicants were admitted by vote of the Board of Governors to the Active grade:

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Brooklyn, N. Y.
HOWSE, S. E.
4240 Dundee Dr.,
Los Angeles, Calif.
JAVAL, I. H. C.
British Acoustics,
Film House, Wardour St.,
London, England.
MAXFIELD, J. P.
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New York, N. Y.
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S. M. P. E. 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 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. 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.

16-Mm. Sound-Film

Approximately 400 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 6000 cps.; the constant-amplitude frequencies are in 11 steps from 50 cps. to 6000 cps.

Price $25.00 each.

16-Mm. Visual Film

An optical reduction of the 35-mm. visual test-film, identical as to contents and approximately 225 feet long.

Price $25.00 each.

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* Term expires December 31, 1939.
** Term expires December 31, 1940.

CARBONS FOR TRANSPARENCY PROCESS PROJECTION IN MOTION PICTURE STUDIOS*

D. B. JOY, W. W. LOZIER, AND M. R. NULL**

Summary.*—Data are given on the amount and distribution of light which can be obtained on the transparent screen with regular high-intensity carbons and various optical systems. These optical systems include two condenser-type systems and two relay-condenser-type systems used with f/2.3 and f/2.0 objective lenses. Values are obtained which are in line with the recommendations on Process Projection Equipment by the Research Council of the Academy of Motion Picture Arts and Sciences.*

In addition, characteristics of two new carbons developed for this purpose are given. These are also evaluated in the relay-condenser system and give the advantage of additional light, or the same light at lower energy input.

(I) INTRODUCTION

"Process projection" or "background projection" are terms used to represent the practice of supplying a background for a motion picture set by means of projection from a film through a translucent screen placed at the rear of the actual set. This field of cinematography has received only scanty consideration in the literature, but persons having first-hand acquaintance with activities in the motion picture studios know of the vast amount of work done in the studios on process projection, the wonderful results accomplished, and the economic and artistic importance of this process to the motion picture industry. However, it is only too well realized that the use of the process has to a large extent been restricted by the technical shortcomings of the equipment, and it is only the skill and resourcefulness of studio technicians that have made the use of background projection as widespread as it is at present.

The Research Council of the Academy of Motion Picture Arts and Sciences appointed in March, 1938, a committee under the chairmanship of Farciot Edouart, composed of motion picture studio experts in the field of process projection and other interested persons,

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 21, 1939.

** National Carbon Co., Fostoria, Ohio.

to consider the problems and needs of process projection in its entirety.

As a result of a year's intensive work, this Committee has published a report of Recommendations on Process Projection Equipment,[1] released in February, 1939. This report, as stated, "presents for the first time, the coördinated viewpoint of the majority of the Hollywood studios on this subject and should be of great value to all the studios and to the manufacturers of process projection equipment." This report is certainly worthy of detailed study by all persons interested in motion picture production and is indicative of the high quality of the work of the various committees of the Research Council of the Academy. It has been of great benefit in visualizing the light-source requirements for process projection and in the development of carbons more suitable for this application.

This Academy Report describes three possible optical systems for use with the carbon arc for process (or rear) projection. It was believed that it would be interesting and helpful to measure the light and distribution of light which can be obtained by these systems with the carbons recommended for this application, and this paper includes such data.

Furthermore, as a result of studying the particular requirements of this process projection, special 11-mm and 16-mm carbons have been developed for this application and are herein described. The 11-mm carbon is of particular importance because it has an intrinsic brilliancy far in excess of any carbon hitherto available. As a result of this characteristic this carbon at 135 amperes gives with the relay condenser system a light on the projection screen equal to that formerly possible only with an arc at 180 amperes on a larger carbon.

(II) DIFFERENCES BETWEEN CARBON REQUIREMENTS FOR PROCESS PROJECTION AND ORDINARY MOTION PICTURE PROJECTION

In motion picture theater projection, the film aperture through which the light is projected is 0.825 × 0.600 inch and it is desirable that there be a falling off in light from the center to the sides of the screen. The ratio of the brightness at the sides to that at the center of the screen may vary from 80 to as low as 60 per cent without being unusual in appearance.

Process or background projection on the other hand uses the much larger silent camera aperture 0.950 × 0.723 inch in size, and sometimes the sound camera aperture, 0.868 × 0.631 inch. Also the desirable distribution of the light on the translucent screen is that the brightness at the sides and corners of the screen should be as high as, or preferably higher than, at the center.

The properties of the translucent screens in use today dictate to a certain extent this desired distribution of light over the screen. In order to obtain sufficiently high transmission of light through the screen, its diffusion properties are somewhat inferior to the "ideal" diffuser. This gives rise to a "hot spot" seen from the camera at that portion of the screen on the line joining the camera and the projector. In general, this effect combines with the usual decrease in illumination at the boundaries of the screen to make a very accentuated variation in brightness over the screen when viewed from the camera position. It is therefore extremely desirable to keep the light falling upon the boundaries of the screen at as high a value as possible relatively to that falling upon the center of the screen in order to avoid this "hot-spot" effect.

The combination of the projected background scene with the foreground action into a single series of images on the motion picture film imposes further restrictions in order to create the desired illusion. The intensity of the background must be balanced with that of the foreground action. The illumination of the foreground and background must remain uniform and free from fluctuations in order to prevent disturbing contrasts between the two from becoming noticeable in the final motion picture. Finally, in color photography it is necessary that the color of the background be balanced with the foreground color.

In process projection, there is not the restricted space of the motion picture projection booth limiting the dimensions of the lamp or optical system, nor is there the necessity of operating the arc for more than 20 minutes of continuous burning. Most rear-projection scenes are of only a few minutes' duration. This has placed less limitation on the design of both carbons and optical systems for process projection.

There is a demand for more light on the translucent screen and this, as stated in the Committee Report,[1] should be combined with "absolute steadiness of the projected picture with a minimum of light variation on the screen and increased efficiency of the light."

In addition to the bulletin referred to above there are two earlier articles[2,3] on process projection outlining some requirements and methods in use.

(III) EXPERIMENTAL METHODS USED FOR MEASURING LIGHT FROM CARBONS IN VARIOUS OPTICAL SYSTEMS

This paper will consider only those cases of process projection in which motion picture film is projected; still backgrounds obtained from stereopticon projection are not directly considered, although some of the results discussed below can doubtless be applied here.

For process projection both the full silent camera aperture and the standard sound camera aperture are at times employed; therefore in the tests described below both these apertures have been used.

At least three distinct optical systems have been considered for rear projection. These are the reflector-type optical system, the condenser-type optical system, and a modified relay-condenser-type system developed by the laboratories of the Technicolor Motion Picture Corporation. The authors are indebted to the Technicolor Company for the details of the latter system. These three types of optical systems that have been considered for process projection differ among themselves in the degree to which they satisfy the requirements. In the following, these optical systems are described and measurements reported of the luminous flux falling on the screen when used with various standard carbons and two experimental carbons. The screen illumination was measured at several points on the screen using calibrated Weston Photronic cells equipped with Viscor filters. The illumination was reduced to convenient values by placing calibrated wire screens in the light-beam.

The actual values of luminous flux falling on the screen are in part determined by the speed and design characteristics of the particular projection lens employed. The desirable projection lens characteristics are described on pp. 12 and 13 of the Academy Bulletin.[1] We have used for these measurements three lenses, all 5 inches in focal length: the Bausch & Lomb *f*/2.3 Super Cinephor, which has been found very satisfactory in design characteristics for rear projection work; and two experimental *f*/2.0 lenses Nos. 506 and 524 loaned to us by the Bausch & Lomb Optical Company, to whom we are indebted for their use. Lens No. 524 gives more total light and a higher proportion of light at the sides and corners of the screen, but this has been done with some sacrifice of the higher quality of projection of lens no. 506.

In the measurements described below values are reported for the lumens falling on the translucent screen; these values were obtained with no film shutter. Screen distribution values for the sides and corners of the screen are quoted and represent the illumination at the sides and corners of the screen relative to that at the center of the screen taken as 100.

Relative heat at the aperture has been measured by placing a suitable device in the plane of the aperture, and all the figures quoted below are on a comparable arbitrary basis. The device used consisted of a thermocouple mounted on a small, blackened silver-plate receiver; the combination was calibrated for thermocouple temperature *vs.* total incident radiant energy.

(IV) CARBONS FOR MIRROR-TYPE LAMP

The basic elements of the ordinary mirror system used in theater projection are well known and the optics of this system have been fully discussed in the literature[4,5,6] so that it will suffice here to give only a summary review. In this system the mirror collects the radiation from the carbon arc and forms an image of the arc on the film aperture; the light passes through the film and is focused on the screen by the projection lens. The diameter of the mirror and its distance from the film-gate determine how completely the light-beam fills the relative aperture of the projection lens; the size of the light-source and the magnification factor of the mirror determine how adequately the film aperture is covered with light.

High-intensity reflector type lamps in use in theatrical projection today employ an ellipsoidal reflector and are largely of two types: first, an angular-trim lamp employing a 9-mm bare positive carbon which is rotated; and, second, the more recent horizontal-trim lamps employing 6-mm, 7-mm, or 8-mm copper-coated "Suprex" positive carbons which are not rotated. The light output would not be sufficient for process projection except for very small screens. Also, these lamps are designed to illuminate the smaller aperture used in theater projection, and will not cover to best advantage the larger apertures used in process projection without an increase in the carbon size or the mirror magnification. Neither the mirrors nor the lamp housing and mechanism are designed to withstand the higher power input called for by the use of larger carbons. A current of possibly 140 to 150 amperes would be necessary with a mirror system to take care of transparency projection adequately with the large silent camera aperture. Some measurements were made with such a system and total light comparable to that possible with the relay-condenser system was obtained. However, the light at the sides was considerably lower than at the center, and since this was on a purely experimental basis, with no assurance that mirrors in a lamp of reasonable size would stand this usage, these data are not included in the present comparisons.

(V) CARBONS FOR CONDENSER-TYPE LAMPS

Condenser-type lamps are used for projection in the larger theaters and have been widely used in background projection in the studios. The basic features of this system are shown in Fig. 1. The condenser lens gathers the radiation at the arc and forms an image of the arc crater on the film aperture. In this respect the mirror and condenser systems behave alike; they differ in respect to the magnification and collecting angle. In general, the size of the cone of radiation collected at the arc is smaller with condensers than with mirrors; therefore, in order to fill fast lenses and obtain intense screen light, the condenser will have a lower magnification ratio than a mirror having a wider collecting angle. This lower magnification of the condenser system necessitates the use of a larger carbon than with the mirror system. Therefore, we find with condenser systems that the positive carbon diameter ranges from 13.6 to 16 mm in diameter. In general, the positive carbon is rotated continuously during burning, and the negative carbon makes an angle of approximately 40 to 60 degrees with the positive carbon.

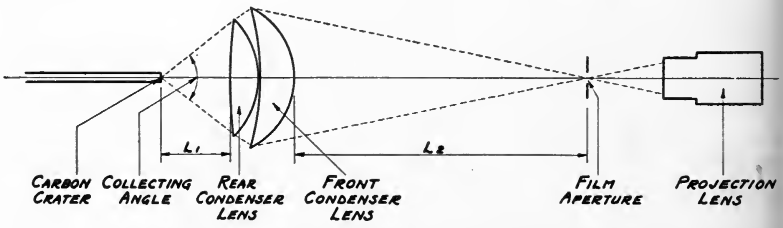

FIG. 1. Diagram of the conventional condenser system.

Screen light and aperture heat measurements were made on four trims of "National" carbons commonly used for rear projection. These carbons were burned in the Brenkert Model *A* lamp. Two sets of condensers, listed in Table I, manufactured by the Bausch & Lomb Optical Company, were used. Condenser combination *A* was designed a number of years ago, and condenser combination *B* is a set of more recent development. The distances employed with these condensers in the tests are given in Table I.

Measurements of screen light were taken with the three Bausch & Lomb projection lenses and two camera apertures previously described, and a summary of the results is given in Table II.

In this table we have listed the results in such a way that the objective lenses can be directly compared under each condenser-lens combination, and the condenser-lens combinations compared for each carbon. The main grouping is according to the carbons used. Each carbon combination was burned at approximately its maximum recommended current.

TABLE I

Distances Used with Condensers for Screen Light Measurements

Condenser Combination	Distance from Carbon to Rear Condenser	Distance from Front Condenser to Aperture
Combination *A* Rear Lens, B. & L. 41-86-27 Front Lens, B. & L. 41-86-28	3.75 inches	15 inches
Combination *B* Rear Lens, B. & L. 41-86-62 Front Lens, B. & L. 41-86-63	2.75 inches	15 inches

The two camera apertures are used since both are employed to some extent for process projection. The relative heat at the aperture was measured as previously described, and the figures are in arbitrary units and give the comparative heat which was obtained at the center of the aperture with each carbon and condenser-lens combination. Changing the objective lens would not, of course, affect this temperature at the aperture. It was felt that the central point of the film aperture would be the most desirable place to take these temperature readings and that any spill-over at the aperture or other parts of the projector mechanism could be taken care of by suitable masks just ahead of the film aperture.

Condenser-lens combination *B* in every case gives about 30 to 40 per cent more light at the aperture than condenser-lens combination *A*. This will probably vary somewhat with different lenses but is a significant increase. It is at least partly accounted for by the fact that the rear lens of combination *B* is closer to the positive carbon and subtends a larger angle of light. Combination *A* subtends an angle of 80 degrees, whereas combination *B* subtends an

TABLE II

Screen Light and Distribution of Light from "National" Carbons with Regular Condenser Systems

Condenser Combination	Projection Lens	SOUND CAMERA APERTURE Screen Lumens No Film Shutter	SOUND CAMERA APERTURE % Screen Distribution Relative to Center		SILENT CAMERA APERTURE Screen Lumens No Film Shutter	SILENT CAMERA APERTURE % Screen Distribution Relative to Center		Relative Heat at Aperture
			Sides	Corners		Sides	Corners	
13.6-mm H.I. Positive—"Orotip" $^{7}/_{16}$-Inch Negative; 125 Amperes-68 Volts; Positive Consumption 11 I.P.H.								
A	$f/2.3$ Super Cinephor	5700	82	60	7300	75	49	175
	$f/2.0$ #506	6400	80	61	8300	76	50	
	$f/2.0$ #524	7300	84	65	9000	77	54	
B	$f/2.3$ Super Cinephor	7900	80	65	10,000	68	52	205
	$f/2.0$ #506	9500	74	63	11,900	70	54	
	$f/2.0$ #524	10,300	81	69	13,600	73	60	
16-mm H.I. Studio Positive—"Orotip" $^{7}/_{16}$-Inch Heavy-Duty Negative; 150 Amperes-68 Volts; Positive Consumption 9 I.P.H.								
A	$f/2.3$ Super Cinephor	6500	79	62	7300	77	55	
	$f/2.0$ #506	7200	81	66	8000	77	55	
	$f/2.0$ #524	8700	85	71	9400	80	64	
B	$f/2.3$ Super Cinephor	8100	77	64	10,500	74	59	225
	$f/2.0$ #506	10,000	80	68	12,400	73	59	
	$f/2.0$ #524	11,600	84	75	14,500	77	62	
16-mm Super H.I. Positive—"Orotip" $^{1}/_{2}$-Inch Heavy-Duty Negative; 195 Amperes-74 Volts; Positive Consumption 16 I.P.H.								
A	$f/2.3$ Super Cinephor	7400	81	68	9600	76	58	
	$f/2.0$ #506	8500	83	70	10,600	79	63	
	$f/2.0$ #524	9800	87	78	12,500	82	72	
B	$f/2.3$ Super Cinephor	9300	83	73	12,000	75	63	280
	$f/2.0$ #506	10,800	81	72	13,400	75	61	
	$f/2.0$ #524	12,900	90	80	16,000	82	69	
13.6-mm Super H.I. Positive—"Orotip" $^{1}/_{2}$-Inch Heavy-Duty Negative; 180 Amperes-78 Volts; Positive Consumption 28 I.P.H.								
A	$f/2.3$ Super Cinephor	8100	79	61	9900	74	50	210
	$f/2.0$ #506	9200	81	64	11,200	75	50	
	$f/2.0$ #524	10,300	84	72	12,700	78	59	
B	$f/2.3$ Super Cinephor	10,900	77	66	13,300	72	57	270
	$f/2.0$ #506	12,300	76	68	15,700	72	56	
	$f/2.0$ #524	14,300	81	73	18,400	76	61	

angle of 95 degrees. Reducing the distance of the rear lens to $2^3/_4$ inches from the positive crater increases the possibility of condenser pitting and breakage, and this may be a serious factor, particularly with the larger-size carbons at the higher currents. Both these condenser systems were positioned to give slightly less than the maximum light in order to bring up the distribution of the light at the sides and corners of the screen and thus more nearly approximate the requirements for rear projection. The total screen lumens for the silent camera aperture is, of course, somewhat higher than for the sound camera aperture, but this is counterbalanced by the fact that the light distribution is poorer on the silent camera aperture than on the sound camera aperture.

The carbons have been listed in the table in the order of the light on the screen; in other words, the 13.6-mm high-intensity positive carbon at 125 amperes gives the least light and the 13.6-mm super-high-intensity positive at 180 amperes gives the most light, with the two 16-mm carbons falling between. The 13.6-mm super carbon at 180 amperes gives with condenser-lens combination *B*, with the *f*/2.3 and *f*/2.0 systems, approximately the values in lumens indicated as desirable in the Academy Bulletin[1] (p. 22). Likewise, the values for the 16-mm super-high-intensity carbon at 195 amperes with condenser-lens combination *B* approximate those values referred to above, and the light distribution on the screen is more favorable for the 16-mm super carbon. The amount of energy at the arc with the 16-mm super carbon is slightly higher than with the 13.6-mm carbon. On the other hand, the 13.6-mm carbons burn at a higher consumption rate. The other carbons considered burn at lower consumption rates, and although the light is not as great as that apparently desirable for many process projection shots, it may be sufficient under some conditions for the smaller screens.

The *f*/2.0 No. 506 lens gave appreciably more screen light and about the same distribution of light as the *f*/2.3 Super Cinephor. The *f*/2.0 No. 524 lens showed in every case an increase in total lumens and higher relative light at the sides and centers than the *f*/2.0 No. 506 lens. This is without doubt compensated for in most applications by the increased definition, *etc.*, of this No. 506 lens, as indicated by the lens manufacturer.

In order to visualize what the total lumens and the comparative screen distribution means in light on the transparency screens, we have listed in Table III the same carbon, condenser-lens, and objec-

TABLE III

Foot-Candle Readings on 14-Foot Screen from "National" Carbons with Regular Condenser Systems

Condenser Combination	Projection Lens	SOUND CAMERA APERTURE Center	Sides	Corners	SILENT CAMERA APERTURE Center	Sides	Corners
13.6-mm H.I. Positive—"Orotip" 7/16-Inch Negative; 125 Amperes-68 Volts; Positive Consumption 11 I.P.H.							
A	*f*/2.3 Super Cinephor	46	37	28	62	47	31
	f/2.0 #506	52	41	32	70	53	35
	f/2.0 #524	57	48	37	76	58	41
B	*f*/2.3 Super Cinephor	61	49	40	88	59	46
	f/2.0 #506	79	59	49	103	72	56
	f/2.0 #524	81	66	56	119	87	71
16-mm H.I. Studio Positive—"Orotip" 7/16-Inch Heavy-Duty Negative; 150 Amperes-68 Volts; Positive Consumption 9 I.P.H.							
A	*f*/2.3 Super Cinephor	53	42	32	61	47	33
	f/2.0 #506	57	46	37	67	52	37
	f/2.0 #524	67	57	48	75	60	49
B	*f*/2.3 Super Cinephor	66	51	42	88	65	52
	f/2.0 #506	79	63	54	99	73	59
	f/2.0 #524	89	75	66	119	91	74
16-mm Super H.I. Positive—"Orotip" 1/2-Inch Heavy-Duty Negative; 195 Amperes-74 Volts; Positive Consumption 16 I.P.H.							
A	*f*/2.3 Super Cinephor	59	48	40	80	61	47
	f/2.0 #506	67	55	47	86	68	54
	f/2.0 #524	74	64	58	98	80	71
B	*f*/2.3 Super Cinephor	72	60	53	99	75	62
	f/2.0 #506	85	69	61	111	83	68
	f/2.0 #524	96	86	76	126	104	86
13.6-mm Super H.I. Positive—"Orotip" 1/2-Inch Heavy-Duty Negative; 180 Amperes-78 Volts; Positive Consumption 28 I.P.H.							
A	*f*/2.3 Super Cinephor	66	52	40	85	63	42
	f/2.0 #506	73	59	47	95	71	48
	f/2.0 #524	80	67	57	104	81	62
B	*f*/2.3 Super Cinephor	88	68	58	113	82	64
	f/2.0 #506	100	76	68	134	96	74
	f/2.0 #524	112	91	82	151	116	92

tive lens combinations, and have indicated the light in foot-candles which would be obtained at the center, sides, and corners of a 14-foot screen using the sound camera aperture and the silent camera aperture. Of course, for the same 14-foot picture the transparency screen would have to be farther away for the sound camera aperture than for the silent camera aperture. The results listed in Table III are significant to one who is accustomed to measuring the light on the transparency screen with a foot-candle meter. For example, the 13.6-mm super-high-intensity carbon at 180 amperes with condenser-lens combination *B* and the *f*/2.0 No. 506 lens will give on a 14-foot screen with the silent camera aperture 134 foot-candles at the center, 96 foot-candles at the sides, and 73 foot-candles at the corners; whereas the 13.6-mm high-intensity positive carbon at 125 amperes with this same condenser-lens and objective lens combination will give on this same 14-foot screen only 103 foot-candles at the center, 72 foot-candles at the sides, and 56 foot-candles at the corners.

Compared with the light at the center, the light at the corners and sides of the screen is somewhat lower than what is apparently desirable for process projection with the present transparency screen and methods used. This ratio of the light at the sides and the corners to that at the center could be improved by changing the position of the condenser-lenses with respect to the carbons, but this would entail a considerable loss of total light on the transparency screen.

(VI) CARBONS FOR RELAY CONDENSER SYSTEM

An optical system which promises to have particular merit for background projection is a modification of the relay condenser system. Relay condenser systems were patented by A. Koehler of the Zeiss Works about 1915[7] and Roger Hill in 1927.[8] The former has found application in photomicrography and microprojection, where it is called "Koehler illumination."[9] Some attempts have been made to use this type of optical system for motion picture projection and some results obtained with it have been described in the literature.[7,10,11,12] A modification of this system has been suggested by the Technicolor Motion Picture Corporation and is shown in Fig. 2.

This system was designed for a speed of *f*/1.6, and differs from the conventional condenser system in that the crater of the arc is not focused on the film aperture P_2 but rather in the vicinity just to the left of the lens L_3. The plane P_1, which is intermediate between the arc crater and the condenser-lenses, is focused by means of L_1, L_2, and the relay lens L_3, on the film aperture P_2. In this manner the coverage of the film aperture is much less dependent upon the distribution of the brightness across the arc crater and its size than with the conventional condenser system shown in Fig. 1. Here the variation of illumination across the film aperture follows more closely that across the plane P_1 than that across the carbon crater. A second image of the arc is formed in the vicinity of the projection lens L_4 and the size of this image, relative to the dimensions of the projection lens, determines how well this lens is filled with light. The size of the light-source, therefore, determines the size of the light-beam at the projection lens, and hence can affect the total projected light but has very little effect on the screen distribution.

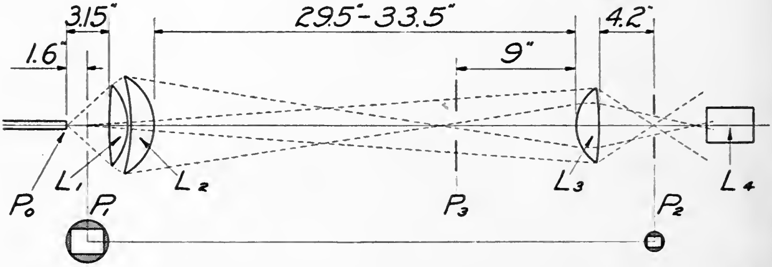

FIG. 2. Diagram of the relay condenser system developed by the Technicolor Motion Picture Corporation.

Previous forms of the relay condenser system imaged a plane at the condensers L_1 and L_2 on the film aperture and suffered the disadvantage that any imperfection or noticeable details in or on the condensers could be noticeable on the projected screen image. Also, it has been the practice in some cases to place an auxiliary aperture lens over the film aperture; the same criticism is applicable here as is expressed in the preceding sentence.

In the experimental set-up, lenses L_1 and L_2 were the same as the combination *A* of Table I, with the single exception that the surface of L_1 nearer the arc was changed from the customary cylindrical surface to a spherical surface of the same curvature. This eliminates the oval image of the carbon which would be formed with the cylindrical-surfaced lens and which would be of no particular value here. L_3 was a $5^1/_4$-inch diameter Bausch & Lomb *PM25* lens.

The spacing of the various parts of the optical system is shown in Fig. 2. After the lens L_3 was set to focus the plane P_1 on the film aperture, and the lens L_4 was focused on the projection screen, it was found that the lens L_3, the film aperture P_2, and the lens L_4 could all be moved back and forth to obtain a spot of light which covered the film aperture. In this manner, the size of the spot was adjusted to cover the two sizes of film aperture which were used. It was also found desirable to adjust this spacing slightly with the different projection lenses to obtain the most satisfactory screen light and screen distribution.

In measuring the relative heat at the aperture, it was found desirable to place a mask in the light-beam at P_3. This prevented light and heat which would not enter the projection lens from passing through the film aperture. This procedure could be used to advantage in process projection practice where an *f*/2.0 objective lens is used, because in several cases, particularly with large-size carbons, it has reduced the heat at the center of the aperture 50 per cent, with no reduction in light. Five standard carbon trims were measured in this relay condenser system using the same lamp, three projection lenses, and two aperture sizes already described. In addition, data were obtained on two experimental carbons which are the result of recent research work and which show outstanding characteristics with this relay system for transparency projection.

Measurements of screen light, screen distribution, and relative heat at the film aperture for these regular and experimental carbons are given in Table IV.

The five regular trims of carbons are grouped as in the case of Table II, in the order of the total lumens on the translucent screen. Each carbon is burned at approximately its maximum current. The values for the *f*/2.3 Super Cinephor and *f*/2.0 No. 506 lens are given for both the silent and sound aperture, and in some cases the values for the *f*/2.0 No. 524 lens also are included.

The relative heat at the aperture is on the same arbitrary basis as in Table II. The total screen light obtained with carbons used in this relay condenser system is noticeably greater than that obtained on the regular condenser system combination *A*, and of about the same magnitude as with the condenser system combination *B*. This is again accounted for to some extent by the fact that the rear condenser on this relay condenser system is at a distance of 3.15 inches from the arc and subtends an angle of light from the crater of 90

TABLE IV

Screen Light and Distribution of Light from "National" Carbons with Relay Condenser System Suggested by Technicolor

Projection Lens	SOUND CAMERA APERTURE Screen Lumens No Film Shutter	SOUND CAMERA APERTURE % Screen Distribution Relative to Center Sides	SOUND CAMERA APERTURE % Screen Distribution Relative to Center Corners	SILENT CAMERA APERTURE Screen Lumens No Film Shutter	SILENT CAMERA APERTURE % Screen Distribution Relative to Center Sides	SILENT CAMERA APERTURE % Screen Distribution Relative to Center Corners	Relative Heat at Aperture
11-mm H.I. Positive—"Orotip" $^{3}/_{8}$-Inch Negative; 110 Amperes-68 Volts; Positive Consumption 19 I.P.H.							
f/2.3 Super Cinephor	8600	101	77	9500	85	68	220
f/2.0 #506	9500	90	76	11,700	87	63	
f/2.0 #524	....	...	..	....	..	..	
13.6-mm H.I. Positive—"Orotip" $^{7}/_{16}$-Inch Negative; 125 Amperes-68 Volts; Positive Consumption 11 I.P.H.							
f/2.3 Super Cinephor	8600	98	78	10,200	89	68	260
f/2.0 #506	10,700	98	82	11,800	87	66	
f/2.0 #524	....	...	..	14,300	92	72	
16-mm Studio H.I. Positive—"Orotip" $^{7}/_{16}$-Inch Heavy-Duty Negative; 150 Amperes-68 Volts; Positive Consumption 9 I.P.H.							
f/2.3 Super Cinephor	9100	105	83	10,600	97	75	
f/2.0 #506	10,800	101	91	11,800	88	75	
f/2.0 #524	....	...	..	15,200	99	70	
16-mm Super H.I. Positive—"Orotip" $^{1}/_{2}$-Inch Heavy-Duty Negative; 195 Amperes-74 Volts; Positive Consumption 16 I.P.H.							
f/2.3 Super Cinephor	10,800	100	84	11,900	95	76	350
f/2.0 #506	13,900	96	86	16,300	93	69	
f/2.0 #524	....	...	..	....	..	..	
13.6-mm Super H.I. Positive—"Orotip" $^{1}/_{2}$-Inch Heavy-Duty Negative; 180 Amperes-78 Volts; Positive Consumption 28 I.P.H.							
f/2.3 Super Cinephor	11,700	94	76	13,100	80	61	325
f/2.0 #506	14,100	84	80	16,900	79	60	
f/2.0 #524	17,500	94	85	20,200	83	68	
11-mm Experimental Positive—"Orotip" $^{7}/_{16}$-Inch Heavy-Duty Negative; 135 Amperes-80 Volts; Positive Consumption 38 I.P.H.							
f/2.3 Super Cinephor	10,900	91	78	12,900	87	68	280
f/2.0 #506	13,500	89	78	16,600	84	62	
f/2.0 #524	17,100	98	84	18,100	87	68	
16-mm Experimental Positive—"Orotip" $^{1}/_{2}$-Inch Heavy-Duty Negative; 225 Amperes-74 Volts; Positive Consumption 22 I.P.H.							
f/2.3 Super Cinephor	....	...	..	15,200	81	69	425
f/2.0 #506	....	...	..	19,400	82	63	
f/2.0 #524	....	...	..	22,900	82	58	

degrees. This angle of light is somewhat greater than that of the condenser system A but smaller than that of the condenser system B. This distance, as stated before, was obtained experimentally, and appeared to be the most advantageous one from the standpoint of total light and distribution for the particular lenses used in this system. Even though the total light on the screen is essentially the same in amount for this relay condenser system as for the regular condenser system combination B, the distribution of the light on the screen is considerably more favorable for the relay condenser system than for the regular condenser system. In other words, it is desirable in process projection or rear projection that the sides and corners of the screen have the maximum amount of light compared with the center. It should be noted that in many instances in this table, the light at the sides of the screen with the sound camera aperture, is as high as or higher than at the center of the screen, and even with the silent camera aperture this condition is approached.

With this relay condenser system the 13.6-mm super and the 16-mm super again approximated the conditions mentioned in the Research Council's report;[1] that is, gave more than 12,000 lumens with the *f*/2.3 system and more than 16,000 lumens for the *f*/2.0 system. The 16-mm super-high-intensity carbon has a more favorable distribution than the 13.6-mm super carbon, the current is slightly higher, and the consumption is considerably lower.

In considering the application and use of carbons for this relay condenser system, it was realized that it would be very desirable to increase the total amount of light available and to cut down, if possible, the amount of energy at the arc and the temperature at the film aperture. A research program was therefore undertaken to achieve these objectives. As a result, we present two carbons known as the 16-mm experimental positive and the 11-mm experimental positive, which offer considerable improvement in these respects. These carbons were designed particularly with the relay condenser system in view, and the data on these carbons are presented in the last two sections of Table IV.

It is seen from these data that the 16-mm experimental positive carbon gives more than 19,000 lumens with the *f*/2.0 No. 506 lens with reasonably good distribution. This is more light than we have obtained with any of the other carbons on the same basis. With the *f*/2.0 No. 524 lens this value is increased to 22,000 lumens. This carbon was burned at 225 amperes and 74 arc volts and has a con-

TABLE V

Foot-Candle Readings on 14-Foot Screen from "National" Carbons with Relay Condenser System Suggested by Technicolor

Projection Lens	SOUND CAMERA APERTURE			SILENT CAMERA APERTURE		
	Center	Sides	Corners	Center	Sides	Corners
11-mm H.I. Positive—"Orotip" $^3/_8$-Inch Negative; 110 Amperes-68 Volts; Positive Consumption 19 I.P.H.						
f/2.3 Super Cinephor	61	62	47	74	63	50
f/2.0 #506	71	64	54	91	79	57
f/2.0 #524	...	...	...	...	...	...
13.6-mm H.I. Positive—"Orotip" $^7/_{16}$-Inch Negative; 125 Amperes-68 Volts; Positive Consumption 11 I.P.H.						
f/2.3 Super Cinephor	62	61	48	78	69	53
f/2.0 #506	76	75	62	105	84	67
f/2.0 #524	...	...	...	122	106	82
16-mm Studio H.I. Positive—"Orotip" $^7/_{16}$-Inch Heavy-Duty Negative; 150 Amperes-68 Volts; Positive Consumption 9 I.P.H.						
f/2.3 Super Cinephor	63	66	52	77	75	58
f/2.0 #506	75	76	68	89	78	67
f/2.0 #524	...	...	...	111	110	78
16-mm Super H.I. Positive—"Orotip" $^1/_2$-Inch Heavy-Duty Negative; 195 Amperes-74 Volts; Positive Consumption 16 I.P.H.						
f/2.3 Super Cinephor	76	76	64	87	83	66
f/2.0 #506	99	95	85	122	113	84
f/2.0 #524	...	...	...	...	...	...
13.6-mm Super H.I. Positive—"Orotip" $^1/_2$-Inch Heavy-Duty Negative; 180 Amperes-78 Volts; Positive Consumption 28 I.P.H.						
f/2.3 Super Cinephor	86	80	65	106	85	65
f/2.0 #506	107	90	85	138	109	83
f/2.0 #524	126	118	107	158	132	107
11-mm Experimental Positive—"Orotip" $^7/_{16}$-Inch Heavy-Duty Negative; 135 Amperes-80 Volts; Positive Consumption 38 I.P.H.						
f/2.3 Super Cinephor	81	74	63	100	87	68
f/2.0 #506	101	90	79	132	110	82
f/2.0 #524	121	119	102	140	121	94
16-mm Experimental Positive—"Orotip" $^1/_2$-Inch Heavy-Duty Negative; 225 Amperes-74 Volts; Positive Consumption 22 I.P.H.						
f/2.3 Super Cinephor	...	...	...	120	97	83
f/2.0 #506	...	...	...	154	127	97
f/2.0 #524	...	...	...	185	152	106

sumption rate of 22 inches per hour. This is a very high energy input, and it is questionable whether it is practicable to position the condenser three inches or less from the arc under these conditions.

For this reason we feel that the 11-mm experimental carbon is of greater interest, giving at 135 amperes light equal in amount and distribution to that produced by the 13.6-mm super-high-intensity carbon at 180 amperes. This is well above the minimum desired by the Research Council Committee;[1] and furthermore, this 11-mm experimental carbon gives slightly less heat at the film aperture than the 13.6-mm super-high-intensity carbon. This differential in heat is approximately 15 per cent and is of considerable importance in this application. The carbon consumption for this 11-mm experimental carbon is 38 inches per hour compared with 28 inches per hour for the 13.6-mm super carbon.

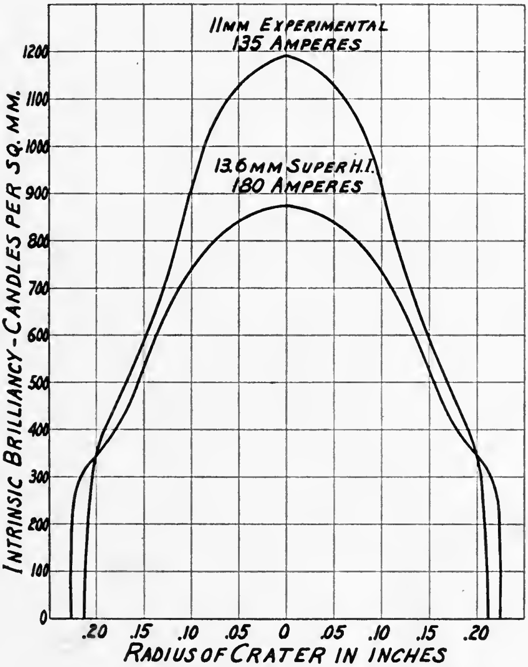

FIG. 3. Comparison of intrinsic brilliancy across the crater face of the "National" 13.6-mm super-high-intensity carbon at 180 amperes and the 11-mm experimental carbon at 135 amperes.

TABLE VI

(a) *Screen Light and Distribution of Light from "National" Carbons with Relay System Using Condenser Combination B*

Projection Lens	SOUND CAMERA APERTURE Screen Lumens No Film Shutter	SOUND CAMERA APERTURE % Screen Distribution Relative to Center Sides	Corners	SILENT CAMERA APERTURE Screen Lumens No Film Shutter	SILENT CAMERA APERTURE % Screen Distribution Relative to Center Sides	Corners
16-mm Studio H.I. Positive—"Orotip" $^{7}/_{16}$-Inch Heavy-Duty Negative; 150 Amperes-68 Volts; Positive Consumption 9 I.P.H.						
f/2.3 Super Cinephor	6,500	100	102	8,600	104	104
f/2.0 #506	8,300	105	108	10,300	112	115
f/2.0 #524	9,600	102	105	12,300	110	110
13.6-mm Super H.I. Positive—"Orotip" $^{1}/_{2}$-Inch Heavy-Duty Negative; 180 Amperes-78 Volts: Positive Consumption 28 I.P.H.						
f/2.3 Super Cinephor	9,000	112	108	12,100	113	112
f/2.0 #506	11,200	112	111	14,700	115	113
f/2.0 #524	13,000	111	108	16,800	118	116
11-mm Experimental Positive—"Orotip" $^{7}/_{16}$-Inch Heavy-Duty Negative; 135 Amperes-80 Volts; Positive Consumption 38 I.P.H.						
f/2.3 Super Cinephor	9,500	105	107	11,800	116	106
f/2.0 #506	11,200	109	112	14,100	117	110
f/2.0 #524	13,200	108	110	16,700	118	110

(b) *Foot-Candle Readings on 14-Foot Screen from "National" Carbons with Relay System Using Condenser Combination B*

Projection Lens	FOOT-CANDLE READINGS ON A 14-FOOT SCREEN Sound Camera Aperture Center	Sound Camera Aperture Sides	Sound Camera Aperture Corners	Silent Camera Aperture Center	Silent Camera Aperture Sides	Silent Camera Aperture Corners
16-mm Studio H.I. Positive—"Orotip" $^{7}/_{16}$-Inch Heavy-Duty Negative; 150 Amperes-68 Volts; Positive Consumption 9 I.P.H.						
f/2.3 Super Cinephor	44	44	45	57	59	59
f/2.0 #506	54	57	58	65	73	75
f/2.0 #524	64	65	67	79	87	87
13.6-mm Super H.I. Positive—"Orotip" $^{1}/_{2}$-Inch Heavy-Duty Negative; 180 Amperes-78 Volts; Positive Consumption 28 I.P.H.						
f/2.3 Super Cinephor	58	65	63	76	86	85
f/2.0 #506	71	80	79	92	106	104
f/2.0 #524	83	92	90	103	121	119
11-mm Experimental Positive—"Orotip" $^{7}/_{16}$-Inch Heavy-Duty Negative; 135 Amperes-80 Volts; Positive Consumption 38 I.P.H.						
f/2.3 Super Cinephor	62	65	66	75	87	79
f/2.0 #506	72	79	81	88	103	97

The reason for this marked superiority in light on the translucent screen for the 11-mm carbon is evident in Fig. 3 which shows the intrinsic brilliancy distribution curves for the two carbons. The experimental carbon gives the heretofore unattained figure of 1200 candles/sq. mm for the intrinsic brilliancy at the center of the crater, or about 300 candles/sq. mm (or 33 per cent) more than the 13.6-mm super carbon. It is because of this very high brilliancy that this carbon is able to furnish such intense light on the translucent screen at a lower energy input than other carbons of lower intrinsic brilliancy. Such a carbon can be run with less danger to the condensers and less likelihood of burning the film than the other carbons mentioned in this table burning at 180 amperes or above, and still give the same amount of light.

TABLE VII

Comparison of Total Screen Light and Foot-Candle Readings on 14-Foot Screen

13.6-Mm Super H.I. Carbon at 180 Amperes; $f/2.0$ No. 506 Lens; Silent Camera Aperture

Optical System	Screen Lumens No Film Shutter	Foot-Candles on 14-Foot Screen Center	Sides	Corners
Condenser Comb. *A*	11,200	95	71	48
Condenser Comb. *B*	15,700	134	96	74
Modified Relay Condenser Using Lenses* from Comb. *A*	16,900	138	109	83
Modified Relay Condenser Using Lenses from Comb. *B*	14,700	92	106	104

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* Rear surface of rear lens spherical instead of cylindrical.

The results in Table IV are retabulated in Table V on the basis of the foot-candles which would be obtained on a 14-foot screen with this relay condenser system, and this table is directly comparable with Table III, for the regular condenser system. It can be seen by comparing Tables III and V that the relay condenser system gives much more light at the sides and corners, where it is most useful, than either of the condenser systems. For example, the 13.6-mm super-high-intensity carbon at 180 amperes gives approximately 17 per cent more light at the sides and corners of the screen with the $f/2.0$ No. 506 lens than with the condenser combination *B*, where the rear condenser is closer to the arc and therefore in greater danger of being cracked. The relay system on the same basis gives 50 per cent more light on the sides and 70 per cent more light at the corners than the condenser combination A, where the rear element is slightly farther from the arc than the relay condenser system.

As previously stated, the condensers used in this relay system are the same as the condensers in combination A except that the rear surface of the rear condenser has been ground spherical. It seems pertinent therefore to know what would result if the condensers of combination B were used in the relay condenser system. We have included in this paper the results obtained with three carbon combinations using this special relay system. It was found desirable to move the rear condenser to a distance of only $2^3/_4$ inches from the arc. This is as close as the lamp mechanism will allow, and the same distance as when these lenses were used in the regular condenser system. This closer proximity of the condenser to the arc materially increases danger from breakage and pitting. However, the results are very interesting and are shown in Table VI.

The total light is slightly less than with the other relay system, but the light at the sides and corners, even with these high-quality lenses, is noticeably greater than at the center and therefore of the quality so much desired for transparency projection. Also for this reason, the foot-candles values at the corners of the transparent screen are much higher for carbons used with this modified relay system than with the other systems. This is illustrated by Table VII, which compares the foot-candle values at the center, sides, and corners of the 14-foot screen for a given carbon such as the 13.6-mm super-high-intensity carbon used in the four systems in Tables III, V, and VI*b*. It is evident that the two relay condenser systems give greater light at the sides and corners, and a much more favorable light distribution.

It is hoped that these data will be of value to the motion picture studio industry. Work on this subject is being continued and we expect to be able to report additional results in the not too distant future.

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RECENT IMPROVEMENTS IN CARBONS FOR MOTION PICTURE STUDIO ARC LIGHTING*

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Summary.—*Recent improvements in carbons for broadside lamps and spotlamps are described. New negative carbons, designed for use with spotlamps result in more quietly burning arcs.*

New carbons have been designed for broadside lamps giving quieter burning and steadier light. The light is of the same spectral quality as that of the spotlamp-filter combinations used for Technicolor photography. Curves of spectral energy distribution of light received on the set and records illustrating the improved steadiness and quieter burning are shown.

(I) INTRODUCTION

The requirements which an artificial light-source must fulfill to be successfully used for the illumination of motion picture studios have been outlined in various articles already published.[1,2,3] These requirements have been modified from time to time by technical developments in the motion picture industry; for example, the advent of sound pictures emphasized the requirement of quietness and the more recent expansion of Technicolor has brought its demands for a suitable color-balance in the lighting.

The carbon arc plays a prominent role in supplying both types of studio lighting in widespread use today; *i. e.*, in furnishing general overall illumination and the intense "modelling" light. New lamp designs have been developed[4,5,6] to utilize in a very efficient manner the high brilliancy and desirable color characteristics of the carbon arc. These improvements in lamps have given a more precise control over the burning of the arc, resulting in a steadier light and minimum noise due to lamp mechanism.

It is the purpose of this paper to record recent developments in carbons for broadside lamps and spotlamps which give additional gains in (*1*) steadier light, (*2*) quieter burning, and (*3*) better color-balance for Technicolor photography.

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(II) METHODS OF MEASUREMENT

Spectral Quality of Light.—The spectral quality of the light has been determined by measuring the spectral energy distribution. For visual purposes of comparison the trichromatic coefficients[7,8] have been calculated and the color-temperature determined according to standardized procedures.[9]

Light Steadiness.—The steadiness of the light has been measured by a Weston photronic cell connected to a General Electric photoelectric recorder to obtain a continuous graphic record of the light-intensity.

Measurement of Sound-Level of the Arc.—In order to obtain a laboratory measurement of the sound-level associated with the arc, a crystal microphone was connected to the input of a resistance-coupled amplifier, the output of which was coupled through a transformer to a General Electric photoelectric recorder connected to record alternating current. Tests were run late at night when extraneous noise was at a minimum, and the gain of the amplifier was kept at such a level that ground-noises were not a disturbing factor. In order better to register the arc noise the microphone was placed close to the lamp. The amplifier gain was maintained constant throughout a series of measurements and ground-level was taken frequently during the series with the arc shut off and without moving the microphone. Power-source noise was eliminated by choke coils and condensers appropriately connected. This gave a permanent record of the comparative quietness of arcs with various experimental carbons. It is probably a less significant record than can be obtained at the motion picture studios where sound-stages and extensive recording equipment are available.

(III) REDUCTION OF SOUND-LEVEL FROM ARCS USED IN SPOTLAMPS

The improvement in spotlamp mechanisms as reported in the JOURNAL by Richardson[5] has reduced the sound from the mechanical operation of the arc to a very low value. Suitable choke coils and condensers have successfully eliminated the generator hum. However, there was still sufficient noise from this arc to give concern when used very close to the microphone or when many units were used on very large sets.

Ways of reducing this noise are being studied by the Committee on Set Equipment Noise Conditions of the Research Council of the Academy of Motion Picture Arts and Sciences. They have observed a significant reduction in noise in lamp units lined with sound-absorbing material and have recommended the use of such material in these spotlamps.

It is difficult for one not intimately connected with motion picture production to visualize the low sound-level with which we are concerned. However, after conducting tests at night in our own laboratory and observing tests conducted by this Committee in sound-proof studios, it was evident that some of this residual noise was intimately connected with the arc itself. Research work indicated that changes in the negative carbon would noticeably reduce this noise.

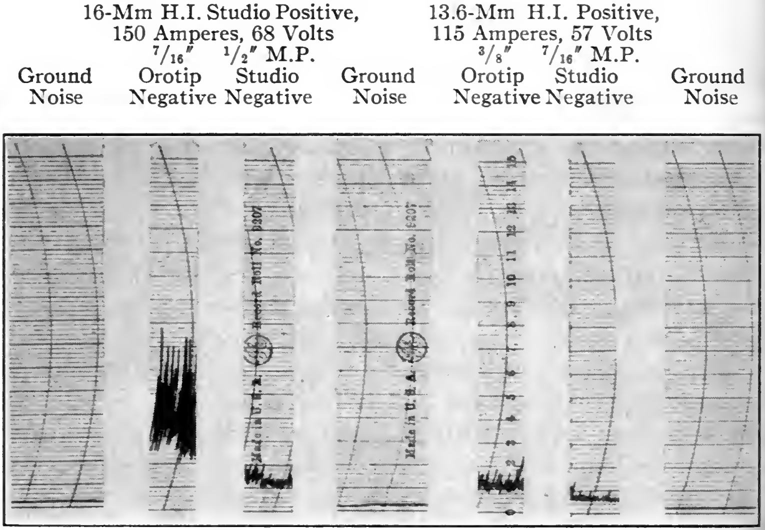


FIG. 1. Effect of new type negative carbons in reducing noise-level.

From this research work new negative carbons have been developed for use with the 13.6-mm H.I. W.F. and 16-mm H.I. studio positive carbons used respectively in the Type *90* and Type *170* studio spotlamps. These new negative carbons, which are known as C.C. M.P. Studio negative carbons, are slightly larger than the "Orotip" negative carbons which they are intended to replace; a $^7/_{16}$-inch diameter C.C. M.P. replaces the "Orotip" $^3/_8$-inch negative carbon and a $^1/_2$-inch diameter C.C. M.P. replaces the "Orotip" $^7/_{16}$-inch negative carbon.

These new negative carbons known as "Motion Picture Studio Negatives" have been submitted to the special sound committee of the Research Council to evaluate in terms of relative noise-reduction under studio set conditions; such tests will be much more valuable than measurements made under our laboratory conditions. However, these latter measurements do give an idea of the magnitude of the reduction and should therefore be of some interest although they should be considered as merely preliminary to the Committee's measurements under the studio conditions.

The method used in our tests has been described earlier in this paper. Sixteen-mm H.I. Studio positive carbons were operated at 150 amperes using consecutively the "Orotip" $^7/_{16}$-inch negative carbon and the new $^1/_2$-inch C.C. M.P. Studio negative carbons; likewise 13.6-mm H.I. positive carbons were operated at 115 amperes with the "Orotip" $^3/_8$-inch and the new $^7/_{16}$-inch C.C. M.P. Studio negative carbons. Fig. 1 indicates the marked reduction in sound-level that can be obtained when the C.C. M.P. Studio negative carbons replace the Orotip negative carbons.

(IV) IMPROVEMENT IN COLOR, STEADINESS, AND QUIETNESS OF CARBONS FOR SIDE ARC LAMPS

The use of flaming arcs for furnishing general illumination in motion picture studios has been common practice for many years and their electrical and radiation characteristics have been described.[10] The earlier carbons, which were $^1/_2$ inch in diameter, were superseded[11] about five years ago by copper-coated carbons 8 mm in diameter, the "National" M.P. Studio carbon. These carbons, in conjunction with the new lamps developed at that time,[4] gave steadier operation. Recently another radical improvement[6] has been made in lamp design as reported by Mole and it is now possible to control more closely the arc current and arc length. In order to give the maximum increase in steadiness of which this new mechanism was capable, it was desirable to design a new carbon trim. This combination of improved lamp design and new carbons gives a very steady light, improved color-characteristics for Technicolor photography, and a noticeable reduction in noise. This new trim for use in the "Duarc" M.R. Type *40* and similar lamps[12] consists of an 8-mm upper positive carbon and a 7-mm negative lower carbon. Characteristics of this new trim are discussed below.

Color.—When Type *90* and Type *170* spotlamps are used in Technicolor photography, it is customary to illuminate the set with these lamps through a light, straw-colored gelatin filter[2] known as the *Y-1* filter, and this combination results in a light-source of satisfactory color-characteristics. The new 8-mm—7-mm trim for side arcs has been designed to be used without a color-filter, in the new broadside lamps. This combination of new carbons and lamps gives the same spectral quality of light as the Type *90* lamp and Type *170* lamp plus the *Y-1* filter. This is best illustrated by spectral energy distribution curves. These curves, shown in Fig. 2, give the proportional amount of energy at the different visible and near-visible wavelengths present in the light-beams from the complete lamp units. The ordinates of Fig. 2 are in arbitrary units, and the heights of the three curves have been adjusted for purposes of comparison to the same value at 5440 Ångströms. These spectral-energy distribution measurements were taken using the complete optical system of the spotlamp including the *Y-1* filter and of the side arc lamp without any filter, in order to obtain values characteristic of the light as received on the set. The burning conditions were 115 amperes and 57 arc volts for the Type *90* spotlamp and 40 amperes and 37 arc volts for the Type *40* side arc lamp. These curves show

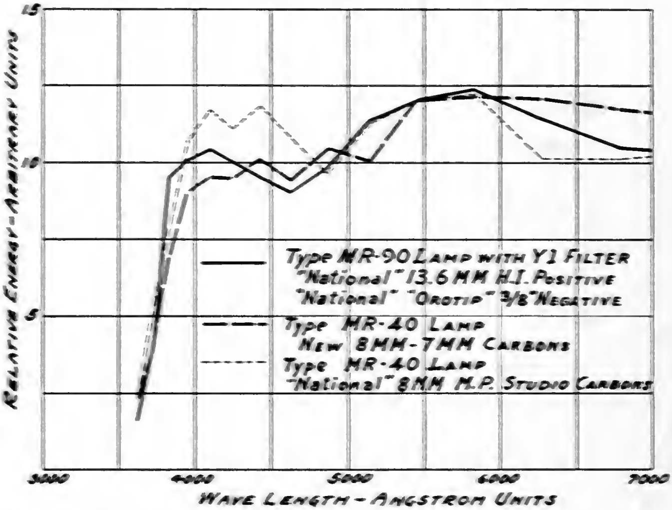
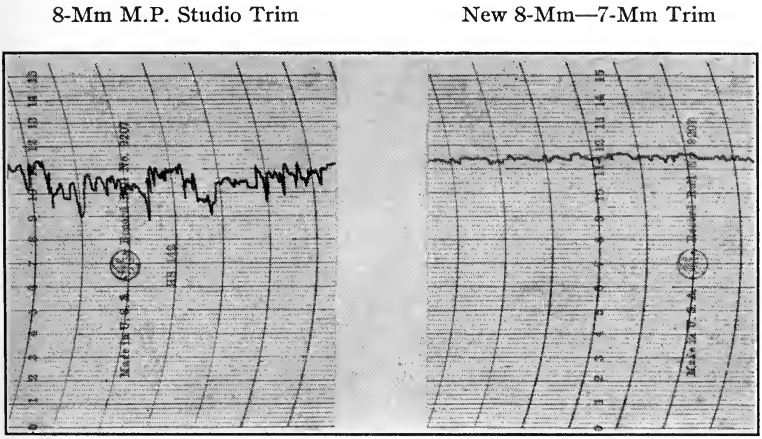


FIG. 2. Spectral-energy distribution curves for studio lamp units equipped with complete optical system.

that the spectral quality of the light from the new 8-mm—7-mm M.P. studio carbons in the Type *40* broadside lamp closely approximates that from the 13.6-mm H.I. carbon in the Type *90* lamp plus the *Y-1* filter. As shown in the figure, these new carbons in the Type *40* lamp give relatively less energy in the blue and more in the red than the 8-mm trim of "National" M.P. Studio carbons.

When we speak, perhaps loosely, of color as applied to the light used for motion picture photography we refer, of course, to the effect of the light on motion picture film rather than to the effect of the light on the human eye. Consequently, the conventional nomenclature of color, based on average eye sensitivity, is meaningless in this connection, except as it may serve as a relatively crude comparative measure of light-sources of essentially similar spectral energy distribution. The spectral energy distribution of the light-source provides the only color data of significant importance in this application. However, to facilitate rough comparisons with other sources, the trichromatic coefficients and the color-temperatures have been calculated and are shown in Table I.



8-Mm M.P. Studio Trim

New 8-Mm—7-Mm Trim

FIG. 3. Light-steadiness curves; *MR-40* Duarc lamp; 40 amperes, 37 arc volts.

The reduction of color-temperature from 5680°K. with the "National" 8-mm M.P. Studio carbons to 4700°K. with the new 8-mm—7-mm trim illustrates how the color of the light from the carbon arc can be altered to give the quality desired. It is evident from these results that the studios have available for color photography sources of illumination of the same color quality for both broadside illumination and spotlighting.

TABLE I

I.C.I. Trichromatic Coefficients and Color-Temperature of Light from Spotlamps and Broadside Lamps

Lamp	Carbons	Current	Voltage	Trichromatic Coefficients		Color Temp.
				x	*y*	°*K*
Type *90* Plus *Y-1* Filter	13.6-mm H.I.	115	57	0.349	0.357	4820
Type *40*	New 8-mm—7-mm N.P. M.P. Studio	40	37	0.353	0.350	4700
Type *40*	8-mm—8-mm N.P. M.P. Studio	40	37	0.328	0.341	5680

Steadiness.—The new 8-mm—7-mm M.P. Studio trim is designed to take full advantage of the automatic motor feed arc control of the recently developed lamps[6,12] and therefore when burned in these new lamps gives a much steadier light than was heretofore possible. Fig. 3 shows the light steadiness curves obtained on the Mole-Richardson Type *40* motor-fed lamp with the older 8-mm upper and lower carbons and with new 8-mm—7-mm trim. This clearly indicates the steadiness and the superiority of this new trim

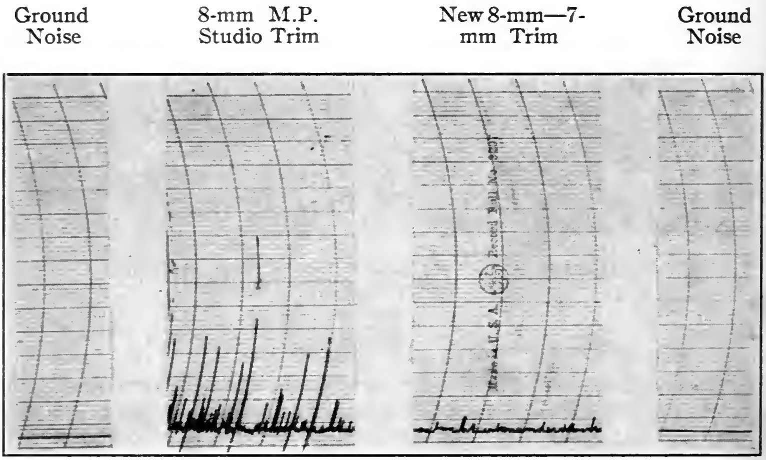


FIG. 4. Effect of new 8-mm—7-mm trim in reducing noise-level in arc lamps; *MR-40* Duarc lamp, at 40 amperes, 37 arc volts.

over the older one. A comparison of these curves with the older type lamps and carbons as given last fall by P. Mole[6] shows the substantial progress over the last few years.

REDUCTION OF SOUND-LEVEL WITH CARBONS FOR BROADSIDE LAMPS

The steadier burning qualities of the new 8-mm—7-mm M.P. Studio carbons have at the same time markedly reduced the sound-level, particularly the frying noise associated with the arc. Fig. 4 shows comparative records of the sound-level of the National 8-mm—8-mm trim and the new National 8-mm—7-mm trim burned in the new *MR-40* lamps. These records were obtained by the method previously described in this paper and show clearly the superiority of the new trim.

The combination of the new 8-mm—7-mm trim and the new lamps has eliminated the occasional disturbances which resulted in changes in intensity of the light, in changes in color of the light, and in slight audible disturbances.

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A NEW MOBILE FILM-RECORDING SYSTEM*

B. KREUZER** AND C. L. LOOTENS†

Summary.—*The design requirements for this type of unit and how these requirements were met in the selection of truck, body design, equipment layout, etc., are discussed. The recording equipment utilized together with the power equipment and other special features of the unit are described. This type of unit has been in successful operation without revision.*

Before designing mobile sound-film recording units to be supplied to Republic Productions, Inc., engineers of that organization met with engineers of RCA Manufacturing Co., Inc., to formulate the design requirements for these units. Briefly, the following requirements were established:

(*1*) The mobile unit was to contain all primary power equipment and a complete film-recording system suitable for either location or studio recording.

(*2*) Maximum accessibility for service and maintenance was required.

(*3*) Maximum convenience of operation was stipulated in order to make the unit useful for fast production shooting.

(*4*) All tires and axles were to be correctly loaded in accordance with factory specifications.

(*5*) An easily maneuverable truck was required permitting fast moves in a narrow studio alley, public highway, or rough location country.

(*6*) The unit must be easily ventilated and well insulated against the sun's rays.

Tentative full-scale layouts were made on the plant floor using white adhesive tape. After suggestions made by operating personnel were reviewed, various alterations were made to the original layout. A full-scale model was then built using a framework of 1 × 1-inch wood strips, to which wrapping paper was nailed for walls and partitions. After further changes suggested by operating personnel, the full-scale model was lifted to a truck chassis in order to check the overall appearance of the unit.

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** RCA Manufacturing Co., Hollywood, Calif.

† Republic Productions, Inc., North Hollywood, Calif.

Following this preliminary work, a truck chassis was selected. It had early become apparent that the cab-over-engine or cab-forward type of truck would provide maximum body length with minimum wheel-base. This arrangement seemed best to fulfill the requirements mentioned above. The cab-forward type of truck was finally selected in favor of the cab-over-engine truck since it was believed the former provided a less fatiguing ride for the driver and because less load was placed on the front axle. It was believed that this would increase ease of handling in rough location country.

Our next requirements were interrelated. Ease of operation indicated head-room of approximately 6 feet 4 inches, together with a reasonably spacious body. Therefore, our problem was to choose a cab-forward truck having the greatest ratio of load-carrying-length to wheel-base, accompanied by an engine-mounting and drive-shaft construction which would allow the maximum portion of this load-carrying-length to have a drop-frame construction applied. These requirements indicated a passenger-bus type of chassis with a dropped-frame construction. The other requirements were the more conventional ones such as: adequate engine horse-power, proper tire size, type and size of brakes, and satisfactory general construction.

These specifications were met within the budgeted price for the truck by employing a cab-forward Studebaker truck with dual rear wheels delivered complete with cab. Following delivery, the frame was dropped 9 inches throughout the portion of the chassis between the rear of the cab and the front spring shackles of the rear springs. This change did not reduce the minimum road clearance of the unit. Because of the construction of the truck, it was possible to run the drive-shaft under the floor without the usual "tunnel." Plans covering the revised frame construction were filed with and included in the original warranty by the automobile manufacturer.

Actual body design followed, and culminated in the choice of hardwood and metal truck construction. The hardwood frame is screwed and glued together with all joints reënforced by metal strips. The entire body has a 2-inch fill of heat-insulating material which practically eliminates heat transfer from the sun. The insulation is sufficient for a future installation of an ice air-conditioning system. In order to enhance the external appearance of the truck, extra-wide metal sheets were used eliminating molding usually employed to cover the joints of two standard size sheets of body metal. In order to add to the appearance of the truck and avoid the usual difficult-to-clean space between the cab and the body, the body was folded around the rear of the cab with a suitable gasket to prevent the entrance of dust.

The completed truck is shown in Fig. 1. The side door shown in the picture is one of the two doors giving easy access to the recording room. Fig. 2 is a floor plan of the truck interior showing the recording room, which is directly behind the cab, and the power room which is at the rear of the truck. Cross-ventilation is secured by windows in the entrance doors, and exhaust ventilation is provided by a ventilating fan built in the roof of this compartment. The interior walls and ceiling are surfaced with an asbestos board with a glazed finish of pleasing design. The floor and equipment decks are covered with linoleum. Nickel hardware and brushed nickel trim are used throughout

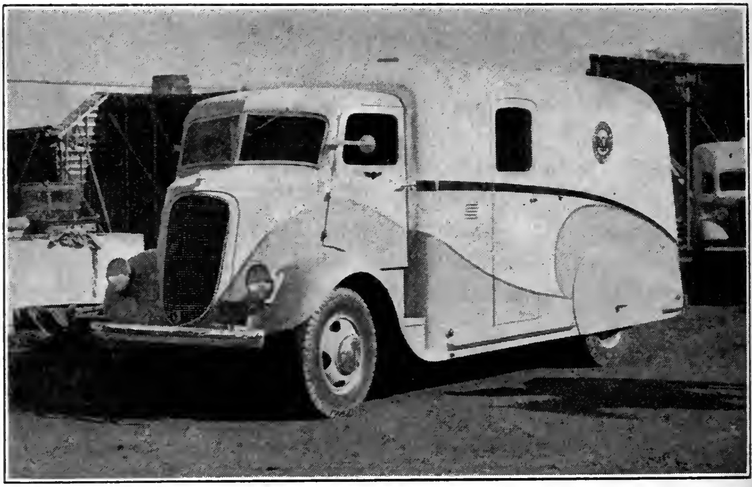

FIG. 1. The mobile sound-film recording unit.

Space against the front wall of the recording compartment is utilized for film, magazine storage cabinets, and the motor-generator batteries. This portion of the truck interior is visible in Fig. 3. Fig. 3 shows the large amount of head-room above the storage batteries for servicing, together with the two lights provided. Not seen in the picture are two louvres for ventilation of the battery compartment. To provide adequate drainage of the battery compartment, the floor is sloped to a lead-pipe drain which empties below the truck mechanism. The batteries are set on an elevated wood grid which allows any spilled liquids to reach the drain. The interior of this compartment and the wood grid are heavily sprayed with a coat of acid-resisting asphaltum. The removable door of the compartment is clamped in an air-tight position, preventing acid fumes from entering the recording compartment.

Above the battery compartment and shown in Fig. 3 is a light-tight film magazine loading compartment. Access for loading through the dual door construction is by means of the shielded armholes. Easily accessible and above the loading compartment is provided a film-storage cabinet for 30,000 feet of film.

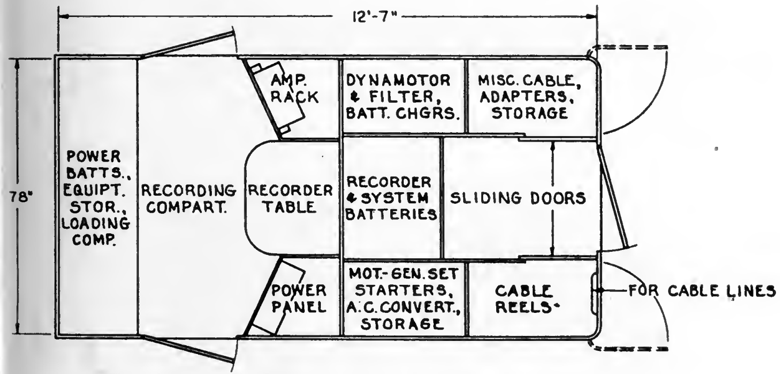

FIG. 2. Truck floor plan.

Adjacent to these compartments is a closed partition-separated space for storage of film magazines. To the right of this space, shown in Fig. 4, is a compartment which is shelved and divided into separate spaces for microphones, preamplifiers, mixer panel, and spare tubes. All the storage compartments are felt-lined to prevent damage to the equipment.

Fig. 5 shows the operating section of the recording room. The power rack on the right and audio rack on the left are built on hinges to provide accessibility to the wiring. An equipment storage compartment is located below the power rack. The small drawer observable below the power rack when pulled out has a cover which acts as a writing desk. The monitor speaker is visible above the ecorder magazine. The vertical portion of the wall back of the

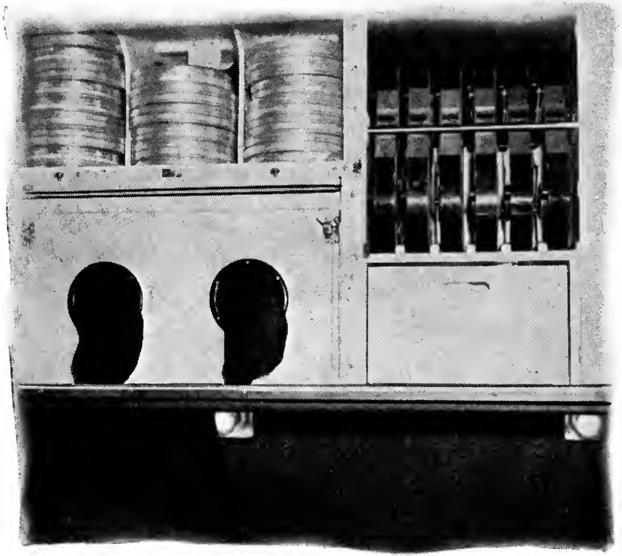

FIG. 3. Cabinets for film and motor-generator batteries.

FIG. 4. Compartments for microphones, preamplifiers, mixer panel, and spare tubes.

recorder is hinged, allowing access to the rear of the recorder from the power compartment. Illumination for this section of the truck is supplied by Lumaline lamps behind opal glass mounted flush in the ceiling.

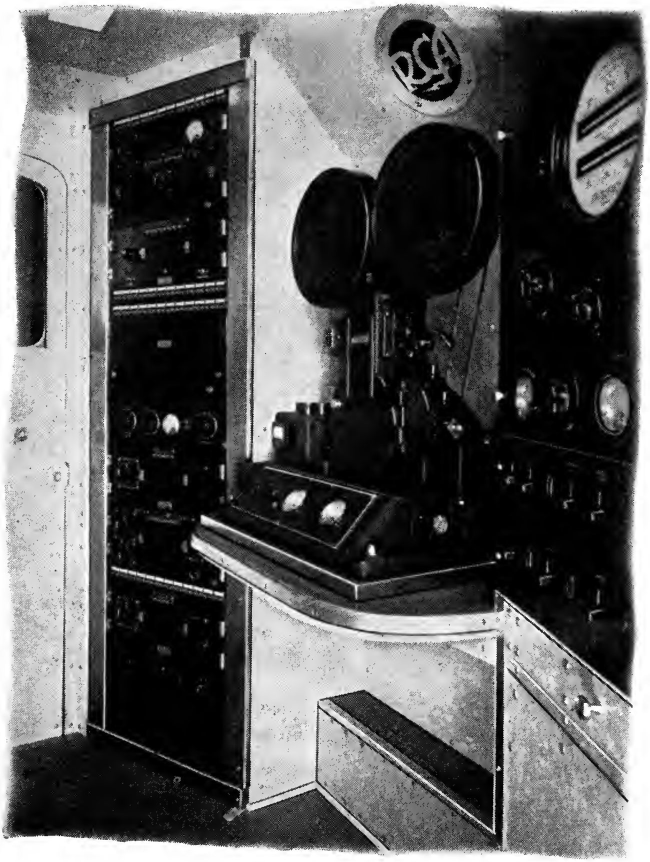

FIG. 5. Operating section of the recording room.

All operating controls have been located so that the recordist can emain seated at the recorder and have all necessary audio controls t his left hand and all power controls at his right hand. This layut permits ease of operation and speeding up of production. Beause of the accessibility of all controls the recordist can easily turn off the motor-generator between shots when on location, thereby reducing the drain on the storage batteries.

A view of the power room from the rear of the truck is shown in Fig. 6. The central door is provided with a large movable window allowing the power compartment to be used by the mixer for "trucking shots" or under poor weather conditions. Both side doors provide access to the cable compartments and are noteworthy since the door catches are operated from the inside of the truck only, preserving the smooth contour of the truck when these doors are closed. The smoothness of the truck exterior was helped further by shaping these doors in such fashion that their hinges were combined with the normal "break" between the sides and rear of the truck which is usually covered by oval molding. The cable reels shown in the left-hand compartment can be cranked from the interior of the truck with a double-ended crank which makes it possible to select any one of the four reels for individual cranking. Directly below the cables is located a plug panel for the connection of all external cables. The cables are fed through a sponge-rubber-lined chute which allows closing the cable compartment door even when cables are connected to the plug panel.

Fig. 6. View of the rear of the truck.

Figs. 7 and 8 show the location of equipment in the interior of the power room. The floor of this room and the deck over the recorder and amplifier-filament storage-batteries are covered with linoleum. This deck is used as a seat for the mixer when he works in the interior of the truck. Since the deck is of the same height as the motor-generator compartment alongside it, easy removal of the motor-generator for servicing is thus facilitated. Other equipment visible in these two pictures are the dynamotor and filter which supplies all *B* voltage, the high-capacity tungar charger for charging all storage-batteries, the motor-generator for supplying camera and recorder power, and the dynamotor for moviola playback supply, together with the various motor-starting relays.

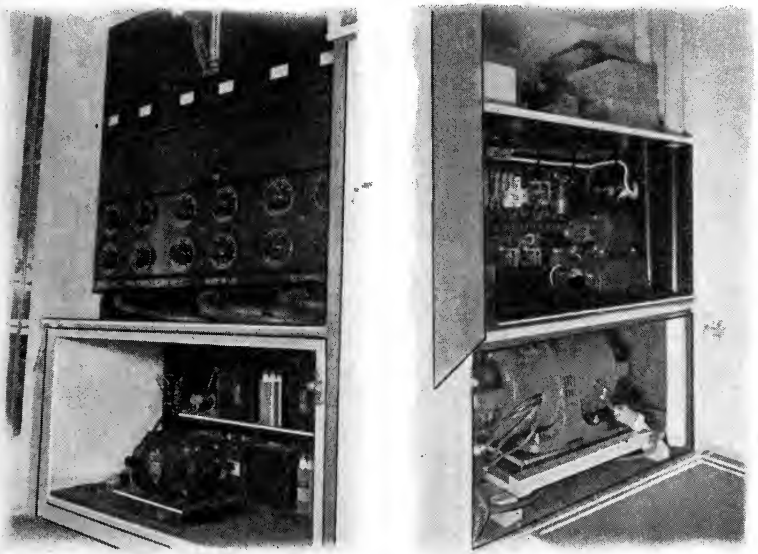

FIG. 7. FIG. 8.

Views of the power room equipment.

The truck is equipped to work with conventional microphones, and utilizes a compact portable mixer mounted on a simple collapsible stand with casters. External and internal views of the mixer are shown in Figs. 9 and 10. A split hinge cover not shown in the photographs can be hooked on the side of the mixer and used for a writing shelf. The mixer is provided with an interphone, high-quality monitor phones, adjustable dialog equalization, and an indirectly illuminated meter type volume-indicator. A talk-back microphone built into the mixer for rapid communication with the recordist can also be used for recording announcements directly on the sound-track. Preamplifiers and all connections to the truck are plugged into the mixer panel by appropriate cables.

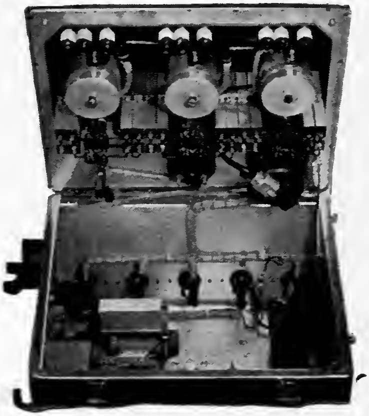

FIG. 9. (*Upper*) External view of the mixer.
FIG. 10. (*Lower*) Internal view.

Fig. 11 shows the transmission diagram of the audio equipment in the truck. This is a bridge bus circuit with one bridging amplifier driving the recorder and a second bridging amplifier supplying volume-indicator, monitor speaker, and monitor headphones. Exponential noise-reduction is provided, and an electronic volume compressor is a standard item in the truck. All jack circuits are normalled and the jack fields have been carefully arranged to resemble the transmission diagram in their physical layout. At the same time, separation of different audio levels has been achieved.

The recorder, powered by a three-phase synchronous motor, is a studio type RCA unit with an electromagnetic film drive. It is arranged for either standard or push-pull duplex ultraviolet variable-area recording. A temperature-compensated exposure-meter is built into the recorder. A built-in negative exposure unit is provided for track exposure at the beginning of each take. A photographic slater records scene and take numbers in the sound-track area and is operated in conjunction with a mechanical punch, providing the identification necessary for the pre-selection of negatives. A self-engaging magazine take-up is provided.

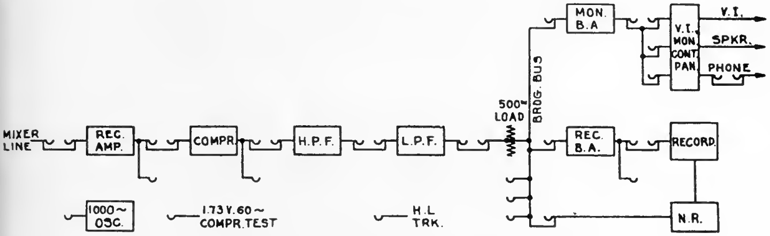

FIG. 11. Transmission diagram.

The power source for location work consists of a 120-volt bank of 105-ampere-hour storage-batteries. These batteries drive a 0.75-kw motor-generator set delivering 220-volt, 3-phase, 60-cycle power for the recorder, cameras, and playback motors; a *B* supply dynamotor generating 250 volts, 300 milliamperes d-c; and a 110-volt, 60-cycle, 225-watt single-phase a-c dynamotor for playback amplifier and lamp supply. When external sources of a-c are available, the motor-generator set and 110-volt, a-c dynamotor are not used.

At times it may be necessary to supply battery power for long shooting schedules which do not allow sufficient time for proper charging of the batteries for the next day's "shooting." To provide for this emergency provisions have been made to "float" the power batteries on any suitable d-c source available, such as that normally used for "booster" lights. Provisions have also been made in the system when external a-c is available for floating the tungar charger across the 8-volt, 210-ampere-hour, amplifier-filament batteries and the 16-volt, 210-ampere-hour, exposure-lamp batteries while recording.

The charger utilizes six 6-ampere tungar bulbs. As is usual with this type of device, the nominal 36-ampere rating can be exceeded for a short period of time in accelerating the charging of exhausted batteries. An interesting design feature of this charger is the specially wound power transformers which allow the charger to be used either on 110-volt, 60-cycle, single-phase; or, by simply throwing a switch, to be fed from a 220-volt, 3-phase, 60-cycle power supply. This is accomplished by utilizing three separate power transformers with two primary windings on each. For 110-volt charging, all six primary coils are paralleled. For 220-volt, 3-phase charging, the two primary coils of each transformer are connected in series and the three sets of these primary coils are then connected in delta across the 3-phase supply.

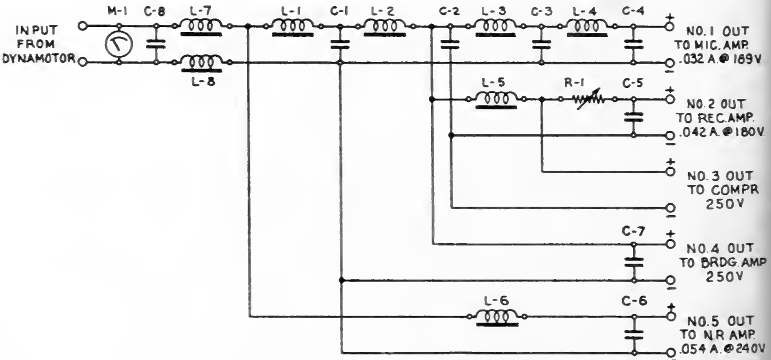

FIG. 12. Filter for *B* supply dynamotor.

The d-c starting mechanism for the motor side of the motor-generator set is a relay-type four-point starting-box.

Fig. 12 shows the *B* supply filter. This filter is of interest because it enables the single dynamotor unit to supply *B* voltage to all parts of the recording system. By providing filtering appropriate to the signal level in the circuit, this filter provides excellent voltage regulation with a negligible amount of cross-modulation between units. This is accomplished in spite of the fact that the current supplied to the noise-reduction unit is constantly fluctuating during recording over a range of approximately 25 milliamperes.

Mobile film-recording systems of this type have been in use by Republic Productions, Inc., for several months and have amply justified the care spent in designing them. The authors wish to acknowledge their indebtedness to Mr. James L. Fields, of the RCA Manufacturing Co., Inc., who was in charge of construction of these units. We also wish to take this occasion to thank Mr. Daniel J. Bloomberg of Republic Productions, Inc., and the many other members of the RCA and Republic organizations who contributed valuable suggestions to the design of this mobile system.

USE OF AN A-C POLARIZED PHOTOELECTRIC CELL FOR LIGHT-VALVE BIAS CURRENT DETERMINATION*

C. R. DAILY**

Summary.—*The use of an a-c polarizing potential on a gas type PEC produces an alternating output current as compared with the continuous current obtained with a d-c polarizing potential. If the output voltage from the cell is suitably connected to a conventional audio-frequency amplifier and copper-oxide rectifier meter, the equipment may be conveniently used as an exposure meter. When used for the line-up of variable-density light-valves, the proper bias current, lamp adjustment, and lamp current may be readily determined. Variations of valve spacing and lamp current are also indicated. Numerous other applications for such a meter are being considered.*

The determination of absolute or differential exposure must be made frequently in connection with recording sound on film. An experimental exposure-meter of a type not commonly employed will be described, which may be applied to the PEC monitor system of a variable-density light-valve recording channel. The device is useful for the determination of the required noise-reduction bias current, lamp current, changes in valve spacing, and other quantities which can be detected by changes in light-intensity on a photoelectric cell.

At the present time adjustments of lamp position and current are checked by a number of methods including exposure meters, either with or without direct-current amplifiers, gain-frequency tests through the valve and the PEC amplifier, as well as routine film exposures. The methods used for the determination and adjustment of noise-reduction bias currents include (*a*) light-interrupting methods such as tone wheels (light choppers); (*b*) proportional bias based on closure current, which is usually determined by visual means; (*c*) stroboscopic methods; (*d*) harmonic observations, either aurally or by meter; (*e*) exposure-meters, direct reading on a PEC or in connection with a direct-current amplifier; (*f*) calculated values based on tuning and spacing.

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 14, 1939.

** Paramount Pictures, Inc., Hollywood, Calif.

Light-interrupting methods in connection with photoelectric cells provide a carrier which is changed in amplitude with changes in the amount of light falling on the cell. The use of an alternating current for the polarized potential of the photoelectric cell likewise provides a carrier.[1] If precautions are taken to reduce the capacity of the PEC system, a reasonable degree of linearity of a-c output from the cell may be obtained as a function of light-changes applied to the cell. In this paper the application of an a-c polarized gas type PEC will be described. The cell, acting as a d-c to a-c converter, may be connected to a conventional audio-frequency amplifier and full-wave copper-oxide rectifier meter and used to measure changes in light falling on the PEC.

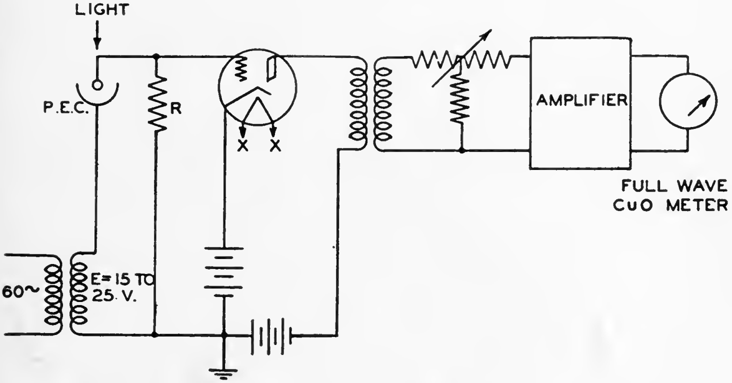

FIG. 1. Schematic diagram of an exposure meter consisting of an a-c polarized gas type PEC, audio-frequency amplifier, and rectifier type meter.

Fig. 1 is the schematic diagram of a PEC amplifier which has been modified for use as an exposure meter. The low-voltage, low-frequency, a-c polarized potential is applied in series between the cathode and ground. The shape and magnitude of the alternating PEC current generated depend upon the voltage applied, the type of cell used, the load resistance, the shielding of the cell, and the amount of light falling on the cell. Satisfactory operation has been obtained with 15 to 30 volts applied to the cell and with a load resistance of 0.5 megohm.

When this arrangement is used as an exposure meter for the determination of bias currents, the gain of the system is first adjusted until a convenient reading is obtained on the ouput meter while the valve is unbiased and unmodulated. Applying bias to the valve then reduces its spacing, the light falling on the PEC, and the measured output current.

The results of a series of such tests are shown in Fig. 2. The reduction in measured output, in db, is plotted as a function of the desired bias current expressed in the same units. The proper bias current was determined from closure tests which agreed satisfactorily with film data over a range of 12 db. The solid curve represents a linear reduction in output, while the three broken curves show the reductions in output obtained with three different *RCA-921* type PEC's. Substantial linearity is indicated over a range of 12 db, one cell being linear over a range of 20 db. Any non-linearity which may exist in a given system can be taken into account by calibrating the output meter directly in terms of film measurements.

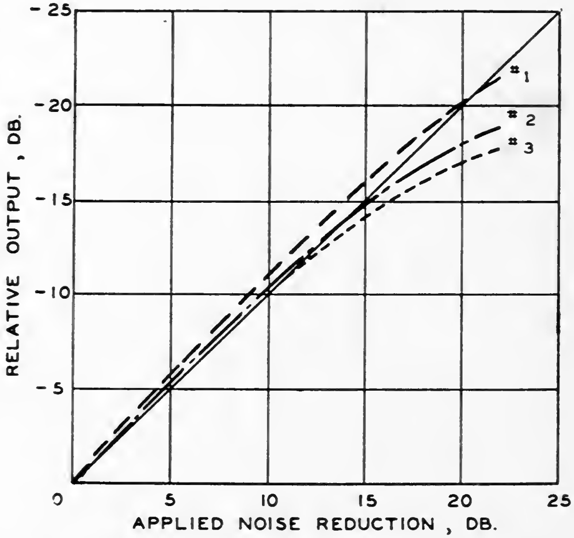

FIG. 2. Experimental calibration of exposure meter. Measured reduction in output with bias current applied to a light-valve *vs.* the desired noise-reduction. Data for three PEC's of the same type.

The approximate efficiency of the system was determined by first measuring the output with a-c polarization of the PEC, using an unbiased, unmodulated valve; and second, with a normal d-c polarized

PEC, the unbiased valve being modulated 100 per cent at a low frequency. With 30 volts of a-c polarization the measured output was approximately 15 db less than that obtained with valve modulation.

This type of exposure meter may be used as an absolute indicator if suitable precautions are taken to stabilize the system. Temperature and voltage variations to the PEC would have to be minimized and the audio-frequency amplifier should preferably be of the feedback type to reduce gain variations to a minimum. With a stable system, direct determinations could then be made of the required lamp current, variations in current, variations in valve spacing, *etc.* Further work will have to be done to determine the degree of stability that can be obtained with this system.

The author wishes to acknowledge the assistance rendered by Mr. L. W. Russell of Paramount Pictures, Inc., in originating and executing this project.

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A DENSITOMETRIC METHOD OF CHECKING THE QUALITY OF VARIABLE-AREA PRINTS*

C. R. DAILY AND I. M. CHAMBERS**

Summary.*—A direct-reading densitometric method is described for the determination of the approximate cross-modulation cancellation of bilateral variable-area prints. This method makes use of the relationship between film rectification and the accompanying change in the mean transmission of a modulated print. The static measurement tells the direction as well as the approximate amount of the print density deviation from optimum. Complete measurements can be obtained with only a few inches of film, compared with several feet required by the routine dynamic measurement of cancellation. The method may simplify the checking of release prints.*

Several years ago it was determined that the quality of variable-area prints was a function of print density, condition of the negative, developer, printer, and other factors.[1] [2] Subsequently the modulated high-frequency test was developed, which provided an index to quality in terms of a readily measured rectification component.[3] The observation had also been made, however, that on a modulated print the average transmission decreased with increasing print density due to the increased fill-in of the wave. This change in transmission may be directly determined by densitometric measurements, and it is the purpose of this paper to present some data which indicate the order of magnitude of the change in terms of cross-modulation cancellation. Possible commercial uses for this method of print quality determination also are mentioned.

Fig. 1 represents a print of unbiased bilateral, 76-mil, variable-area track. Two types of track are shown: (*a*) unmodulated, and (*b*) 7000-cycle, modulated approximately 80 per cent by 400 cycles, the so-called cross-modulation track. The quality of such a print is normally determined by reproducing the modulated wave through a calibrated system and measuring the amplitude of the 400-cycle component of the wave which is caused by film rectification. Thirty

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 14 1939.

** Paramount Pictures, Inc., Hollywood, Calif.

db or greater suppression of this component is readily attained, a value which is generally indicative of satisfactory processing. Other factors contributing to quality such as printer contact must, of course, be taken into account.

In order to determine whether direct densitometric measurements would be of any value in checking variable-area prints, use was made of a barrier type PEC densitometer which had a light aperture of approximately 85 × 240 mils. A number of prints were made from a normal negative which had three types of unbiased track: (*a*) unmodulated, (*b*) 7000-cycle, and (*c*) 400-cycle modulated with 7000 cycles. The cross-modulation cancellation was measured in the routine manner, an optimum print density being indicated at a print density of 1.41. The mean track densities of the same print sections were then measured on the PEC densitometer, the track being centrally located with respect to the slit as indicated by the dashed lines (Fig. 1). In Fig. 2, the measured mean track densities for each of the three types of track are plotted as a function of print density. The measured cross-modulation cancellation is also plotted in the same figure, using the ordinate scale on the right. It will be noted that the same mean track density was obtained for the unmodulated and cross-modulated tracks at approximately the same print density as indicated for maximum cancellation, whereas the same mean density for the 7000-cycle and unmodulated tracks was obtained at a lower print density, in this case at a density of 1.06.

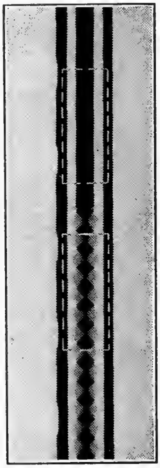

FIG. 1. Bilateral variable-area track. Unmodulated and 400-cycle modulated 7000 track. Dashed lines indicate approximate area measured by a PEC densitometer to determine the amount of film rectification.

In Fig. 3, the measured differential track densities of the cross-modulated and 7000-cycle modulated tracks, with respect to the unmodulated track are plotted against the corresponding cross-modulation cancellation. These data indicate that with the measuring set-up used, if the differential density of the cross-modulated track, referred to the unmodulated track, does not exceed ±0.02, the cancellation should exceed 30 db. A number of other observations have indicated that the shift of the zero-differential density may be as much as ±0.006 from that obtained by cross-modulation measurements.

The reasons have not been fully ascertained as to why the 7000-cycle modulated track apparently requires a lower optimum print density than that indicated for the cross-modulation track. Factors such as the possible non-linearity of the modulator will require investigation, since the cross-modulation test does not fully analyze the performance of this type of modulating system. In general it may be said, however, that the dynamic method of checking processing is a reliable index of quality as indicated by actual listening tests on production recordings. Therefore the densitometric method of analysis described here should also indicate the same result.

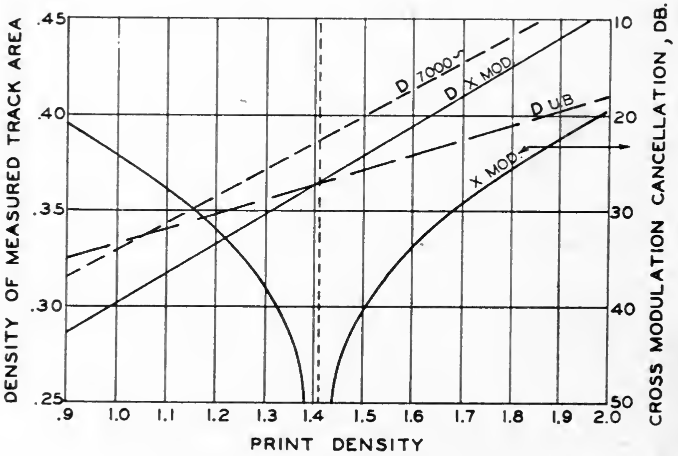

FIG. 2. Measured densities of a section of variable-area track, at a number of print densities, for (*a*) unmodulated, (*b*) 7000-cycle and (*c*) 400-cycle modulated 7000 cycles. Also dynamic measurements of cross-modulation cancellation for the same prints.

No investigation has yet been made of the accuracy of (*a*) the method as a function of amplitude and percentage modulation of the cross-modulation track, (*b*) types of film stock, (*c*) track width, (*d*) slit dimensions, (*e*) condition of the printer, or (*f*) fogging condition of the developer. Limited tests on push-pull variable-area prints have not yielded promising results and no data are available on negatives.

This processing check may be useful to laboratories releasing considerable quantities of variable-area track. If each roll of negative contained a few inches of suitable track, a rapid check could be made as frequently as found necessary to check the approximate quality of the print. Occasional routine dynamic measurements of cancellation would still be made as a check. One distinct advantage of the densitometric method is that it shows directly whether the print is light or dark, because the sign of the differential density changes in passing through optimum, a directive indication that is not given by a single routine cross-modulation measurement.

The data reported here were obtained on a single-aperture densitometer. A more rapid method might consist of the use of a special densitometer wherein one light-beam would be split into two sections and directed through two identical apertures to two PEC's. With the cells connected in a bridge circuit, balance could be established for the condition of equal light transmission over the two paths, this balance being obtained with unbiased, unmodulated track over both apertures. The film would then be moved until the unmodulated track was over one aperture and the cross-modulated track over the other. If the transmissions were no longer equal, the bridge would become unbalanced, indicating directly on the balance meter the direction of print density variation from optimum as well as the approximate degree of cancellation.

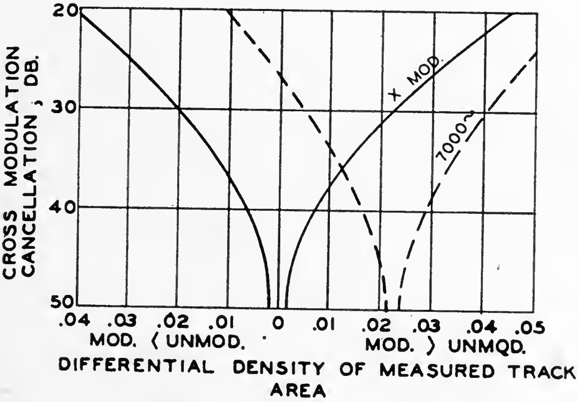

FIG. 3. Difference in measured densities of the cross-modulated and 7000-cycle tracks, referred to the unbiased track, *vs.* the dynamic measurement of cross-modulation cancellation.

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[2] DIMMICK, G. L.: "High-Frequency Response from Variable-Width Records as Affected by Exposure and Development," *J. Soc. Mot. Pict. Eng.*, **XVII** (Nov., 1931), p. 766.

[3] 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), p. 3.

DISCUSSION

MR. SOLOW: In checking processing by this method, does it matter if the length of track scanned by the densitometer aperture is in one case equal to an integral number of waves and in another to an integral number plus a fraction?

DR. DAILY: As previously mentioned, the aperture was 240 mils long, a value conveniently available on the commercial densitometer used for this study. With that length, the track could be moved longitudinally with only slight variations in indicated density. A longer scanning length might have been preferable to average out variations.

MR. KREUZER: Would there not be some danger in determining the optimum print value for a printer when using only a short section of film? A particular section of sound-track might give very good performance but there doubtless would be periodic fluctuations in the machine. I should be concerned about taking one reading and then determining the correct density.

DR. DAILY: Irregularities in the film print do occur, traceable to irregularities on the original negative, stock, and printer contact troubles. For these reasons this method is not entirely satisfactory since it indicates the condition of the print for only a limited section. The present commercial types of checks on printers for contact would still be indicated.

MR. AALBERG: Which of the two methods do you prefer; or do you have any preference?

DR. DAILY: The dynamic method is normally used. The static method was developed to facilitate the determination of the direction of required changes in print density.

The principles upon which this method are based have been observed before, but no reference appears in the literature as to the order of magnitude involved. The data so far obtained indicate that the static method is practicable and further study by organizations which handle considerable quantities of variable-area film may indicate that it has some commercial value in reducing the amount of film and time required to check the condition of prints.

A DIRECT-READING PHOTOELECTRIC DENSITOMETER*

D. R. WHITE**

Summary.—*A direct-reading photoelectric densitometer has been built which shows the density of the area being measured at a reading window. A density range from 0 to 3.0 is covered with a reproducibility of approximately ±0.005. A motor-driven circular neutral wedge is used as the balancing means and the density scale marked on the wedge is read by a stroboscopic flashing light.*

Many different types of physical photometers have been built and placed in use as densitometers in photographic work. No one type of instrument has yet gained wide acceptance as standard, and different laboratories have built different types to meet their needs. Photometers are usually required to measure both rapidly and accurately. The photometer which has been built and placed in routine use and is described here meets the requirements of speed and accuracy in a different way from the way they have been met before. The instrument is direct-reading, and its limit of speed essentially the speed limit of reading numbers on a scale. Accuracy has not suffered from this high speed, since readings are more reproducible than with the usual type of visual polarization instruments.

Optical System.—The optical system of the instrument shown in Fig. 1 was designed to fulfill reasonably closely the conditions requisite to the measurement of the diffuse density of the deposit. An image of the ribbon filament of an exciter lamp was formed at the plane of the density being measured by two achromatic condenser lenses. This light-beam passes through a circular neutral wedge just before it reaches the density being measured and is collected by a photocell placed close behind the film, so that the sensitive surface of the photocell subtends a fairly large solid angle as viewed from the film. Since a production instrument was desired rather than a primary standard, any failure to achieve complete integration of the transmitted beam would lead only to second-order errors, depending

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*Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 6, 1939.

**Dupont Film Manufacturing Corp., Parlin, N. J.

upon differences in scattering power of various deposits as the first-order effect would automatically be eliminated by the initial calibration. No trouble of commercial importance was found as it has been possible to measure satisfactorily both motion picture positive and negative films with one calibration.

The rotation of the circular neutral wedge produces a periodic variation in the light reaching the photocell, the period of which depends upon the mechanical speed of the circular wedge and the amplitude of which depends upon the initial filament of the exciter lamp, the aperture of the condenser lenses, and the density being measured. Thus, by providing a means of flashing a stroboscopic lamp each time the illumination reaches some arbitrary fiducial value within a certain attainable range, the position of the neutral wedge at those instants can be determined by direct observation of a scale attached to the wedge.

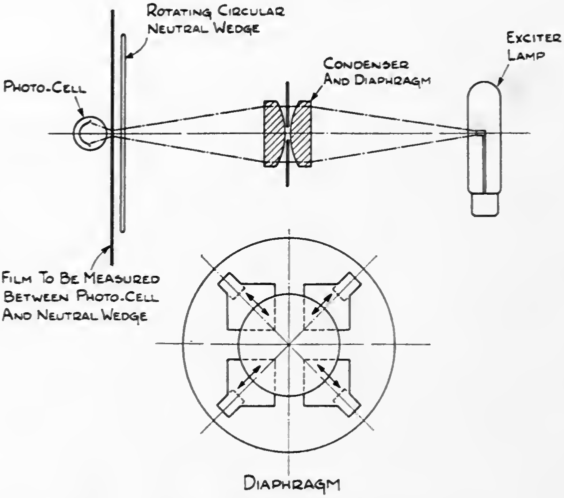

FIG. 1. Optical system of the densitometer.

For our purposes, it was desired to separate the density due to exposure from the density due to absorption and reflection by the base and due to fog, on the basis of a simple subtraction. To make this simple, a mechanical diaphragm was introduced between the condenser lenses. With no film in the instrument, adjustments are made to show *0* on the scale with the diaphragm partly closed. An unexposed area of the film is inserted, and the total reading noted. The diaphragm is then opened sufficiently to bring the reading to *0* again and the densities due to exposure then appear directly, as the base and fog density has been compensated by the increase in optical aperture.

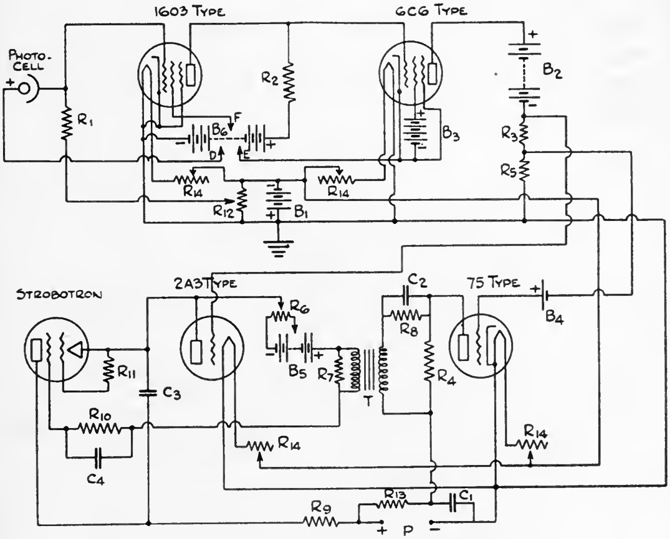

FIG. 2. Circuit of the densitometer.

R_1	10 meg	T	Audio transformer
R_2	1 meg	C_1	8 mfd
R_3	100,000 ohms	C_2	0.01 mfd
R_4	100,000 ohms	C_3	1.0 mfd
R_5	5,000 ohms	C_4	0.03 mfd
R_6	100,000 ohms	B_1	6-volt storage-battery
R_7	100,000 ohms	B_2	180 volts; *B*-batteries
R_8	200,000 ohms	B_3	45-volt *B*-battery
R_9	1,000 ohms	B_4	$1^{1}/_{2}$-volt dry cell
R_{10}	1 meg	B_5	135 volts; *B*-batteries
R_{11}	10,000 ohms	B_6	$22^{1}/_{2}$ volts; dry cells
R_{12}	5,000 ohms	D	$+10^{1}/_{2}$ volts
R_{13}	100,000 ohms	E	$+13^{1}/_{2}$ volts
R_{14}	6 ohms	F	+18 volts
		P	300-volt power-pack

One special feature was introduced in the design of this diaphragm. Four leaves, moving radially, driven by a spiral thread, leave a +-shaped aperture as shown in Fig. 1. The total length of each arm remains constant, but the breadth of each arm changes with the setting. This form leaves the cone of light striking the measuring elements with approximately the same angular distribution. This refinement was introduced to avoid a change in the angular distribution of radiation such as would occur with an ordinary iris diaphragm. For density measurements of non-scattering media, such a refinement would have no value.

Electrical Circuit.—The heart of the densitometer is the amplifier, the circuit for which is given in Fig. 2, and the means provided for the flashing of the stroboscopic tube, a General Radio Strobotron, which illuminates the scale, permitting an accurate reading thereof while in continuous rotation.

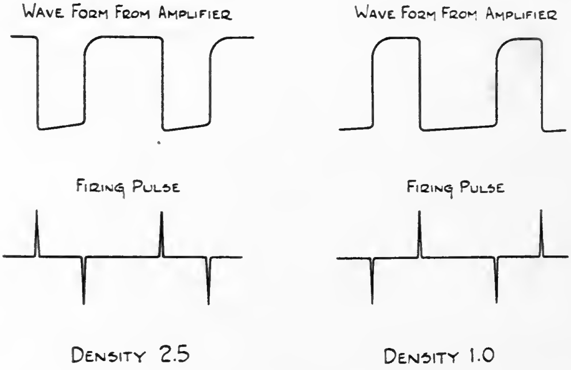

FIG. 3. Wave shapes.

A two-stage amplifier, connected as a d-c amplifier, *i. e.*, with resistances for interstage coupling without condensers or inductances, is used to connect operatively the photocell with the tubes operating the Strobotron. This amplifier is designed to take the voltage pulse from the photocell and distort it completely, to the extent that at the output of the amplifier, it has become approximately a square wave (Fig. 3) having the special characteristic that the times of current or voltage change are directly controlled by the occurrence of the standard or fiducial illumination of the photocell. One of these points is essentially fixed in the time of rotation of the circular wedge and is the time of abrupt change from maximum to minimum transmission of the wedge. The second time of current or voltage change corresponds to the time in the cycle when the light transmitted by the diaphragm, the neutral wedge and the density measured all add to a fixed value, permitting the standard illumination of the cell. Thus an oscillograph fed by the output of the amplifier shows a square wave, the two portions of which vary with the density measured.

There are certain features of the photocell and amplifier circuit the importance of which was not at first apparent. An attempt was first made to use conditions of photocell voltage and coupling resistance such that the photocell current could be essentially a measure of the incident illumination. This would probably have been satisfactory for an instrument of small range, but for a density range of 0 to 3.0 which was desired, it soon became apparent that the large current pulses, 1000 or more times the value for balance, introduced serious charges on the small capacities inherent in the system, with consequent erratic and spurious effects. These disappeared when a low voltage was used on the photocell, which was connected in such manner that high illumination tended to make the first grid positive, thus introducing through grid current, an effective shunt of the coupling resistor, and reducing the actual voltage changes of that grid to a swing between an amount sufficient to block the tube with no light on the photocell and a value great enough to produce saturation during the time of maximum illumination. Using low plate and screen grid voltages, high grid and plate coupling resistors can be used. The wave-form from this stage is not square, as one side has considerable slope, but the second stage completes the squaring process adequately and furnishes sufficient power to operate the other tubes.

Preliminary consideration had suggested that since actually a repetitive varying current was involved, a capacity-coupled amplifier could be used with greater circuit simplification. This view is incorrect, as the requirements for the production of a square wave from this type of original pulse are not met by such a circuit.

The output of the square-wave amplifier feeds two tubes, one of which charges a condenser, C_3, during one part of the cycle which is subsequently discharged through the strobotron when that is triggered off by a pulse from the second or firing tube. The condenser-charging circuit is simple, consisting merely of a tube blocked during one part of the cycle and conductive during the other. A tube with rather high plate current is required since for some of the measurements only a small portion of the cycle can be devoted to that function, and in that short time, actually only about $^1/_{200}$ of a second, sufficient charge must be stored in the condenser to produce a normal flash of the strobotron. When this condition is not met, the strobotron may flash only alternate cycles, or even less regularly when more than one charging period is required for the condenser.

The firing of the strobotron is accomplished by a voltage pulse (Fig. 3), applied between the cathode and one of the grids of the strobotron. A bias battery and a parallel resistance and capacitance are used in this circuit to limit the firing to the one pulse needed, as the firing tube actually supplies two pulses of opposite polarity, from the square-wave input. These pulses are produced in the secondary of a transformer, the primary of which is fed by a square wave through a vacuum tube and simple net work. Some trouble was experienced with oscillations from the pulse nature of the excitation, but these were removed by trial-and-error use of loading resistances in the

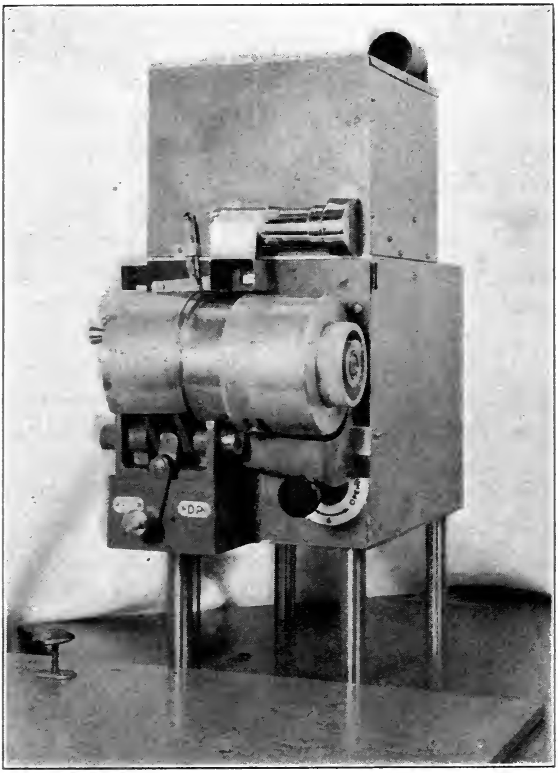

FIG. 4. General view of the instrument.

circuit. The resistance, R_4, shown between the power-supply and the condenser, was also the result of trial-and-error elimination of irregular operation. Effectively, it prevents the formation of a continuous glow discharge through the strobotron. Such trouble occurred unpredictably and irregularly before the insertion of this resistance.

D-c operation of the exciter lamp and amplifier filaments was found necessary, as a-c at these points introduced too much disturbance of a frequency to which the system was sensitive. The exciter lamp is operated from a battery floating on a rectifier charging system, but for the first stages of amplification, this system still left too great residual disturbance, so a two-battery system was installed, such that one battery charges while the second is in use.

The timing precision of the strobotron flashes has been interesting to many seeing the machine in operation. With a rotational speed of 20 rps, the repetition of the flashing of the strobotron is within $\pm {}^{1}/_{16,000}$ of a second under actual operating conditions, and the duration of the flash can not be greater than ${}^{1}/_{100,000}$ of a second, as judged by the distinctness of the lines, and probably is actually appreciably less than this.

The instrument was calibrated by the use of a temporary arbitrary scale on the circular wedge. Strips with known densities, as determined by polarization visual instruments, were put in the new instrument and the corresponding scale readings noted. From these results a final density scale was constructed and mounted. Further checks showed that procedure had been carried through successfully, and the calibration has remained constant for months.

Mechanical Features.—The mechanical design (Fig. 4) was adopted to facilitate the handling of test strips. The strips to be read are held in a revolving drum by simple clips. The shaft is tripped between positions for successive densities by a ratchet escapement mechanism which is provided for either foot or hand operation. The diaphragm control knob is brought to the front of the machine.

No other control requires frequent attention. Bias adjustments and battery checks are occasionally required, but experience has shown that none of these affects the reading in such manner as to result in minor errors, easily ignored. In practice it either reads correctly or not at all. Actually, servicing this densitometer has taken less time than maintenance of a group of visual instruments of similar total capacity, and the reproducibility of the readings has been considerably greater.

ACOUSTIC CONDITION FACTORS *

M. RETTINGER**

Summary.—*The term "acoustic condition factor" is used as a general term descriptive of the acoustic environs of a point in an enclosure. Relationships expressed as ratios are given for several quantities, such as "useful" and "harmful" sound, direct, and generally reflected sound energy and sound intensity. Curves are shown representing loci for partial antinodes produced by interference between direct and first as well as second reflections in a rectangular room in which the sound source is located symmetrically. Equations are given expressing the minimal distance between source of sound and microphone for the probable avoidance of recording absolute nodes.*

In recording sound for motion pictures as well as in a general evaluation of the acoustics of a room one often desires to know more than the value of the calculated or measured reverberation time in the enclosure. Recordings of sound, like various acoustic measurements, are specific; that is, they are related to a definite position of the microphone in the room. Varying this position may change the character of the reproduced sound, may make it sound crisper, or more reverberant, or may enhance or lessen its intelligibility. The reverberation time, being practically the same at every point in the room, provides no explanation for this acoustic condition and should therefore be considered only as a summary or average factor.

The term *acoustic condition factor* is used in the following as a general term descriptive of the acoustic environs of a point in the enclosure, although other names are sometimes used for one or the other of these "factors," as shall be noted.

Following is a list of the symbols used:

S = total interior surface of room

a = average absorptivity

$$= \frac{\Sigma a_1 S_1}{S}$$

b = average reflectivity

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 1, 1939.

** RCA Manufacturing Co., Hollywood, Calif.

$= \dfrac{\Sigma b_1 S_1}{S}$

A = total absorption in room

$= aS$

V = volume of room

t = time

T = time of reverberation

P = power output of source

c = velocity of sound

E_d = direct energy density

E_R = generally reflected energy density

E_0 = steady state energy density

I_D = intensity due to direct sound

I_R = intensity due to generally reflected sound

I_0 = steady-state intensity

λ = wavelength

D = distance between source of sound and point of observation in room

f = frequency

Ω = solid cone of reception of microphone

The sound-pressure at any point in a room is made up of two parts —sound which comes to the point of observation directly from the source, and that part which is reflected from the walls of the enclosure. In the literature of architectural acoustics this latter part is sometimes divided into "initial" and "residual" sound,[1] the former being all that part of the reflected sound which comes to the point of observation within one-sixteenth of a second after it is emitted. The latter part—all the reflected sound which comes to an auditor after one-sixteenth of a second after emission—is considered as not contributing materially to the intelligibility of speech, but being assistant mainly in establishing the character, timbre, or tone-color of the sound.

As far as intelligibility of speech is concerned, sound in a room can be divided into two components, useful and harmful. The former, besides the initial sound, naturally also includes the direct sound, while the latter is the "residual" part mentioned above plus what unwanted sound, that is, noise, is existing in the room. This division of sound is due to Strutt,[2] who thus expanded Zwikker's equation[1] dealing only with initial and residual sound in a room. Strutt's "acoustic condition factor" is given by:

$$Q_1 = \frac{\dfrac{P}{4\pi c D^2} + \dfrac{P}{V}\displaystyle\int_0^{t\,=\,1/16} e^{-13.8t/T}\,dt}{\dfrac{P}{V}\displaystyle\int_{t\,=\,1/16}^{\infty} e^{-13.8t/T}\,dt + E_n}$$

where E_n represents the noise level in the room. Assuming the noise level to be negligibly small, as in a well-insulated recording studio, the above equation reduces to:

$$Q_1 = \left(1 + \frac{V}{1030TD^2}\right)e^{\frac{0.862}{T}} - 1 \qquad (1)$$

For good intelligibility the value of this equation is by some investigators set equal to unity, although Strutt himself places it "somewhat greater." Setting it equal to 2, to be on the safe side, as the saying is, we get for the distance beyond which no dialog recording

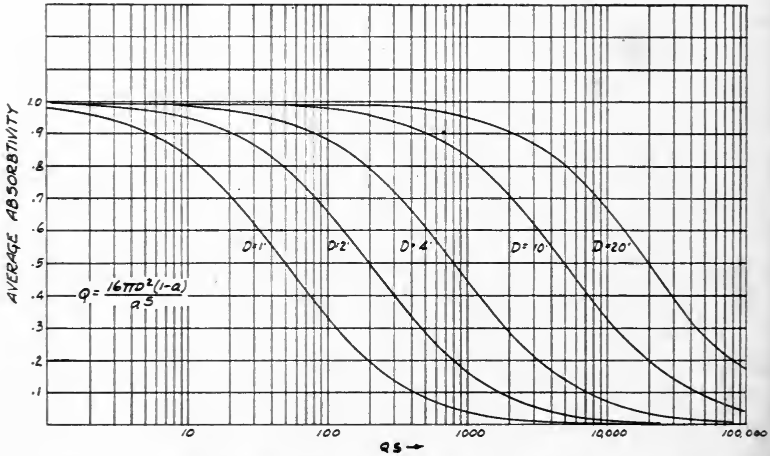

FIG. 1. Acoustic condition factor for non-directional microphone.

should be made, or for that matter beyond which no critical judging of intelligibility of reproduced sound should be done, as in a review room,

$$D = \sqrt{\frac{Ve^{\frac{0.862}{T}}}{1030\left(3 - e^{\frac{0.862}{T}}\right)T}}$$

It is therefore well also in theaters whose length is considerable to reduce the reverberation time a little beyond its optimal value to secure good intelligibility in the rear sections of the house.

Olson[3] showed that the *effect* of the ratio of direct to generally reflected sound energy at a point in a room is dependent upon the solid cone of reception of the particular type of microphone used. Letting Ω be the solid cone of reception of the microphone, we have:

$$Q_2 = \frac{E_R}{E_D}\frac{\Omega}{4\pi} = \frac{\dfrac{4P(1-a)}{cA}}{\dfrac{P}{4\pi c D^2}}\frac{\Omega}{4\pi} = \frac{4D^2(1-a)}{A}\Omega \qquad (3)$$

since the response of a directional microphone to generally reflected sound will be $\Omega/4\pi$ times that of a non-directional microphone. In the case of a non-directional microphone ($\Omega = 4\pi$), we have

$$Q_3 = \frac{16\pi D^2(1-a)}{aS} \qquad (4)$$

This equation is shown graphically by Fig. 1. It illustrates the great preponderance of generally reflected sound at some distance from the source.

Maxfield[4] has introduced an acoustic condition factor termed "liveness." In place of the generally reflected sound energy density ($E_R = 4P(1-a)/cA$, that is, of all the sound remaining after the first reflection), the steady-state energy density is used. Thus

$$Q_4 = \frac{E_0}{E_D} = \frac{\dfrac{4P}{cA}}{\dfrac{P}{4\pi c D^2}} = \frac{16\pi D^2}{A} = \frac{1000TD^2}{V} \qquad (5)$$

From experiments it was found that technicians preferred a lower range of liveness than did musicians and the public (that is, a closer recording distance or a less reverberant room, distance remaining constant); also, that the range of liveness acceptable to any one person was broad, and that technicians accepted as tolerable a much smaller range of liveness than did musicians or the public at large.

Rabinovich[5] examined the case of the minimum perceptible variation of distance for three different sources of sound—singing, speech, and violin playing. By the use of the equation:

$$Q_6 = \frac{I_D}{I_D + I_R} = \frac{A}{A + 4\pi D^2(1-a)} \qquad (6)$$

he was able to show that the value of $\Delta Q_6/Q_6$ (ΔQ_6 being the value corresponding to the increment in Q_6 for the related minimum perceptible variation in distance for the particular source of sound) was a constant for values of D not too close to the source.

The acoustic conditions at a point in space produced by the phase relationship of direct and reflected sound are of utmost importance in the recording of sound, and can at large recording distances constitute a frequency distortion factor far more influential in controlling the quality of recorded sound than the irregularities in the frequency response characteristic of the microphone used. While the interference field in a room with regular contours can to some extent be determined theoretically, as shall be shown a little later, it would involve considerable labor to evaluate such a field, even for a simple case, when obstacles in the room have to be considered.

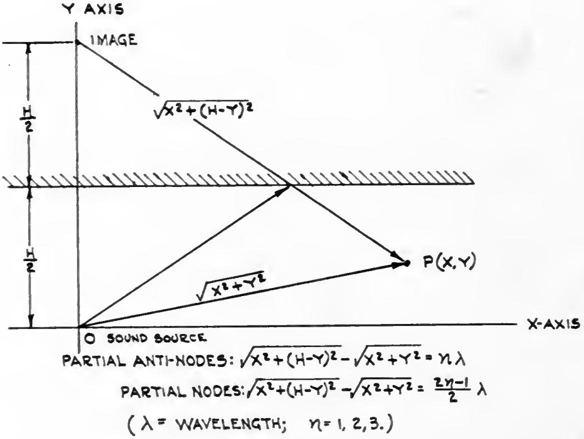

FIG. 2. Illustrating effect of reflective surface near the sound-source.

The problem of reducing the effect of sound-pressure peaks produced by interference has, together with other factors, stimulated the use of so-called compressors or amplitude range controllers in the recording of sound. At the point P of Fig. 2 the ratio of the reflected to direct sound pressure is given by:

$$\frac{P_R}{P_D} = \frac{(1-a)^{1/2}\sqrt{x^2+Y^2}}{\sqrt{x^2+(H-Y)^2}}$$

In the simplified case where $Y = 0$, this equation comes to

$$\frac{P_R}{P_D} = \frac{x(1-a)^{1/2}}{\sqrt{x^2+H^2}}$$

Fig. 2*A* shows the variation of this ratio with frequency for the case indicated on the figure. It is seen that serious distortion can result in the recorded sound when a highly reflective surface is in proximity of the transmitter. The use of two microphones can do little to correct such a condition, since it is practically extremely improbable that while partial antinodes exist at the position of one microphone there will be compensating partial nodes at the position of the other transmitter.

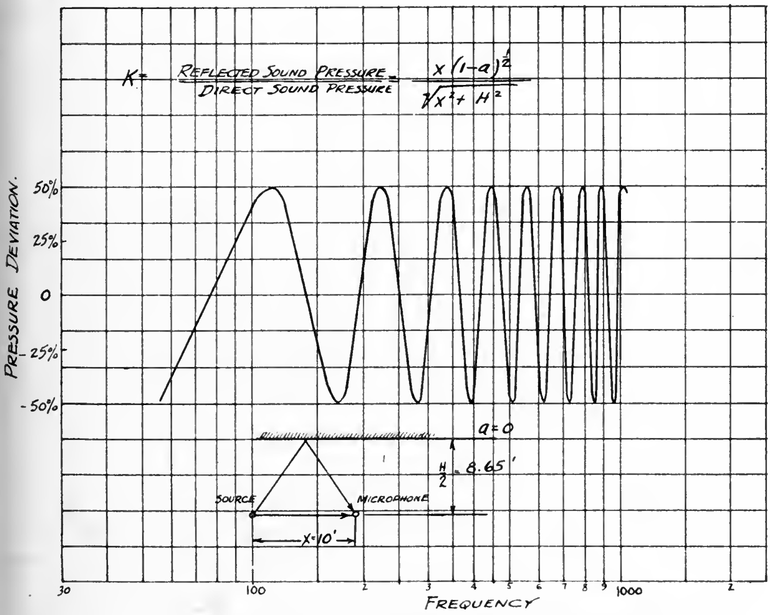

Fig. 2*A*. Variation of ratio of reflected to direct sound with frequency.

Fig. 2*B* shows the frequency response of a loud speaker as taken in the open and also curves obtained at two different positions in a room using the same measuring equipment. It is these large fluctuations in sound-pressure which can seriously distort recorded sound when the microphone distance becomes too great to suppress the influence of the reflected sound. While these curves were obtained under practically steady-state conditions, the situation is not changed much for transients, since it takes but a small fraction of a second in many a room for the sound-energy to build up within two or three db of the steady-state energy density.

The use of a compressor, therefore, can do much to reduce the effect of these extreme pressure peaks due to partial interference antinodes. A perhaps rare but nonetheless interesting instance where the compressor can be made a useful tool arises when a pressure microphone is located during a sustained tone, not at a pressure maximum but at a pressure minimum. With but little sound coming from the monitoring speaker, the mixer may likely open the volume control in the mixing console to secure a higher volume level. If now the direct sound (almost equal in strength but opposite in phase to most of the generally reflected sound) is suddenly stopped, the sound level will rapidly build up, since the opposing direct sound is absent, and a noticeable sharp increase in recording level may result with a possible serious overloading of the recording mechanism in the absence of a compressor.

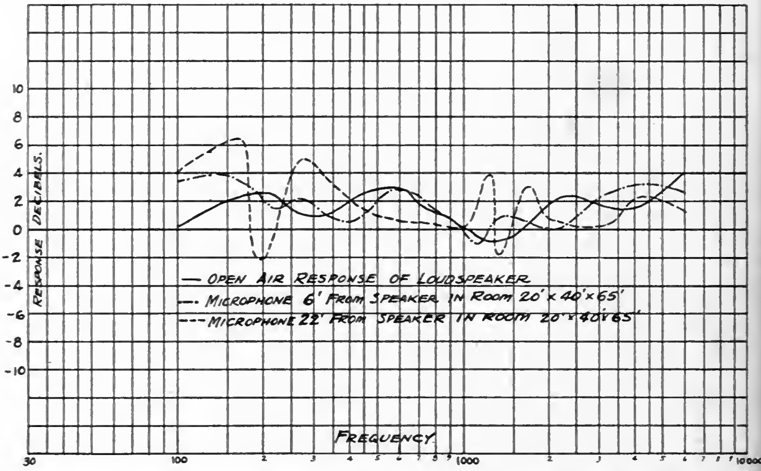

FIG. 2*B*. Response of a loud speaker in the open and two different positions in a room.

It may be of value now to consider in some detail the interference field for a simplified and ideal case in a rectangular enclosure of dimensions large in comparison to the wavelength of sound. Considering Fig. 2 and assuming a point source of sound we know that the sound from the reflecting surface will be in phase with the direct sound whenever the path difference between the reflected and the direct sound equals a wavelength or a multiple thereof of the frequency under consideration; also, the reflected sound will be out of phase with the direct sound when this path difference amounts to half a wavelength or an odd multiple thereof.

There are of course an infinite number of points within the confines of the sound field where the reflected sound will be in or out of phase with the direct sound. For any n, however (n = integer representing a multiple of the wavelength), there will be a locus along which this phenomenon occurs. As shown by Fig. 3, along any one of the curves marked $n = 1$, $n = 2$, *etc.*, the reflected sound will be in phase with the direct sound. Attention should be paid to the fact that the loci of partial nodes and antinodes do not simultaneously refer to pressure and particle velocity—a fact important to consider when measurements are made with different types of microphones. We deal here, of course, with partial nodes and partial antinodes, not only because a reflecting surface is never 100 per cent sound-reflective, but also because the reflected sound has to travel a greater distance than the direct before it can combine with it.

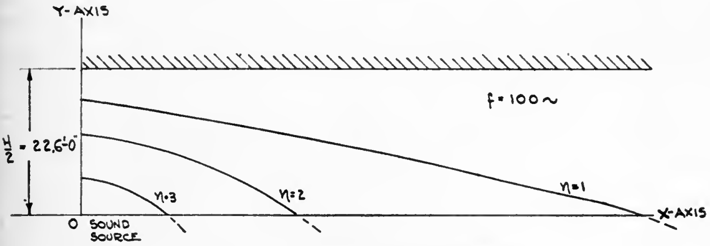

FIG. 3. Loci of partial antinodes.

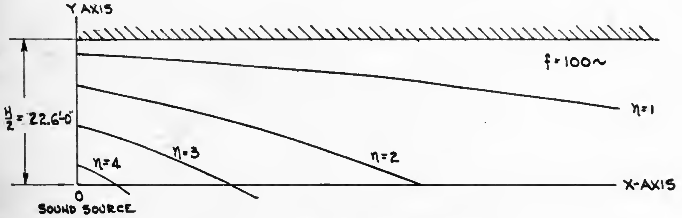

FIG. 4. Loci of partial nodes.

Fig. 4 shows the loci of partial nodes for the same geometric configuration used in Fig. 3 for the loci of partial antinodes.

Fig. 5 shows "first-reflection loci" of partial antinodes for a frequency of 100 cycles for a plane through a rectangular room of dimensions indicated on the figure. If the room is as high as it is wide the loci are curves of revolution about the center axis of the room Points marked P_1, P_2, P_3, P_4, P_5 are points where the reflected soun from each one of the three reflecting surfaces meets the direct soun in phase with the direct sound, and hence are points where a marke increase in pressure or reduction in particle velocity may be expected

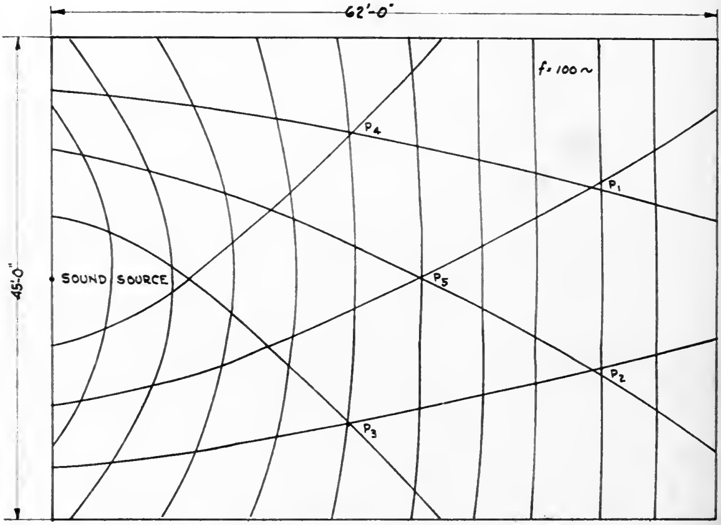

FIG. 5. Loci for partial antinodes produced by interference between direct sound and first reflections.

Fig. 6 shows a few of the possible second-reflection loci of parti antinodes for the same room. Second reflections still constitute a important factor in establishing the space interference field for steady state conditions, although they may be less important when th field in a large room assumes a transient character.

Frei[6] has shown that for a sound-source located within a rectangular room, absolute nodes at a distance D from the sound-sourc are not probable if the mean reflectivity of the room is of the orde of a factor Q_6 given by:

$$b = Q_6$$

$$= 2V\left[\frac{1}{D^2S^2 + 4V^2}\right]^{1/2}$$

This means, for instance, that in the case of a sound-stage of volume 100,000 cubic-feet, having a total interior surface of 14,000 square-feet, the mean absorptivity should be no less than 0.5 if we wish to count with the probability of not observing nodes at a recording distance of $D = \sqrt{V/2} = 24.8$ feet. For shorter recording distances, obviously, the average absorptivity need not be so large. At 10 feet from the source, this average absorptivity can be of the order of 0.20.

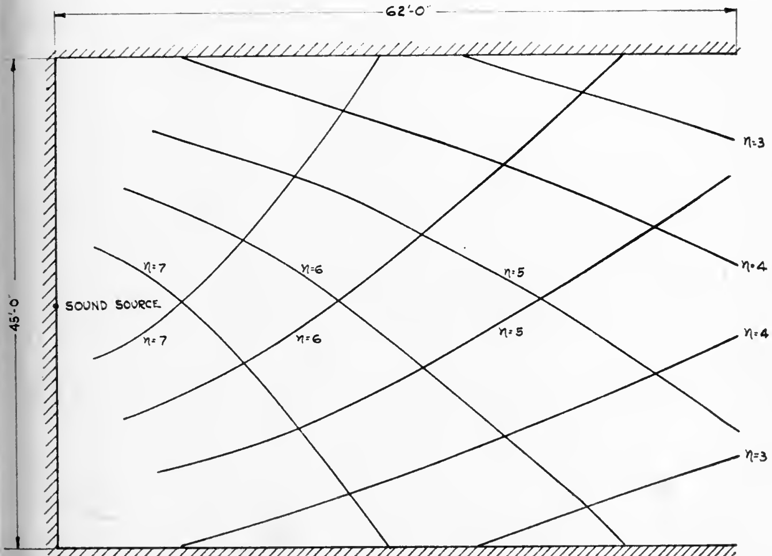

FIG. 6. Loci for partial antinodes produced by interference between direct sound and second reflections.

It should be remembered that a partial node or antinode for 100 ycles is also one for multiples of that frequency—100, 200 cycles, *tc.* The exact magnitude of the total pressure at points of such artial nodes or antinodes will not be the same for all multiples of fundamental frequency, since the average absorptivity of the surace of a room is generally a function of frequency.

Recently interest has been revived in the work started by Wente,[7] ho plotted the difference in the irregularities of a "sound transission curve" against the amount of absorption in the room and btained a smooth function. Hunt,[8] by means of a small-model hamber, was able to show qualitatively the effect on the acoustic transmission curve of placing sound-absorbing material in the chamber, and also determined quantitatively the variation of absorptivity of the acoustic material with angle of incidence of the sound.

It is possible that such sound transmission measurements will some day give us a factor representing the degree of sound diffusion in a room. Such a factor would certainly be helpful toward a more comprehensive evaluation of the acoustics of an enclosure.

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CONTROLLED SOUND REFLECTION IN REVIEW ROOMS, THEATERS, ETC.*

C. M. MUGLER**

Summary.—*This paper avoids technicalities and formulas, reaching back to elementary acoustics which are often side-tracked. Controlled reflection plays the leading role, with the minor parts delegated to sound diffusion and uniform energy distribution. Although much can be mathematically proved, the only satisfying conditions are the apparent ones, which are judged and gauged by the normal human ears.*

Audio effects due to the physical characteristics of both sound absorbents and building materials are explained and their proper locations emphasized. Although a room can have the desired optimal reverberation time over the entire frequency response characteristic, it can still be unsuitable for the rendition of speech and music that is clear and distinct; the shape, size, and contours of the six surfaces in a room, plus the incidental equipment and purpose, are the deciding factors on how much and where the reflecting and absorbing materials should be placed.

Instead of composing a technical paper containing many formulas and mathematical proofs, a brief discussion will be presented on some elementary facts of acoustics which, because of their obviousness, are often completely overlooked. In light of new experiences and experiments, an occasional review of fundamentals, by reduction to the simplest forms of analogy, will bring us closer to the correct solution and appreciation of our daily problems in acoustics.

Sound is a complex form of energy. Conversion to other forms of energy, such as heat or mechanical energy, forms the usual method of control. In some respects it obeys certain basic laws of optics but, due to its very much longer wavelengths, it can not be as readily collected and focused in a direct path as can a beam of light. Sound bends around barriers and corners in a manner similar to eddy currents in fluids but, if its path in a certain type of room enclosure can be predetermined, it is possible to prevent many of the undesirable conditions which result in the average auditorium or room.

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 1, 1939.

** Acoustical Engineering Co., Los Angeles, Calif.

Proper acoustic control is accomplished by the consideration and satisfaction of the following:

(*1*) relation of reflected and direct sound-waves;
(*2*) uniform energy distribution;
(*3*) diffusion;
(*4*) reverberation period;
(*5*) room dimensions;
(*6*) physical contouring;
(*7*) types and character of reflecting and absorbing surfaces;
(*8*) purpose and intended utility of the room.

Reflected sound is the most important consideration in this group—reflected sound which is controlled to certain definite limits.

In an enclosure wherein the ears receive the direct waves only, the rendition of speech and music is lifeless and without character. This condition is created outdoors or by the treatment of all surfaces with a low absorption material, yet the reverberation characteristics could be within optimal time limits. In other words, uniform distribution of an absorption material will not produce acceptable acoustic conditions. Conversely, we can not install at random on the surfaces of a room a highly absorptive material and be assured of acceptable acoustic conditions.

Reverberation formulas are of little value in the proper design of acoustic correction, except as a check. All reverberation time formulas are based upon two fundamental assumptions which have proved to be fallacies:

(*1*) they assume uniform distribution of sound energy;
(*2*) that absorption is proportional to the area of the absorbent.

Although it is not advisable to disregard absolutely the data obtainable from this time-honored method of calculation, the sole consideration of acoustic problems upon this basis would certainly lead to unsatisfactory acoustic treatment. Emphasis must be placed upon the proper selection of a sound absorbent and its proper and strategic location with the subject room.

A room has acceptable acoustic conditions when the rendition of speech and music is characteristically reproduced and is clear and distinct. It is the controlled reflection which builds up the energy and gives character and intelligibility to this speech and music—"brilliancy," implying that speech and music possess depth and properly sustained energy impulses without the "dampened" effect. "Brilliancy" is not produced by, or associated with, any degree of "liveness" or "deadness" in a room. "Brilliancy" concerns the maintenance of the initial energy impulses at a high level for a longer period of time by controlled reflection without exceeding the optimal reverberation time. Such a room has the apparent effect of longer reverberation time without interference, standing-wave patterns, *etc.*, and, therefore, gives sharply defined clarity of tone to speech and music.

Conventional rooms or auditoriums can be fundamentally analyzed as follows: each room contains three sets of parallel reflective surfaces: *i. e.*, floor and ceiling, side walls, and end walls. There is only one logical solution for the elimination of standing waves, flutter echoes, and phase distortion, and for building up and uniformly diffusing the sound energy in a room:

(*a*) the side walls require the installation of a definite amount of sound-absorbing units calculated for all audible frequencies;

(*b*) the end wall opposite the source of sound must likewise be treated;

(*c*) as the floor is generally carpeted and contains seats, the ceiling which is opposite will not require any acoustical treatment in the average room. It should remain hard and reflective.

This last statement is conditioned upon the time lag between the reflected and direct waves not exceeding one-fifteenth of a second.

The absorbents are to be acoustical materials or systems of materials having not less than the following sound-absorption characteristics at these frequencies which are selected at a 60-db level above the threshold of audibility and closely correspond to the normal ear response curve:

Frequency	64	128	256	516	1024	2048	4096	8192
Absorption	25	30	50	70	70	70	65	60

Uniform energy distribution can be achieved only by splaying certain parts of the wall and ceiling areas. In order to produce proper diffusion, this splaying must be carefully designed to break up or diverge the reflected waves. The splays must be surfaced with an absorbent or hard reflective material according to their locations in relationship to the source of sound and the size and purpose of the room.

In order to prevent panel vibrations, all the surfaces, including the floor, walls, and ceiling, must be rigidly braced. In construction where panels or walls can vibrate there is always the possibility of induced transient distortion. Cavity resonance feed-back in the form of background noise is a serious condition which is found in many otherwise acoustically acceptable rooms. This is caused by the sound building up between the various surfaces of the floor, walls, and ceiling construction and returning at audible levels to the normal room interior. This is a general condition when the wall surfaces are furred out with lath and plaster. Even with an approximate attenuation of 24 db, the sound transmitted into the cavity behind would build up in energy and be directed back as noise, and not as sound, into the room.

Serious consideration must be given to the subject of sound-absorbing materials. It is very important to consider the physical characteristics of the materials and to scrutinize carefully the sound absorption coefficients at all frequencies, particularly in the lower end of the spectrum. Acoustical materials are generally divided into the following types:

(*1*) The direct-absorbing type, where the sound energy is converted into heat by friction encountered in passing through the crevices and pores of the material. Examples are acoustical plasters and hard rigid precast tiles.

(*2*) The direct-absorbing type composed of felted fibers, which absorbs sound in the same manner as type *1* and, in addition, gains efficiency through a dampening effect due to the resiliency of the material. Examples are bagasse fiber tiles and wood fiber tiles.

(*3*) The high-efficiency type, which is covered with a perforated hard surface. The hard surface material serves only as a mask for the unsightly absorbent behind. Example is mineral wool surfaced with perforated metal, transite, or hardboard.

Summarizing, the three types of materials are more easily described as (*1*) hard and porous; (*2*) resilient and porous; (*3*) hard and perforated.

The effect of these three types of materials will be different even when they possess identical sound-absorption characteristics. Theoretically and practically, the reverberation times would be identical in any three average rooms individually treated with each of these three types of materials, based on an equal amount of absorption units. However, the apparent effect upon the character and brilliance of the speech and music, as judged by the human ears, would be distinctly different. The effect would be directly due to the character of the reflected sound.

Particular importance must be attached to the installation of these acoustical materials. Too often the material is installed in such a way that panel vibrations and the subsequent detrimental effect of resonating peaks are generated. The simplest case is wherein the material is mounted on furring strips. In most cases these resonating peaks can be predicted and at what frequency range they will occur, depending upon the type of material utilized and the method of mounting.

Observation of the reflected sound will determine the relative merit of these three types of materials. Exact preference should be influenced by the intended use. There is little difference between the absorption coefficients of metal and wood but the apparent effect is radically different. The reflected sound from wood is clear and bell-like with individual characteristics of harmonics and overtones, whereas the reflected sound from metal is sharp and shrill. The absorbent must be selected by studying its sound-absorption coefficients at each and every audible frequency.

Although carpets and velour drapes are inexpensive to install for acoustical treatment, they are not suitable for critical listening because they absorb too little energy at the pitch of the male voice and pitch of the female voice, and too much energy at the high frequencies. For instance, lined carpet absorbs only approximately 7 per cent of the incidental sound at 128 cps, whereas at 1024 cps it absorbs approximately 55 per cent. Therefore, were a room treated with such materials, it would have a booming effect due to the masking of the higher frequencies by the lows.

More attention must be given to the loudness curve and to the ear response characteristics. Too often the higher frequencies and their delicate tonal components are masked out by the energy of the lower frequencies. For instance, to raise a 1000-cycle note from the threshold of inaudibility to 80 db requires 80 db, whereas it requires only 35 db to raise a 100-cycle note from the threshold of inaudibility to 80 db.

The remedy in preserving the naturalness of speech and music within a room is not in further improvements of mechanical and electrical equipment, but in restudying elementary acoustics and in choosing those materials which have selective sound absorption coefficients. Reverberation time formulas should be used only as a check against the superior methods of image projection of reflected sound and energy-level distribution analysis.

THE STATUS OF LENS MAKING IN AMERICA*

W. B. RAYTON**

Summary.—*When the modern optical industry was born, this country was predominantly agricultural. Its principal industrial developments related to transportation. It was natural, therefore, that Europe should have gained great prestige in the field of optics in the final quarter of the nineteenth century.*

With the turn of the century, however, agricultural developments had about reached their limit and industrial activity began to occupy a larger place in American life. Along with others the optical industry felt the incentive to greater activity and the first fifteen years of this century saw a rapid advance in the magnitude of the industry and improvement in the quality of its product.

We are still, however, completely dependent on European sources of supply for our optical glass and for some of the small-demand class of laboratory instruments. Then came the war that not only cut off all aid from Europe but ultimately led Europe to our doors with appeals for optical munitions.

The war only hastened what would have been inevitable anyway, viz., *the complete independence of America in optical matters.*

The American optical industry has now reached a point where its raw materials (optical glass) and its technical skill recognize no superiors. It can make any practical optical element or instrument for which quantitative specifications can be written.

If any justification is required for such a review as this, it lies in the fact that it is always a salutary procedure to pause occasionally to look back to see whence we have come and to look ahead to see where we are going. In view of the dependence of the motion picture industry upon the achievements of the optical industry such a review should not be out of place in a meeting of this kind where there are gathered together the principal technicians of the country engaged in both the production and projection of motion pictures as well as in the manufacture of equipment therefor.

Prior to 1875 practical optics was virtually an art. It is true that in spite of the handicaps of an inadequate theory of image formation and a limited range of optical glasses men like Galileo, Leeuwenhoek, Dollond, Fraunhofer, Chevalier, Petzval, and Amici produced tele-

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 7, 1939.

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scope objectives, microscopes, and photographic lenses of astonishingly good quality. Each lens they made, however, had in it something of the nature of a painting, for example. It was in no sense a manufactured product.

Applied optics began to develop into an industry at about the same time and in response to the same forces as many other activities. The modern optical industry did not develop because Schott learned how to make some new kinds of glass nor because of Abbe's contributions to the theory of optical instruments but, on the other hand, they were impelled to conduct their investigations by the same conditions that produced such phenomena as Thomas Edison and Henry Ford. Developments in optics paralleled more startling developments in illumination, transportation, and communications. To support this view it will be pointed out a little later that the same forces were operating at the same time in this country.

At the time the modern optical industry was born this country was engaged in the gigantic task of taming a continent. Our foremost industry was agriculture and our second most important activity was to provide means of transporting our agricultural products to the seaboard for shipment to Europe. We had few people interested in the slow and painstaking task of developing the manufacture of such nonessentials as lenses or optical instruments.

We did have a few pioneers, however. At a time when no one had even a workable theory of the microscope, Spencer and Tolles were making microscope objectives that were rated as equal to any produced in Europe. Alvan Clark, Senior, was making good achromatic lenses and training his son Alvan Clark, Junior, who was later to make so distinguished a mark as the maker of some of the world's finest telescope objectives. The largest of these was the 40-inch lens of the Yerkes Observatory—the largest refractor in the world and likely to continue to hold that honor. J. J. Bausch and Capt. Henry Lomb were establishing the foundations of the present Bausch & Lomb Optical Co. and the Wells family those of the American Optical Co.

At the time applied optics was beginning to develop in Europe, Edward Bausch in this country began to have visions of making microscopes in such a way that all who needed them might have them. Fifty years later there were more microscopes in any well equipped high school than there were in the whole of the United States of America when he made his first instrument.

In spite of these illustrious American pioneers, the resources of Europe applied to the development of optics led to a much more rapid growth of the industry there than could be managed here and from 1875 to approximately 1910 there is no doubt that both in theory and application optics in Europe led the world. The impetus supplied by Schott's optical glasses and by the enrichment of the theory of optical instruments provided by Ernst Abbe and his colleagues as well as the awakened demand for microscopes, optical measuring instruments, photographic lenses, and optical munitions of war resulted in a relatively tremendous growth of the infant optical industry during this period. The optical industry of America was drawn along more or less like the tail of a kite but remained dependent upon Europe for its supply of optical glass and for much of its supply of optical instruments.

Because the American optical industry did not during this period attempt to meet all of the optical needs of the American laboratory the impression arose that American technical and scientific abilities were not equal to the task. This idea was nourished by the impressions gained during their post-graduate studies abroad of American scientific and medical students who felt that the educational institutions of this country could not offer instruction comparable with that obtainable in the universities of Germany and England. Using there for the first time optical equipment in their researches they returned to this country imbued with the idea that such apparatus could only be made in Europe. Perhaps some of this fixation remains still in some quarters but it is certainly insignificant in volume compared with thirty years ago.

As an illustration, there was a time some years ago when a good American citizen assured me when we first planned to put a spectrograph on the market that Bausch & Lomb would have to make a better spectrograph and sell it for less money than the principal European maker of such apparatus before we could interest him. To offset his discouraging attitude we had the encouragement offered us by a European-born and educated chemist who told us that if we could make an instrument somewhere near as good as the European instrument and sell it for not too much more money, he would use it and promote its acceptance in the field of American spectroscopy. The outcome was an instrument that has changed the conception of the world as to what a spectrograph ought to be.

While by 1910, the optical industry of America was beginning in some measure to parallel the achievements of Europe, it still made no optical glass and still failed to make many of the optical instruments that although tremendously important from the standpoint of the research laboratory were salable only in the most limited quantities.

The outbreak of the World War changed the picture abruptly. The isolation and a little later the increased military needs of our country focused attention on three weaknesses: first, optical glass; second, military optical instruments; and, third, optical measuring instruments. The ophthalmic needs of the country were adequately provided for; we did not need to go to Europe for fine microscopes, Bausch & Lomb and the Eastman Kodak Co. with its then subsidiary, Folmer-Schwing Division, were able to supply the country with excellent cameras and photographic lenses; the needs of the American astronomer were met with equipment second to none in the world, and we were making excellent surveying instruments. On the other hand, we depended on Europe for glass; we imported many of the optical elements needed in the manufacture of range finders, and we obtained from European sources our spectrographs, refractometers, spectrophotometers, colorimeters, *etc.*

The story of the development of optical glass production has been told frequently enough to permit omitting it here beyond saying that we are now absolutely independent in so far as concerns the manufacture of essential glasses. We no longer import optical elements for range finders and in so far as we have had an opportunity for making comparisons it is our conviction that the Inspectors of the U. S. Navy would not accept the product of the European manufacturers and that they demand from us qualities and performance that are not equalled elsewhere. I regret that I am not permitted to fortify this statement with more definite information. Some of the finest optical work accomplished lies concealed behind the wall of secrecy imposed with probably good reason by the military authorities.

Since the War the optical industry of this country has designed and now manufactures practically every kind of optical instrument required by the research laboratory, in addition to improving and increasing production of all of the more common kinds of optical instruments.

Coming a little closer to the interests of this organization, the production of instruments for the projection of pictures has been preeminently an American achievement. In the field of projection of still pictures the Bausch & Lomb Optical Co. name has become incorporated in the word *Balopticon* recognized by the dictionaries as an instrument for the projection of pictures, and projectors made in Rochester have been sold in all parts of the world. Motion pictures are, of course, conspicuously an American development. From the beginning of the art, motion pictures have employed domestic equipment and, very definitely contradicting the statement made a few years ago by our friends the British Optical Instrument Manufacturers Association, the great majority of motion pictures projected in American theaters today, yesterday, and ever since the birth of the art, are and have been projected through American lenses.

For some reason not too easy to understand, the people who photograph professional motion pictures have not shared the confidence in American lenses manifested by those whose business it is to project these pictures after they are made. In view of the fact that the effect observed by the audience in a theater is the combined effect of the photography and the projection, and having further in mind the fact that, in some respects, the demands made on a projection lens today are more severe than those made on the "taking" lens, it is not unreasonable to suppose that the condition just stated is a temporary one and that the American cinematographer will eventually come to share with the microscopist, the spectroscopist, the astronomer, the ophthalmologist, and the metallurgist the conviction that he does not need to go outside the products of his own country to find lenses of the finest obtainable quality.

Some indication of the ability of American optical firms to produce photographic lenses of the highest quality may be found in the relatively new field of photogrammetry. Herein photographs taken from the air are used for the construction of maps. Photographs intended for this purpose must be characterized by the highest possible quality in respect of definition and by a freedom from distortion that would have been regarded as fantastic a few years ago. The reasons for these requirements are easy to comprehend. Because of unsteady air a flight altitude of less than a mile is impracticable. Other considerations lead to actual flight altitudes lying generally between 10,000 and 20,000 feet. Photographing the surface of the earth from such distances, details such as road intersections, buildings, boulders, clumps of bushes, *etc.*, that might serve as identifiable points whose location must be identified on the map must be clearly recognizable in the photograph. This calls for exquisite definition. On the other hand, the scale of the photograph must be uniform over its entire area. If the scale of reduction varies over the photograph measurement of distances is accompanied by corresponding errors. This leads to the requirement of freedom from distortion. Since perfection in this world is unattainable, the map makers do concede to the lens manufacturers a little departure from the ideal—an error of one part in four or five thousand which would correspond to an error in planimetry of roughly a foot in a mile.

Aerial photographs are used not only for planimetry, however, but also for topographic mapping by employing the stereoscopic parallax obtained by photographing the same view from two separate points in the flight of the plane. There are various methods by which this stereoscopic parallax can be employed to yield information as to dimensions perpendicular to the surface of the earth, one of the most interesting of which is to employ two projectors to reproject a stereoscopic model of that section of the earth's surface common to two consecutive photographs. Such projectors permit the reconstruction of the earth's surface in a very much reduced scale, say, one to ten thousand, for example, in which both horizontal distances are reproduced in the same scale and are measurable with a high order of accuracy. On such a scale a difference in elevation of five feet would appear as 0.15 mm or 0.006 inch. Such a value is perfectly easy to read so that in the stereoscopic model reproduced by such projectors from two pictures taken with a lens of 6-inch focus from an altitude of 10,000 or 12,000 feet, two miles or more, it can easily be observed that an automobile has a definite height and is not just a flat, dark spot on the ground. Such results, however, can not be accomplished without lenses and mechanical work of the most exquisitely accurate nature. This equipment is being produced by the Bausch & Lomb Optical Co. in Rochester and lenses adequate for the photography are produced by the same company as well as by the Hawk-Eye Division of the Eastman Kodak Co. and the American Goerz Co.

The drive for accuracy in this work has led to some progress in the field of lens testing. Too much, in the past, lens performance has been judged by purely qualitative standards. Two photographs are taken under what it is hoped are identical conditions and then judgment is rendered by comparison as to which is the better. In photogrammetry something more has been done. Definite standards have been set up for definition in terms of resolving power and for distortion. The measurement of distortion is a relatively simple problem fundamentally although it becomes difficult enough in execution when the degree of precision required reaches the values involved in photogrammetry but the matter of definition is not so simple. The test for resolving power is open to criticism not for giving false information about a lens but because it perhaps does not give enough. Improvements are likely to follow and out of the requirements of this science may come some methods of evaluating lens performance that may more truly indicate the relative merit of lenses than the best judgment of the photographer no matter how conscientious he may be in reaching his conclusions.

One thing I wish especially to emphasize and that is that whenever quantitative specifications have been set up for lenses we have been able to meet them in this country if they have been met anywhere.

Having thus sketchily indicated whence we have come and, all too briefly to do justice to the subject, outlined where we stand, it is logical to ask, where are we going from here?

A complete optical industry involves four things: first, adequate raw materials; second, competent scientific research and engineering application; third, skilled craftsmen to convert the products of the research laboratories and the engineering departments into practical lenses and instruments; and, fourth, a market for the product.

The first of these has been discussed. For the second, we have resources we did not possess twenty-five years ago. We have an Optical Society of America, organized twenty-four years ago, that is stimulating interest in both research in the field of optics and in the use of optical instruments and methods in the laboratory, in education, and in industry. We have several colleges and universities wherein more interest is being taken in optics and more competent instruction is available than could have been had anywhere in the country twenty-five years ago. At the University of Rochester is an Institute of Optics organized to run parallel with and in closest cooperation with the Department of Physics with a four-year course leading to a bachelor of science degree. From personal experience with the graduates of this Institute I can say that they leave it with a knowledge of optics and of optical instruments that was formerly attainable only by years of work in an optical plant. With the incentive set by the Optical Society and the educational advantages now available, the supply of competent optical engineers, if not yet fully equal to the needs of the country, is certainly in a vastly better state than it has ever been before.

In respect of the third point, perhaps conditions are here more favorable also than they have been for some time. In these days of unemployment it would seem easy to get all the factory help that could be desired. We found in 1937 that such was far from the truth, an experience that was shared by every other industry that depended on skilled workmen. It takes high qualities of intelligence, initiative, muscular coördination, ambition, industry, and the ability to coöperate with others to make a competent instrument maker. For a long time youths with such qualifications sought in a college education a passport to a white-collar job and disdained consideration of any job that involved working with their hands. With college graduates without outstanding qualifications for some particular kind of work rating at about a dime per dozen, many of them are sensibly passing up the $30 per week office jobs for the $60 per week of the skilled mechanic and they are making white-collar jobs out of such work. It seems not unlikely that there may be a definite movement back to the realization that a comfortable living obtained as a skilled craftsman is not an undesirable way of life for even a college graduate.

Finally, as for the market for the product of the optical industry, it is increasing constantly. It is perhaps beyond reason that a product that practically never wears out, such as most of the products of this industry, should not more often develop a saturated market. Such things happen to a certain extent, of course, but less frequently than one would expect.

The last twenty-five years, therefore, appear to have brought the optical industry of this country to a point where it can supply practically anything of an optical nature that can be required. It is not an unimportant matter in these times, for optical equipment is a vital necessity for national defense in both a military and a medical sense. Optical instruments are indispensable tools in practically every branch of science and are steadily becoming more and more important in such fields as metallurgy, paper-making, machine shop practice, the manufacture of chemicals, and the manufacture of textiles.

In this brief summary of the state of the optical art in America I have deliberately tried to avoid making disparaging comparisons with the progress of other countries. In certain respects it is the easiest course to measure our progress by comparison with developments in other countries, and where necessary, that has been done to outline our progress with our needs. I believe that our present optical industry is completely adequate to those needs.

MOTION PICTURES IN EDUCATION*

A. SHAPIRO**

***Summary.**—A brief survey is made of the history of motion pictures in education and their use as a teaching aid; the present status of 16-mm sound pictures and projectors in schools; types of educational pictures available and their sources; the distinction between auditorium and classroom films; types and sources of auditorium films currently used; types and sources of classroom films; cost of films; their acceptability by teacher groups and coöperation of non-profit educational groups toward creation of adequate classroom libraries; and a plan is suggested for an educational-film-producing organization to meet school needs.*

It is only within recent years that educators have begun to make use of modern aids to improve the teaching process. For thousands of years education depended principally on the teacher talking and the pupil listening. The educational process was carried on by word of mouth, and was strongly colored by the temperament and personality of the teacher. With the invention of the printing press, the scope of education became enlarged because it brought to the pupil a world outside the curricular descriptions of the teacher. The printed word brought a vast storehouse of accumulated knowledge to the pupil, and he became exposed to the thinking processes of many minds. Illustrations accompanying printed texts aided greatly in clarifying words. A vast world came under the observation of the pupil which would have been otherwise impossible, except within the limits of his own observations. The importance of the illustration to the teaching process is aptly described in the words of an old Chinese philosopher: "One picture is worth a thousand words."

The printed word and the picture recorded the experiences of others. There still remained the element of personal experience, and out of this need was evolved the laboratory. Here the pupil could see for himself and complement his learning process by doing things. The laboratory is the proving ground where trial and often

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** Ampro Corporation, Chicago, Ill.

error supply the convincing proof of the recorded laws of man and nature.

As the horizon of human knowledge widened, the records of the accumulated knowledge of mankind multiplied. Gradually, the teacher became a guide to the pupil, rather than the center about whom the entire learning process revolved. His role became more and more that of a leader through the complex structure of knowledge which was being erected. Numerous aids were developed to facilitate the effectiveness of teaching. Essentially, however, the three fundamental processes of education still remain, listening, reading, and seeing.

It is the seeing process with which we are here principally concerned. Visual education, as it is termed, is today one of the most important forces in education. It surmounts time and space. It extends into the past and projects into the future. It pushes out the walls of the classroom to the farthermost corners of the universe. It replaces and often surpasses the most elaborate clinical and laboratory facilities.

Motion Pictures as a Teaching Aid.—Almost since the birth of motion pictures, educators have been aware of its value as an instructional tool of great power and its potential value as an aid in the teaching process. With motion pictures, subject matter can be presented with added emphasis to compel interest on the part of pupils. The use of motion makes possible more comprehensive illustrations supporting text-book matter and oral teaching. Animated drawings serve to x-ray invisible phenomena. The addition of sound still further enhances the effectiveness of this modern teaching tool.

Research by Educators.—Repeated experiments by leading educators have proved definitely that pupils who have the advantage of the motion picture learn more and remember more. Examinations given to different classes reveal that those who have been aided by the motion picture have materially higher grades and acquire a greater comprehension of the subject taught than those who were not so aided. This makes possible an economy in time of learning which is of great importance to education. More important is the enrichment which comes through viewing scenes or activities which are exceedingly difficult or impossible to show under ordinary schoolroom conditions.

For example, in the field of botany animated drawings can show plant reproduction through its entire process; stop-time-lapse photography can show the evolution and growth of a plant; animated pictures can show how an automobile engine works; countries and peoples distant from one's own land can be brought home to the pupil; mechanical and electrical apparatus not commonly found in school laboratories can be demonstrated in operating conditions.

History of Barriers to School Use.—When motion pictures were first introduced to schools some seventeen years ago, it was necessary to use the same film equipment as was used in motion picture theaters. This meant handling 35-mm film with its well known fire hazards. It involved large and expensive equipment. In most cases a professional operator skilled in the technical complexities of the equipment was required. These obstacles proved a serious barrier to the general use of this medium and made it impracticable for use in classrooms. Consequently, motion pictures were confined to educational showings in school auditoriums before large assembled groups.

With the introduction of 16-mm safety film, which had first been developed for amateur use, these obstacles disappeared. The new film did not present a fire hazard, the equipment required to project pictures was nominal in cost, and a professional operator was not required. It became practicable to use motion pictures in the classroom, the projector in most cases being operated by the teacher. Libraries of teaching films were developed, and the educator was given a new aid for facilitating pupil understanding.

Up until 1929, which marked the point of general acceptance of the talking film, the 16-mm silent film had been making steady progress as an aid to education. Eastman Talking Films, with its more than two hundred subjects, was one of the first companies to provide a fairly comprehensive educational film library. The Yale Chronicles of America produced fifty-two reels on American history for school use. Hundreds of other productions were made, and distributing centers were formed to provide for their circulation. Over thirty universities developed such circulating libraries for the benefit of the schools in their districts.

Introduction of Sound Pictures to Education.—With the general acceptance of the talking film in entertainment, educators were faced with the problem of whether the silent or the sound-film was the best instrument for school use. It was quickly realized that the sound-film had tremendous advantages over the silent. However, once more there appeared a number of new obstacles. First, there were no libraries of educational sound-films available. Second, 16-mm sound-on-film was not yet developed and, consequently, the use of sound-film would mean going back to the cumbersome and expensive 35-mm equipment. Third, such equipment brought with it the old disadvantages of fire hazard and the complexity requiring a professional operator. On the other hand, there were so many advantages which the sound picture had over the silent, that the production of educational silent films practically ceased and much effort was concentrated on the problem of making sound pictures practicable for classroom use.

One of the first efforts in this direction was made by Electrical Research Products, Inc., which produced several educational pictures on 16-mm film with a phonograph disk accompaniment for sound. In order to synchronize the picture with the sound, a very cumbersome and complicated equipment was developed, involving a turntable attached by gears to a projector. Occasionally the needle would slide off the sound record and the ensuing sound would be out of synchronism with the picture being shown. Records would be misplaced and considerable care had to be exercised to insure using the proper record for the proper film. If a portion of the film were destroyed, a piece of film having the exact number of frames would have to be inserted where the break took place; otherwise, the accompanying sound would not match the picture for the entire remainder of the reel. Altogether, it was an impracticable means for making use of sound pictures in the classroom. It served, however, to show conclusively that the sound picture was greatly superior to the silent for teaching purposes, and pointed the direction for future developments.

Available Projection Equipment.—In 1930 the first 16-mm sound-on-film projector was publicly demonstrated. Based on present standards of quality, the results were very poor, but it formed a starting point from which the modern 16-mm sound projector has been developed. By 1935 the improvements had reached a state which led to the general acceptance of 16-mm sound-on-film for non-theatrical purposes. The perfection of equipment led to instruments which were inexpensive as to first cost and operation, safe and simple to use, and capable of highly satisfactory performances. These improvements made entirely practicable the classroom use of sound pictures.

The Present Status of Sound Pictures in Schools.—In the early days of development of sound pictures in schools there was considerable opposition on the part of teachers, based on the theory that the sound picture might replace many of them. It was argued that by bringing noted educators to the screen, classes could be enlarged and a good deal of the teaching processes could be carried on without personal instruction. This, however, has not been proved to be the case. It is now fairly established that the sound picture is an aid, and in no way a substitute, for the teacher. It is another tool, albeit a very powerful one, to aid the teacher in the educational process, and today such opposition to its use by teachers is virtually unknown.

Types of Educational Pictures.—There are two general types of educational pictures. One group consists of pictures which are of a general nature containing material which correlates classroom activity with the life outside the school. The classroom is a little world all by itself, and when it is devoted to the teaching of a particular subject or form, it tends to become isolated from the real world in which we live. This type of picture is designed to coördinate the little world of the classroom with the larger world of which it is a part. Pictures of this sort, being of a general nature, can be shown to groups of classes assembled in the school auditorium. They are, therefore, referred to as auditorium pictures.

The second type consists of pictures integrated with the text-book and oral technic used in teaching a particular subject. These pictures may be considered as explanatory of text-book material and can be viewed as illustrations in motion, transcending the limitations of the still picture in the text-book. The sound accompanying these pictures creates an added effectiveness and gives continuity to the subject matter. This type of picture is generally referred to as a classroom picture, because its greatest use is in the classroom under the coördination of the teacher.

This classification of educational pictures must be taken in a broad sense. It is often very difficult to draw the line between what is specifically educative and what is generally educative. Auditorium pictures are often effectively used for classroom teaching, and *vice versa*. The definition does not relate specifically to the place in which the picture is being shown. It is rather a distinction as to the place which the picture has in the general educational program.

Auditorium Sound-Films.—There is available for school use today a large supply of films of the auditorium type. These films have been prepared mainly from the following sources:

(*1*) Theatrical pictures
(*2*) Commercial pictures
(*3*) U. S. Government films
(*4*) Documentary films

(*1*) Theatrical pictures offer the largest present source of educational pictures for auditorium use. The vast amount of material in the vaults of the theatrical film makers are of significant educational value. By proper editing this material is being made available for school use. In December, 1937, the Motion Picture Project of the American Council of Education received a grant of $135,000 to finance a research program involving the evaluating and cataloguing of existing theatrical films so that they might be fitted into a broad educational program. The Motion Picture Producers and Distributors Organization added $50,000 to this fund, thereby not only aiding in financing it, but giving this project the official endorsement of the producer groups. Approximately 8500 films of educational significance have already been listed. Unquestionably, this project will form the basis of an extensive library of films of this type.

(*2*) Commercial pictures, although primarily produced for the benefit of their sponsors, have a definite educational value in bringing to the pupils information on the manufacture, nature, and use of products or services. They serve to acquaint the pupils with the applications to which their schooling serves to prepare them. Young folk with vague ideas about their careers are able to visualize more clearly what is to be expected of their future activities. These pictures form an invaluable background for correlating the outside world with the school. These pictures, incidentally, are available for school use in most cases without cost to the schools. At the present time there are 143 commercial organizations listed as offering such films for school use.

(*3*) The United States Government has produced more than 500 federal films, nearly all of which have educational value. Many of them have been made for specific purposes, relating to the safety and well-being of our people. Three Federal Departments are actively engaged in production with their own laboratory and filming facilities. These are the Department of the Interior, the Department of Agriculture, and the War Department. The films made by the Department of the Interior cover a wide variety of interesting subjects such as the National Parks; State and County Parks; the position of the Indian in this modern age; federal projects, such as the Boulder and Grand Coulee Dams, showing their relations to desert reclamation and their generation of power; the conservation of our oil and range resources; mining; pictures on our outlying possessions, such as Alaska, Hawaii, Puerto Rico, and the Virgin Islands; activities of the Civilian Conservation Corps; *etc.* These pictures are designed to illustrate the principle of the conservation of our natural resources and the waste resulting from the lack of such conservation. The Department of Agriculture has produced about 350 films covering the improvement of American farming. Pictures produced by the War Department are primarily for war training purposes. With the new program of rearmament in America these pictures will, no doubt, find use in the R. O. T. C. and other military divisions of our schools.

(*4*) Documentary films form a rather new category in the library of visual aids. These are films which throw light on current activities of sociological, historical, and political interest. An example of this type of film is the pictures called *The March of Time.* These show reënactments of current events which have important historical significance. Recently, the U. S. Government has produced several films of this nature. Two of these films, *The River* and *The Plow That Broke the Plain,* are now in circulation and have been widely acclaimed by educators as outstanding productions in this field. The approbation which these two pictures have received from educators will undoubtedly stimulate the production of more pictures of this character.

The Classroom Sound-Films.—Present methods of teaching do not permit very much time to be spent in auditorium group meetings correlating school activity with outside interest. The classroom forms the foundation of our educational system and it is here that the greatest lack of sound-film exists. Up to the present, the principal source of this material has been Erpi Pictures Consultants, Inc., which has produced about 110 classroom sound-films. Unfortunately, most of these films have been designed for use in colleges and high-schools. The need for films for grade schools, and even the kindergartens, is only now beginning to receive some belated attention.

There is a great immediate need for the production of a comprehensive library of classroom sound-films. It has been estimated that to provide sound-film pictures to accompany grade school instruction, approximately 300 films are required. For high schools, at least 200 films are necessary to complement text-book teaching. What is now available does not make even a beginning of such a program and has merely served to indicate the possibilities for better teaching which the sound picture promises.

It is quite likely that after classroom pictures have become widely used, such use will have a profound effect upon the character of the text-books used. It is even conceivable that text-books will be written with the idea of coördinating the sound pictures with the text to the best advantage. For the present, however, the classroom pictures can be so designed as to blend with the majority of the text-books used for a particular course. The pictures would help clarify and make the text-book more readily comprehensible. They would form an invaluable complement to the course of study.

For most effective use the classroom picture should be timed so as to fit in with the program of the subject being taught. The effectiveness of the film is very much decreased if it is not shown at the time the subject is under discussion. It is then that it can create its most effective impression on the pupils. For this reason, it is believed that wherever possible each school should have its own library of classroom films. In this way the films are available whenever they are needed and are not subject to the inevitable delays to which any circulating plan is subject.

Cost of Films.—At present very few schools maintain their own libraries, but depend chiefly upon the rental of films from distributing organizations maintaining circulating libraries of films. Some thirty-nine universities as well as numerous state or local departments of education are engaged in this activity. One of the chief factors for the development of these distributing organizations is the high cost of films, which has been a serious barrier to the purchase of school libraries. It has been proposed by mass production to reduce the cost of films so as to make possible a package-plan low enough in cost to permit schools to purchase their own libraries of classroom films. It has been found by experience that the use of classroom films is restricted according to the degree in which the films are available and, by making the films available at all times to its classes, the individual school can obtain the greatest benefit from them.

It is generally understood that the cost of making present classroom films has varied from $4000 to $10,000 per subject. Since these subjects have been produced in the past under somewhat experimental conditions, this cost can be considered much higher than would result in a program involving planned economy. Only a small number of prints have been made of each subject, so that the per print production costs have been the largest factor of film cost. A plan assuring an outlet for a large number of prints of each subject would reduce this cost substantially and make it possible to place a low sales price on such prints.

If from 3 to 5 per cent of the total of 276,000 schools may be thus served, approximately 10,000 prints of each subject would be required. On this basis, the production cost per subject would be $1 or less per print, and the total cost, including film and printing, would be between $5 and $6 per print. This should make possible a sale price of about $20 per subject, which is less than one-half the cost of the present sale price of corresponding subjects. It is believed that a distribution of 10,000 prints per subject is a very conservative estimate of the potentialities of this field. Already some 7500 schools possess 16-mm sound equipment. It would need only the promise of such a library to multiply this figure many times.

Acceptibility.—Motion pictures in education have captured the imagination of the public and of educators. Active coöperation is being given by leading educators and educational organizations for the use of subject matter and the best methods of presenting it. Teachers who are now using motion pictures are enthusiastic about the results obtained and render all possible coöperation. A number of colleges are providing courses for teachers in the use of equipment and film. The National Educational Association, with 157,000 teacher-members, has a special division devoted to motion pictures in education. In very few fields of endeavor is as much coöperation available so freely and so sincerely as in the field of visual education.

Coöperation.—Foundation groups such as the Rockefeller Foundation and the Carnegie Institute have made available funds for research and aid in furthering the use and production of motion pictures for schools. The General Education Board of the Rockefeller Foundation has a motion picture project involving the evaluation of existing films as educational aids. Another Rockefeller Foundation called The Association of School Films Libraries, Inc., is engaged in the work of compiling a catalogue covering these evaluations. The Commission on Human Relations of the Progressive Films Association is investigating the work of reëditing films of theatrical distributors for school use. The Museum of Modern Arts Film Library is collecting a historical library of films. The American Film Center acts as adviser to film producers who engage in making pictures for the educational field. All these are non-profit organizations operating by means of private funds for public benefit.

Due to its serious purpose, the motion picture in education can not be treated in the same manner as a picture made for entertainment. First and foremost, it must be considered as a pedagogic tool and the art of education becomes more important than the art of film production. Most assuredly, the best equipment and technical facilities must be at the disposal of the producers of educational motion pictures. But the guidance and the correlation with school curricula are best controlled by educators. In a sense, the production of educational pictures represents a new art which is a blend of the best of the older technic with modern science.

Suggested Organization of Educational Film Production.—There is a definite place at present for an organization which will coördinate all the findings of the various research groups and devote itself to making the educational pictures which are most needed. While the profit motive need not be ignored, it is highly desirable that the principles of public interest be given first place. A suggested program for such an organization is as follows:

(*1*) Form an independent council of leading educators to act in an advisory capacity.
(*2*) Prepare surveys of subjects taught and text-books used, and short synopses of proposed appropriate films.
(*3*) Develop scenarios under expert scenario-writing supervision, coupled with educator editing.
(*4*) Arrange for suitable production facilities.
(*5*) Appoint publicity director to handle school and public relations.
(*6*) Prepare sales and exploitation plans with appropriate personnel.
(*7*) Coördinate efforts of production, sales and exploitation together with advisory council.

The Social Aspect.—It is felt that the field of supplying educational pictures offers not only an opportunity for profit, but also for public welfare work of a high degree. The educational system of America is the foundation of our system of democracy. Any improvements therein are bound to have fundamental effects upon the character of our future citizens. The possibilities for good effects are boundless and well merit the enterprise and support of those who are socially minded.

SCREEN COLOR*

W. C. HARCUS**

Summary.—*The color intensity of a motion picture projection system may affect the presentation of the picture. Using sample comparison methods the average color of projection systems can be determined and the deviation of a particular system measured.*

Considerable data have been collected and published concerning motion picture screen illumination from the standpoint of intensity. There is very little information concerning the color of projection systems. A projection system includes the light-source, optical system, and screen. The color of the light-source may vary from the yellow of a Mazda lamp to the blue-white of a high-intensity arc. The quality and condition of the elements of the optical system will affect the color of the light leaving the projector. The color of the light reflected from the screen will be affected by its type and condition.

A rapid and simple comparison method of determining the color of the system by measurement of the light reflected from the screen has been developed. The equipment used consists essentially of a light-source of adjustable color and intensity and a power-supply unit. The variable light-source consists of a slide-film projector unit equipped with a 500-watt Mazda lamp, a lens with iris diaphragm, and a filter holder mounted in front of the lens. The power-supply unit consists of an autotransformer with an output range up to 130 volts when supplied with 115-volt, a-c power. A voltmeter and ammeter are wired into the unit which also serves as a support for the projector. Auxiliary equipment includes a set of "Daylight Blue" filters ranging in thickness from 0.04 to 0.10 inch in steps of 0.01 inch, a white "standard screen," and a set of colored reflection screens. The technic of making a screen-color measurement with the "comparator" is essentially as follows:

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 18, 1939.

** Technicolor Motion Picture Corp., Hollywood, Calif.

(*1*) Set up the standard screen as near the center of the projection screen as practicable.

(*2*) Set up the comparator in front of the screen and adjust the beam so that it just covers standard screen.

(*3*) Operate the projector system, and erect a mask to shield a small standard screen from the light-beam.

(*4*) Insert a suitable filter in the comparator and adjust the intensity to match that of the projector system.

(*5*) Refine the color match between the standard screen and the screen being measured by adjustment of the filters, and record the filter thickness.

(*6*) An alternative method employs tinted screens instead of a white-screen-and-filter combination. The procedure is essentially the same.

Interpretation of the results of comparative measurements may be in arbitrary units such as filter thickness, which in turn may be translated into other units as desired.

A number of measurements have been made with the comparator in East and West Coast theaters, and in many of the Hollywood studios. Analysis of the data indicates that there is appreciable variation in color of projection systems. The average system color may be reproduced with a 0.13-inch Daylight Blue filter in the comparator; deviations of ±0.03 inch in thickness from the 0.13 average are found.

DISCUSSION

MR. CRABTREE: How does this variation in color affect audience reaction? That is the only way we can estimate the importance or seriousness of this variation in screen color. Have you made any audience tests?

MR. HARCUS: Not in the sense in which you are thinking, I believe. In viewing a picture on the screen, whether black-and-white or colored, the viewer, unless the color deviation is very marked, may not notice the difference in terms of neutral gray in the case of black and white, or the color variation in the case of a colored picture. If the deviation is very marked the difference becomes very objectionable.

MR. HOOPER: What kind of instrument do you use to determine the color of the light on the screen in case you want to get any particular color?

MR. HARCUS: We are using this type of comparison unit with which the color of the screen is matched, as demonstrated.

MR. HOOPER: Do you have any instrument with which to measure the color-temperature of the light on the screen?

MR. HARCUS: We have not yet undertaken any studies to that extent.

MR. CARLSON: Does the range of color difference shown here represent an acceptable range? Do you have any means of measuring screen brightness rather than incident light? In several instances where a balance presumably was demonstrated, differences in brightness seemed to be apparent. Was that due possibly to the fact that the photocell is not color-corrected and due to the selective reflectivity of the screen itself?

MR. HARCUS: There is the degree of difference we have observed here. I believe this represents a greater deviation than is desirable for the presentation of either black-and-white or colored pictures. The meter we use for this type of work is a simple Weston meter. This is a photoelectric type of meter and measures the light falling on the screen. It is not accurately color corrected so far as color-sensitivity of the eye is concerned.

MR. KELLOGG: I take it from your answer to Mr. Crabtree's question that the audience is not very critical of the color and that if the color source did vary over a certain range the audience would not criticize it. If that is the case, I do not quite see the purpose of making this rather exact study.

For color projection do you find a still greater premium on very high screen brightness than you need for black-and-white pictures and do you get more return psychologically from high brightness in the case of color than you do black-and-white?

MR. HARCUS: The purpose of the initial investigation was to determine the average screen color of the many theaters we encounter. This was to be determined as a control for the manufacture of color pictures. Color pictures that look the best on the "average screen" may not look quite so good on screens that deviate from the average.

We find in terms of light falling on the screen, that the average large motion picture screen does not exceed ten foot-candles by any substantial amount. We have found some running as high as thirteen and a few as high as eighteen or twenty. We have found some as low as five foot-candles at the center of the screen. We manufacture color pictures to show to the best advantage on an average screen of ten foot-candles.

MR. RICHARDSON: In lighting for color photography we have a problem quite similar to the one here under consideration. The requirements of color photography rather closely limit the spectral quality of the sources used on the motion picture set. Until we devised a qualitative instrument for measuring the spectral distribution of light-sources, we had only our eyes with which to make comparisons. In lighting for color photography, we have a very satisfactory reproducible standard in the *M-R Type 90* high-intensity arc lamp using a 13.6-mm carbon operating at 120 amperes with 57 volts across the arc.

Before we devised our comparison instrument, we had to go through an elaborate routine of photographic testing whenever a new unit was under development, in order to adjust the arc voltage and amperage of the unit to give a proper balance in the light. The instrument consists of three small General Electric light meters assembled in a light-tight box, each before a window provided with an adjustable shutter. Each of the windows carries a color-separation Wratten filter—one green, one red, one blue. We use the instrument comparatively, first setting the shutters to give equal readings of 50 foot-candles through the three filters from our standard *M-R Type 90* light-source; then readings are taken on the source under examination, and a comparison is obtained. We choose the 50-foot-candle readings as standard because the small General Electric light meters had been selected to read equally in this position. Having separate readings through each of the separation filters, we are able to study the ght-source under examination and explore for the conditions that will bring it ost nearly to the standard required.

We use this instrument qualitatively through the development of our Duarc, nd it may be of interest that our observations made with the instrument cor- esponded very well with the photographic check results made in the Technicolor boratories. We do not use the instrument quantitatively, although if it were ore carefully developed, it might be arranged for quantitative color measure- ents. The instrument could probably be developed to analyze screen bright- ess and be of particular value for studying screens and light-sources used in the rojection of color motion pictures.

MR. ZURICH: What have you found to be the best type of projection screen r Technicolor work?

MR. HARCUS: I am sorry to say I can not answer that question. We take he equipment just as it comes, and your question has not been part of the study.

MR. ZURICH: If you take anything from a dirty bronze yellow to a dark blue n the various screens, the color will show up very well on certain screens and ith certain projected light and not so well under other circumstances. Surely here must be some "average" screen.

MR. HARCUS: A screen that is clean and white will certainly present a picture f any type much better than one that is off color or one that is not clean.

MR. ZURICH: If the light from the various lamp houses ranges from a dirty ronze yellow to a dark blue, in addition to having a dirty screen, that is some- hing to consider.

MR. HARCUS: That is what we are trying to simulate. We have this device, hich has enabled us to determine the average screen color in the average theater.

MR. ZURICH: We all face the need today for an instrument that will measure he light reflected from the screen—one that we can take into our auditoriums nd measure the reflective quality of the screen as well as the color-temperature. his will give us a standard that we do not have today.

MR. HARCUS: That is right. I believe that some instruments have been eveloped which may soon become available.

MR. RICHARDSON: In England there was at first a very heavy import of merican carbons for use in Technicolor photography and projection. One nglish manufacturer has undertaken the problem of supplying the English arket with suitable carbons for photographing Technicolor pictures and has pproached the problem in a very scientific way. They have developed an nstrument that would almost exactly meet the need you mentioned. In England he air is foggy and there is considerable soot in the atmosphere. Screens de- eriorate quite rapidly. These English carbon manufacturers have developed n instrument for installation in the projection booth which integrates the screen llumination and enables the projectionist at periodic intervals to check his screen nd each projection lamp against the optimum performance that was established hen the screen was new or was re-surfaced. This instrument would meet the equirements mentioned by Mr. Zurich.

MR. JOY: In regard to this instrument that Mr. Richardson referred to, I elieve that it does give some indication of the total relative light on the screen ut it does not take into consideration the distribution of the light, that is, the elation of the light at the sides to the light at the center or the color of the light.

One of the things we have found time and time again in our own tests is that if we do not take into consideration the distribution of light, the total light reading is often misleading and does not necessarily give a true comparison.

MR. GRIFFIN: The Projection Practice Committee is trying to get an instrument that will indicate when the screens are deteriorating. We are not primarily interested, for this purpose, in an instrument that will give the light distribution. We simply want to be able to determine what the brightness i and when the screen needs changing or resurfacing. We have not been able t find any such instruments other than illuminometers like the Macbeth, wher one must read the brilliancy of a target or other surface. Instruments of thi type are expensive, and apart from that it is difficult to get two men to agree o identical readings. We want an instrument that is definite in results, simple t operate, and with which comparisons can be made from time to time, beginnin when screens are first installed and periodically thereafter.

MR. RICHARDSON: The English instrument referred to is designed especiall for that, and is intended to be used in the projection room. In England ther are fewer of the small theaters which we designate as neighborhood theaters, o which we have so many in this country, but in their larger theaters they ca afford to install this instrument which gives such complete information.

MR. JOY: Getting back to Mr. Harcus' paper, is the small comparison scree that you use a standard color or are these sheets of colored paper that you use standard color sheets?

MR. HARCUS: It is a white target screen made from a white cellulose board The colored screens are manufactured to match certain screens that we have encountered. They vary as to their content of blue, blue-green, and magenta, an represent white closely when reflecting mazda light.

MR. GARBER: Has there been set up any standard of screen brightness.

MR. GRIFFIN: The Projection Practice Committee, after some years of studying the problem, have submitted a recommendation to the Standards Committee As a recommended practice it has been suggested that 7 to 14 foot-lamberts b the range of screen brightness, with no film in the projector and with the shutte running. It is a matter of selecting the proper illuminant behind the film an the proper optics to obtain the best result.

MR. HARCUS: The instrument that Mr. Richardson has described is essentiall a camera with a very sensitive photographic cell mounted in focus behind th lens. The cell is wired to a calibrated meter which can be mounted in front o the projectionist.

MR. KELLOGG: About the desirability of high illumination, Mr. Harcus sai that an effort was made to make the Technicolor film to project satisfactoril with a screen illumination representing what one might expect in the averag good theater. Presumably that is a matter of not making the prints so dens that they will be too dark under those conditions. Would the same picture loo still better if projected with higher illumination?

MR. HARCUS: My personal opinion is that any good print will show to bette advantage on a brighter screen. A print that will show to good advantage o a 10-foot-candle screen will show to better advantage on a brighter screen. print made to show to best advantage on a 2-foot-candle screen would probabl be "burned up" at higher illumination.

NEW MOTION PICTURE APPARATUS

During the Conventions of the Society, symposiums on new motion picture apparatus 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 LIGHT-WEIGHT SOUND RECORDING SYSTEM*

F. L. HOPPER, E. C. MANDERFELD, AND R. R. SCOVILLE**

The trend toward mobile recording equipment has been brought about by a desire to use the equipment interchangeably for stage and location work. It is further emphasized by new sound-stage construction, sufficiently remote from the original centralized recording plant to make it uneconomical to supply such recording facilities from one point. Portable channels,[1] complete from microphone to film recorder, have been developed to fulfill these needs. Their use has demonstrated that a high degree of mobility may be had without a sacrifice in overall quality or operating ease. Experience gained with such equipment has indicated a reduction in the number of units comprising the channel, and an elimination of facilities not requisite to the general run of production recording. As a result, a light-weight channel has been designed for production recording.

The basic design requirements for the channel were formulated in conjunction with engineers of the Metro-Goldwyn-Mayer Sound Department, for whom the first channel was intended. At the same time, sufficient flexibility was allowed, so that the basic design might serve as the foundation for a simplified system for other users.

The complete system comprises two main units: the first, a stage or pick-up unit containing mixing and monitoring facilities, an amplifier with sufficient gain and carrying capacity to operate a light-valve, and a carrier type of noise-reduction unit; the second, a film-recording machine containing the modulator and motor system controls. Power for the system may be supplied from a-c operated rectifiers or from batteries. The units are interconnected by means of standard 6-conductor cables equipped with plugs and jacks. A schematic drawing showing the transmission features of the apparatus connected for operation is shown in Fig. 1. The appearance of the amplifier-noise-reduction unit is shown in Fig. 2, and the recorder in Fig. 3.

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 1, 1939.

** Electrical Research Products, Inc., Hollywood, Calif.

General Design Features.—Close coöperation with studio personnel has strongly influenced the physical design and the transmisson and operating features of the channel. The case housing the amplifier-noise-reduction unit is duralumin, adequately braced for strength and containing doors affording access to the equipment items. A chassis type of mounting is used carrying single side-mounting equipment units. Wiring is from point to point, and is confined to the terminal side of the mounting chassis. Vacuum-tubes in low-level circuits are shock-mounted. Shielding is employed between vacuum-tubes and equipment parts wherever necessary to eliminate cross-talk. Low-level transformers are magnetically shielded with permalloy to reduce pick-up due to exposure to power fields All filament and plate circuit metering is accomplished by means of a switch and meter. The meter indicates percentages, reading 100 per cent when operation i normal.

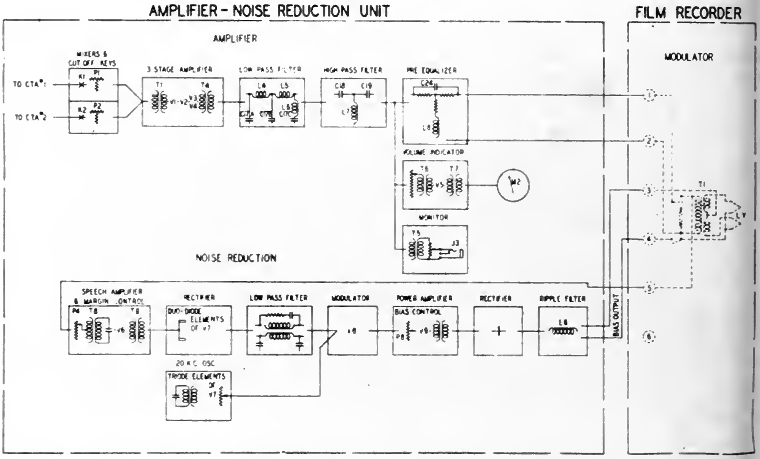

FIG. 1. Transmission features of the equipment, connected for operation.

Transmission Features.—Heater-type vacuum-tubes are employed throughout allowing operation on either a-c or d-c sources. The use of special tubes in som instances has made it possible to combine circuit functions, with resulting simplification in equipment. Tubes having extremely low noise and low microphoni outputs are used in low-level stages. All tubes are self-biased.

All grid and plate circuits are protected by filtering, minimizing disturbance resulting from coupling through a common power-supply. Further improvemen in the amplifier's stability is secured by the application of negative feedback to it circuits.[2]

The maximum gain of the amplifier system is 80 db. This is somewhat les than that of previous systems, but is adequate since the amplifier is intended t operate from single-stage condenser-transmitter amplifiers, whose output is considerably higher than that of the moving-coil microphone. The latter microphon may be used with this channel by the introduction of a single-stage amplifier b tween the microphone and the recording amplifier. The frequency-response characteristic of the amplifier is essentially uniform from 40 to 10,000 cycles. Its carrying capacity is adequate for light-valve operation.

Amplifier-Noise-Reduction Unit.—All recording facilities except the film recorder are contained in this unit. It is housed in a duralumin case 16 inches long, 9 inches wide, and 12 inches high, weighing 42 pounds. All operating controls and meters are located on the top panel which is hinged to the case. Raising the panel permits access to the panel-mounted equipment, as well as to all other equipment units mounted on the chassis beneath it. Small doors near the base at opposite ends of the case cover jack connections to the microphones and film recorder. A door in the front of the case provides access to all vacuum-tubes. The entire base is easily removed by means of four thumb-screws, and gives access to the wiring compartment. The base is gasket-sealed, preventing moisture from entering if the unit is set in damp places. Fig. 4 is a view of the case with the hinged control panel opened, exposing the chassis-mounted equipment.

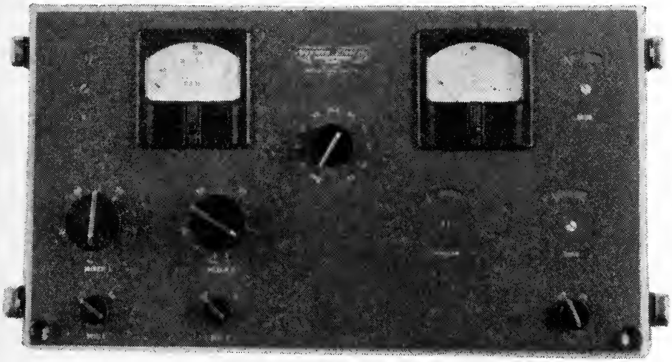

FIG. 2. The amplifier noise-reduction unit.

The operating controls on the top panel are of two types, knob and screw-driver adjusted. The former includes those used at all times; *i. e.*, the mixer potentiometers, microphone cut-off keys, and metering switch. The latter are usually adjusted only once or twice a day, and include noise-reduction margin and bias controls, monitoring volume, and volume-indicator sensitivity. Fig. 2 illustrates the control panel.

The functions and characteristics of the circuit elements indicated in Fig. 1, exclusive of the noise-reduction, are as follows:

(*Mixer*) A two-position mixer using 200-ohm step-by-step "Bridged T" type potentiometers is employed. Microphone cut-off keys having click suppressors are associated with each mixer position.

(*Main Amplifier*) The mixer is transformer-coupled to a three-stage amplifier having a push-pull output stage. Negative feedback is applied to the first two stages as well as to the output stage. The 1000-cycle gain of the amplifier is 80 db, and its frequency-response characteristic is essentially uniform from 40 to

10,000 cycles. The output impedance is nominally 500 ohms and is connected through the various equalizer and filter networks to the light-valve transformer. The amplifier's carrying-capacity using 180-volt B supply is +16 db/0.006 watt for 1 per cent total harmonics at 400 cycles. An increase in power output to meet special requirements may be easily secured by an increase in plate voltage.

(*Networks*) Various types of special networks may be supplied to meet particular recording requirements. Those contained in this unit are low and high-pass filters, and a pre-equalizer. All networks are easily removed from the circuit by strap connections, which also facilitate testing the individual networks. The low-pass filter has a nominal cut-off at 8000 cycles and contains an M-derived end-section, permitting adjustment of its peak attenuation to a frequency corresponding to the tuning frequency of the light-valve. The high-pass filter has a nominal cut-off at 50 cycles. The pre-equalizer is a constant-resistance network of the type having a 6-db insertion loss at 1000 cycles.

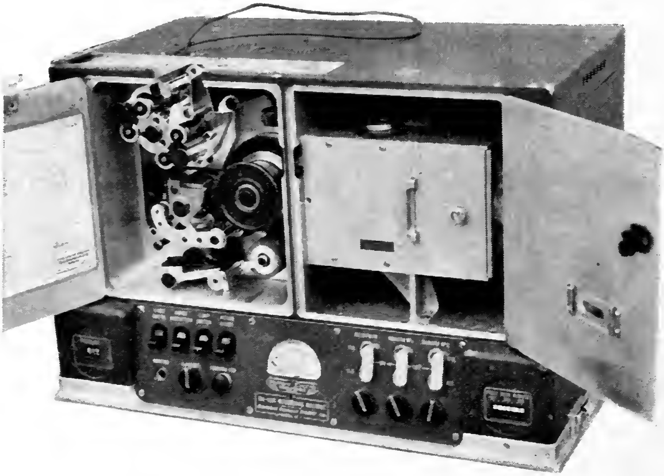

FIG. 3. The recorder.

(*Power Level Indicator*) The power level indicator is of the high-speed, critically damped type. It is supplied by a single-stage amplifier bridged across the main amplifier output following the high and low-pass filters. A sensitivity switch permits adjustment in 2-db steps from −10 db to +10 db/0.006 watt.

(*Monitoring*) Monitoring is provided by means of a bridging transformer connected across the main amplifier's output between the filter and pre-equalizer. It is intended to supply a high-quality moving-coil headset. Volume control in 2-db steps over an 18-db range is provided.

(*Metering*) A single meter in conjunction with a switch and metering shunts is used to measure vacuum-tube plate currents, plate and heater voltage, and noise-reduction bias current. The meter has a double scale, reading percentages for vacuum-tube measurements and milliamperes for bias current.

(*Power Requirements*) For normal operation the power required is 3 amperes at 6.3 volts, and 0.054 ampere at 180 volts.

Noise-Reduction.—The noise-reduction circuit is of the carrier-modulated type. Referring to Fig. 1, the output of the recording amplifier is connected through the recorder circuits to the noise-reduction input. Here the signal is connected through a gain control to a single-stage amplifier. The signal is amplified with a slightly rising frequency characteristic (about 4 db at 8500 cycles). The signal is then rectified by the diode elements of a duo-diode triode vacuum-tube, filtered, and caused to modulate a 20-kc carrier in a manner proportional to the signal envelope. The modulator stage employs a single vacuum-tube grid biased beyond cut-off, using grid voltage variation for controlling the transmission of the 20-kc signal through it. The triode elements of the duo-diode triode are used in an oscillator stage generating a frequency of about 20 kc. After subsequent amplification, rectification, and filtering, a bias current having a range of 0–400 mils in a 1-ohm load is obtained.

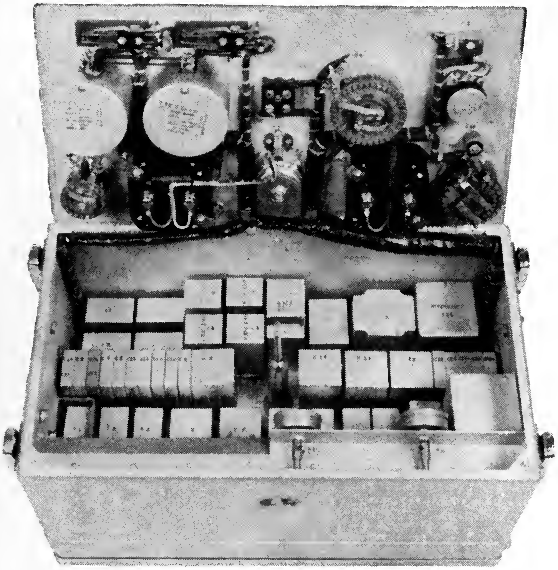

FIG. 4. View of the amplifier noise-reduction unit with the hinged control panel open.

The input required to cancel the bias current to zero is approximately −1 db relative to 0.006 watt across the 500-ohm circuit. The controls for bias current and bias cancellation are screw-driver adjusted so that once set they will not be inadvertently disturbed. The unit is set up for an operating time of 0.014 second, and a restoring time of 0.032 second.

These figures represent the time required for 90 per cent of the change to occur when a test tone is keyed on or off, respectively. This timing is suitable either for normal single-track recording or for push-pull recording. Owing to the fact that the rectifier-filter circuit is so designed that the cancellation of bias current is proportional to peak signal amplitudes rather than to average amplitudes, the margin may be reduced considerably over that used in older equipments. This in turn permits reduction of the operating time to the value shown.

Since no photocell monitor has, as yet, been supplied with this equipment, the necessary bias current may be determined by removing the light-valve from the recorder and setting it, with magnets, on a microscope jig. After connecting the light-valve terminals to the amplifier-noise-reduction unit, the closure current may be determined by direct observation of the ribbon deflection. The light-valve overload point may be observed in a similar manner when a constant frequency is impressed, or other methods may be employed, depending upon the degree of precision desired.

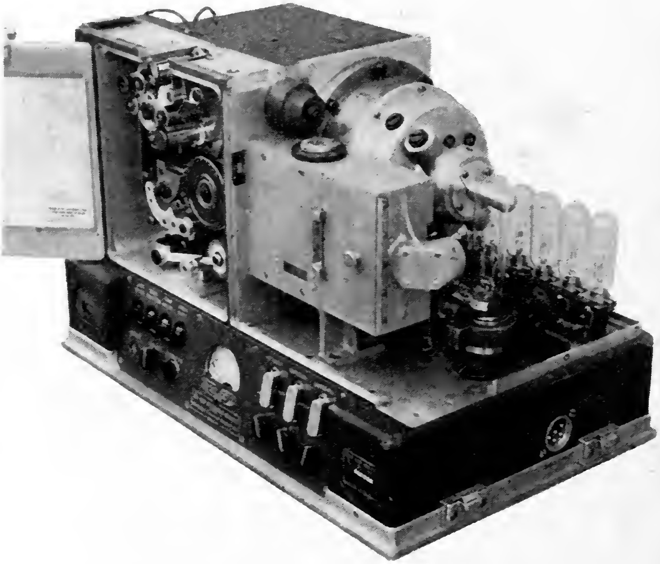

FIG. 5. The recorder, with part of the duralumin case removed.

Film Recorder.—The chief consideration in the design of the film recorder was to keep the weight at a minimum. The problem was complicated by the requirement that all the motor and modulator control switches, film-speed indicator, film-footage counter, and exciting-lamp current meter, were to be mounted as integral parts of the film recorder.

As the basic design arrangement of the film-pulling mechanism of a preceding type of recorder known as the *RA-1007-A*[1] had proved practicable as regards weight and sound-quality, it was decided to incorporate a similar film-pulling mechanism in the new type. Instead of casting the film-pulling compartment, gear-assembly housing, and base in one piece, the base was cast as a separate unit, to which the recorder case proper can be attached later. The base which serves mainly as a frame for mounting the sundry switches, meters, and other necessary equipment used in operating the recorder, can be made light in weight. The recorder case being nearly cubical in exterior dimensions—about 20 by 13 by 13 inches—allows unusual resistance against mechanical warpage, which, when present, results in poor alignment of shafts and gears. As a further aid in reducing total weight, sheet duralumin was used wherever possible. These precautions enabled the total recorder weight to be kept to 100 pounds.

Fig. 5 shows the recorder assembled and mounted on its base with the duralumin parts removed, thereby exposing the driving motor, modulator, and other associated equipment. Fig. 3 shows the same recorder, except for the film magazine, completely assembled for operation.

(*Controls*) Referring to Figs. 3 and 5, the controls incorporated in the recorder may be examined. At the extreme left is the film-footage counter. It is driven by means of a flexible shaft, the driving end being coupled to a gear assembly driven directly from the end of the driving-motor shaft. To the right of the footage counter are four electrical switches for controlling the modulator speech circuits, the exciter-lamp circuit, and an overall start and stop switch for the recorder and interlocked camera-driving motors. Below these four switches are a monitoring jack and a lamp-current rheostat knob. The meter in the center of the panel indicates the exciter-lamp current.

To the right of the lamp-current meter are three sets of motor-control switches. This type of channel is so arranged that either one or two picture camera motors can be interlocked to the recording motor. All the switches and field rheostats which operate these three motors are entirely under control of the recorder man. Thus, each set of switches, together with the rheostat control knob immediately below each set of switches, provides independent switching facilities for each motor, whereas the master start switch located immediately to the left of the lamp-current ammeter controls any motors which have been previously connected to the interlock circuit. The meter at the extreme right is a film-speed indicator of the vibrating-reed type. It is driven by a-c power derived from one of the three phases of the interlock circuit. As each motor can be independently connected to the interlock and d-c power-circuit, it is possible to use this speed-indicator to set the average speed of every motor before interlocking. Such a presetting to about proper operating speed for each motor results in a minimum of strain on the interlock circuit, allowing quick and reliable starting of the entire interlocked motor system.

Fig. 6 shows the under side of the base, exposing the miscellaneous wiring, resistances, and other components. The large vacant space below the recorder case and toward the rear is for use in housing a two-stage PEC amplifier when such a facility is desired.

(*Modulator*) The modulator, shown in Fig. 5, uses the latest type of permanent-magnet light-valve, and employs some new design features. In order to allow the use of an objective lens system covering 200 mils, as demanded by some studios for push-pull recording, a longer distance from light-valve to film was necessary in order to provide sound-quality comparable to that of the fixed-channel studio recorders. This longer optical path distance, due to minimum space requirements, necessitated bending the light from the exciter lamp through an angle of 90 degrees before passing into the condensing lens of the modulator. While no PEC monitoring facilities were required by the studio for which the recorder was designed, additional optical parts may be added to the modulator to provide this facility. A visual monitoring means is incorporated, obtained by deflecting a small amount of light from the light-valve to the lens path and focusing the light-valve ribbons by means of lenses and prisms on a rectangular ground-glass screen. This screen is shown in the lower left side of the modulator. The image of the ribbons on the screen is enlarged about two to one, allowing easy inspection of the light-valve ribbon edges at all times. This visual monitoring feature, although primarily incorporated as a substitute for PEC monitoring, need not be discarded when PEC monitoring is provided. The exciting lamp is of the 9-ampere, 11.1-volt type, in order to provide ample coverage over the entire length of the light-valve ribbons. In this film-recorder electrical power for the exciter-lamp is obtained from a generator winding which is a part of the driving motor. If desired, this feature may be omitted, and the lamp current obtained from a 12-volt power-supply. The lamp is mounted in an adjustable socket which allows simple and ample adjustment of the lamp in any position without the use of any tools.

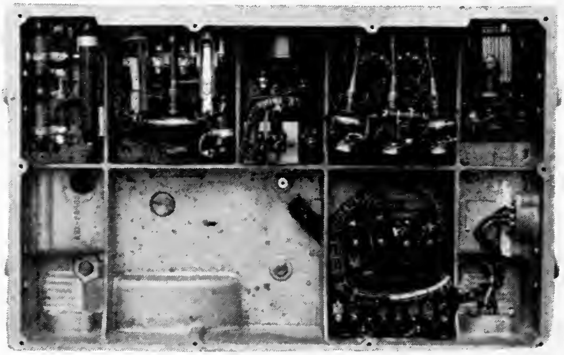

FIG. 6. Base view of the recorder.

(*Motor System*) The driving motors for this particular channel are designed to operate from a 120-volt, d-c power-supply instead of from the customary 12-volt source. This higher line voltage results in two advantages: first, the line-current being considerably reduced, line-drop troubles are eliminated at the camera motors; second, the low line-current makes it practicable to supply all the motors from a common battery power-supply located at the film recorder, and do all the switching and controlling at the recorder position.

The motor system for the channel is of the d-c interlock type; that is, the motors are essentially d-c. operated, the 3-phase interlock circuit being obtained by tapping into the d-c. commutator. In order to prevent direct short-circuits in the interlock circuit, two sets of three ballast-lamps are used between the recorder and each of the camera motors. These ballast-lamps have the characteristic of having a very low filament resistance when cold (low current flow), which rises to a fairly high value when hot (high current flow). Thus, on a direct short-circuit which ordinarily causes an excessive interlock current flow, the corresponding ballast-lamp resistance rise introduces an effective curb to limit the total current flowing in the interlock circuit. At normal interlock conditions, when the current flow is relatively low, the lamp resistance is a minimum, and therefore produces no appreciable effect in the interlock circuit.

The speed of each motor when not connected to the interlock circuit is controllable by variation of its associated field rheostat. These rheostats are all located in the base of the recorder, connecting leads running out from the recorder through the motor cables to the camera motors. The operating speed for the channel described in this paper is 2880 rpm, but other speeds such as 3600 or 1800 rpm can be obtained by a slight change in motor winding constants. If one of the latter speeds is used it is possible to interlock the channel to the standard 3-phase, 60-cycle commercial power system and thus obtain very excellent speed control whenever regulated 3-phase power is available.

The light-weight recording system which has been described has been used for considerable studio production. The results of this operating experience have shown that the system is capable of a standard of performance comparable with that of the more elaborate studio channels. The added convenience of the few equipment units emphasizes again the trend toward this type of recording system.

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[2] BLACK, H. S.: "Stabilized Feedback Amplifiers," *Bell Syst. Tech. J.*, **XIII** (Jan., 1934), p. 114.

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.

American Cinematographer

20 (July, 1939), No. 7

British Cinematographer Talks of Hollywood (pp. 303, 334) F. Young

Shoot Three Dimension Picture with Polaroid (p. 304)

Time and Temperature Versus Test for Negative (pp. 308–309) I. Millard

Dye Transfer Enters Commercial Field (pp. 310, 327)

Doolittle Builds Rewind and Film Viewer (pp. 312–314) W. Stull

Kodak Puts on Market Its Supermatic Shutter (p. 318)

20 (August, 1939), No. 8

White Border Screen? (pp. 344–345)

Debrie Building Rugged 16 Mm. Reduction Printer (pp. 348–349) R. F. Mitchell

Faster Color Film Cuts Light in Half (pp. 355–356)

Process Shots Aided by Triple Projector (pp. 363–366, 376)

British Journal of Photography

86 (June 30, 1939), No. 4130

Progress in Colour (pp. 405–506)

86 (July 28, 1939), No. 4134

Progress in Colour (pp. 467–468)

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19 (July, 1939), No. 7

Sound Motion Picture Films in Television. III (pp. 23–24)

Fernseh, A.G.

1 (July, 1939), No. 4

Zehn Jahre Fernsehtechnik (pp. 111–122) R. Möller and E. Schubert

The Ideal Kinema

7 (July 20, 1939), No. 80

Imperfections in Projector Design (pp. 29–30)	R. H. CRICKS

International Photographer

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Projection Symposium, Parts VII, VII (pp. 9–12)	J. HILLIARD

International Projectionist

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Supplementary Aids to Servicing Sound Reproducing Systems (pp. 7–10, 25–26)	L. CHADBOURNE
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Baird Theatre Television Receiver (p. 21)	M. RAYMOND, JR.
New Academy Theatre Test Reels (pp. 22–24)	

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Die Messfilmeinrichtung beim Weltrekordflung mit der He 112U der Heinkel-Werke (Installation of Time Recorder on Film on the World Record Flight of Heinkel-Werke's He 112U) (pp. 141–143)	W. BEYER
Hilfsgeräte zur sensitometrischen Ueberwachung der Filmverarbeitung (Accessories for Sensitometric Supervision of Film Manufacture) (pp. 143–146)	H. BRANDES, K. VAN BRIESSEN, AND E. FESS
Optische Systems für Ton-Abtastung (Optical System for Sound Scanning) (pp. 147–150)	E. R. LEHMANN
Artgleichung (Comparison Tables) (pp. 150–154)	R. THUN
Grundsatzliches über Belichtungsmesser (Fundamentals of Exposure Meters) (pp. 154–155)	H. ETZOLD
Zur Farbtemperatur/Kerzenstärkcharakteristik von Wolframfadenlampen (Color Temperature Candle Power Characteristic of Tungsten Lamps) (pp. 155–157)	K. S. WEAVER AND H. E. HUSSONG

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Tonaufzeichnung in Doppelzackenschrift auf 16-mm-Filme (Sound Recording on 16-Mm Films with Double Edged Variable Width Track) (pp. 167–172)	A. KÜSTER
Zur Sensitometrie der Umkehrentwicklung von Tonaufzeichnungen (On the Sensitometry of Reversal Development of Sound Records) (pp. 172–174)	R. GÖRISCH
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1939 FALL CONVENTION

SOCIETY OF MOTION PICTURE ENGINEERS

HOTEL PENNSYLVANIA, NEW YORK, N. Y.
OCTOBER 16th-19th, INCLUSIVE

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Headquarters

Headquarters.—The headquarters of the Convention will will Hotel Pennsylvania, where excellent accommodations have been assured, and a reception suite will be provided for the Ladies' Committee.

Reservations.—Early in September room reservation cards will be mailed to members of the Society. These cards should be returned as promptly as possible in order to be assured of satisfactory accommodations. The great influx of visitors to New York, because of the New York World's Fair, makes it necessary to act promptly.

Hotel Rates.—Special *per diem* rates have been guaranteed by the Hotel Pennsylvania to SMPE delegates and their guests. These rates, European plan, will be as follows:

Room for one person	$ 3.50 to $ 8.00
Room for two persons, double bed	$ 5.00 to $ 8.00
Room for two persons, twin beds	$ 6.00 to $10.00
Parlor suites: living room, bedroom, and bath for one or two persons	$12.00, $14.00, and $15.00

Parking.—Parking accommodations will be available to those who motor to the Convention at the Hotel Fire Proof Garage, at the rate of $1.25 for 24 hours, and $1.00 for 12 hours, including pick-up and delivery at the door of the Hotel.

Registration.—The registration desk will be located at the entrance of the *Banquet Room* on the ballroom floor where the technical sessions will be held. All members and guests attending the Convention are expected to register and receive their badges and identification cards required for admission to all the sessions of the Convention, as well as to the Capitol Theater, Paramount Theater, Radio City Music Hall, Roxy Theater, and Warner's Strand Theater.

Luncheon and Banquet

The usual informal get-together luncheon will be held in the Grand Ballroom of the Hotel on Monday, October 16th. The Semi-Annual Banquet and Dance will be held in the Grand Ballroom of the Hotel Pennsylvania on Wednesday, October 18th, at 8:30 P. M. At the banquet the annual presentation of the SMPE Progress Medal and the Journal Award will be made, and the officers-elect for 1940 will be introduced.

Entertainment

Motion Pictures.—At the time of registering, passes will be issued to the delegates of the Convention admitting them to the motion picture theaters named above.

Golf.—Golfing privileges at country clubs in the New York area may be arranged at the Convention headquarters. In the Lobby of the Hotel Pennsylvania will be a General Information Desk where information may be obtained regarding transportation to various points of interest.

Miscellaneous.—Many entertainment attractions are available in New York to the out-of-town visitor, information concerning which may be obtained at the General Information Desk in the Lobby of the Hotel.

Ladies' Program

A specially attractive program for the ladies attending the Convention is being arranged by Mrs. O. F. Neu, *Hostess*, and the Ladies' Committee. A suite will be provided in the Hotel where the ladies will register and meet for the various events upon their program.

New York World's Fair

Members are urged to take advantage of the opportunity of combining the Society's Convention and the New York World's Fair on a single trip. Information on special round-trip railroad rates may be obtained at local railroad ticket offices. Trains directly to the Fair may be taken from the Pennsylvania Station, opposite the Hotel: time, 10 minutes; fare, 10¢. Among the exhibits at the Fair are a great many technical features of interest to motion picture engineers.

Points of Interest

Among the points of interest to the general sightseer in New York may be listed the following:

Museum of Modern Art Film Library.—As part of the summer exhibition at the Museum of Modern Art, "Art in Our Time," the Museum Film Library is conducting "A cycle of Seventy Films" from 1895 to 1935. The Museum is open to the public daily from 10 A. M. to 6 P. M. The film showings are daily at 4 P. M. Admission to the Museum at a nominal charge; to the film showings, no charge.

Metropolitan Museum of Art.—Fifth Ave. at 82nd St.; open 10 A. M. to 5 P. M. One of the finest museums in the world, embracing practically all the arts.

New York Museum of Science and Industry.—RCA Building, Rockefeller Center; 10 A. M. to 5 P. M. Exhibits illustrate the development of basic industries, arranged in divisions under the headings food, industries, clothing, transportation, communications, *etc.*

Hayden Planetarium.—Central Park West at 77th St. Performances at 11 A. M., 2 P. M., 3 P. M., 4 P. M., 8 P. M., and 9 P. M. Each presentation lasts about 45 minutes and is accompanied by a lecture on astronomy.

Rockefeller Center.—49th to 51st Sts., between 5th and 6th Aves. A group of buildings including Radio City Music Hall, the Center Theater, the RCA Building, and the headquarters of the National Broadcasting Company, in addition to other interesting general and architectural features.

Empire State Building.—The tallest building in the world, 102 stories or 1250 feet high. Fifth Ave. at 34th St. A visit to the tower at the top of the building affords a magnificent view of the entire metropolitan area.

Greenwich Village.—New York's Bohemia; a study in contrasts. Here are located artists and artisans, some of the finest homes and apartments, and some of the poorest tenements.

Foreign Districts.—Certain sections of the city are inhabited by large groups of foreign-born peoples. There is the Spanish section, north of Central Park; the Italian district near Greenwich Village; Harlem, practically a city in itself, numbering 300,000 negroes; Chinatown, in downtown Manhattan; the Ghetto, the Jewish district; and several other such sections.

Miscellaneous.—Many other points of interest might be cited, but space permits only mentioning their names. Directions for visiting these places may be obtained at the Convention registration desk: Pennsylvania Station, Madison Square, Union Square, City Hall, Aquarium and Bowling Green, Battery Park, Washington Square, Riverside Drive, Park Avenue, Fifth Avenue shopping district, Grand Central Station, Bronx Zoo, St. Patrick's Cathedral, St. Paul's Chapel, Cathedral of St. John the Divine, Trinity Church, Little Church Around the Corner, Wall St. and the financial district, Museum of Natural History, Columbia University, New York University, George Washington Bridge, Brooklyn Bridge, Triborough Bridge, Statue of Liberty, American Museum of Natural History, Central Park, Metropolitan Museum of Art, and Holland Tunnel.

ABSTRACTS OF PAPERS OF THE FALL CONVENTION AT NEW YORK, N. Y.

OCTOBER 16-19, 1939

The Papers Committee submits for the consideration of the membership the following abstracts of papers to be presented at the Fall Convention. It is hoped that the publication of these abstracts will encourage attendance at the meeting and facilitate discussion. The papers presented at Conventions constitute the bulk of the material published in the Journal. The abstracts may therefore be used as convenient reference until the papers are published.

J. I. Crabtree, *Editorial Vice-President*
S. Harris, *Chairman, Papers Committee*
L. A. Aicholtz, *Chairman, West Coast Papers Committee*

P. Arnold
C. N. Batsel
L. N. Busch
O. O. Ceccarini
G. A. Chambers
A. A. Cook
L. J. J. Didiee
C. Flannagan
L. D. Grignon
E. W. Kellogg
G. E. Matthews
R. F. Mitchell
W. A. Mueller
F. A. Richardson
P. R. von Schrott
W. H. Robinson
C. R. Sawyer
H. G. Tasker
R. Townsend
I. D. Wratten
C. K. Wilson

Photographic Duping of Variable-Area Sound; F. W. Roberts and E. Taenzer, *Ace Film Laboratories,* Brooklyn, N. Y.

In release print laboratories it is necessary to have some method of quickly making duplicate sound negatives which are used to replace damaged original negative sections. New negative may, of course, be re-recorded from a release print, but inasmuch as recording equipment is not always available, a suitable photographic process had to be developed. For this process, the following criteria were set up:

The quality of sound from the dupe negative should be high, so that a trained observer would have difficulty in telling where a dupe had been inserted. All developing should be done in the regular release print positive bath at standard developing time. Inasmuch as this bath is in constant use, no special machine need be started to develop a dupe. The dupe negative must have the same optimum print density as the original negative, and the same fog value in order that the inserted dupe may be printed on the same printer light as the original.

The method that was developed operates as follows: Master positives of every reel of a release and the accompanying cross-modulation tests are first printed on high-contrast title stock. A density of 2.20 is used, a family of cross-modulation curves having indicated this value as best. The reels of master positive are stored, but the cross-modulation test positives are detached and printed on regular positive stock to make dupe negative cross-modulation tests. The test from reel *1A* is printed at three negative densities, and the tests from the remaining reels are printed to a density of about 1.80. Cross-modulation prints at several densities are then made from each of the dupe negative cross-modulation tests, and from these prints the optimum print density for each dupe negative test is determined. Reel *1A* gives a three-point slope curve of negative density *vs.* print optimum density.

The print optima of the dupe negative tests are now compared with the print optima of the original negative tests (these data being on file). If the dupe values are different from those of the original, the slope curve of *1A* is used to find the negative density that will yield a print density the same as that of the original, and these values of corrected negative densities are kept on file for use when it becomes necessary to make a dupe from the stored master positive.

The paper includes a complete cross-modulation treatment of the subject and a demonstration.

A Sound-Track Center-Line Measuring Device; F. W. Roberts and H. R. Cook, Jr., *Ace Film Laboratories*, Brooklyn, N. Y.

The types of instruments now in use for measuring the position of sound-tracks on film are not completely suited to the use of a release print laboratory. Microscopes using micrometer stages or oculars are slow in operation because they require mental arithmetic to arrive at the distance from the film edge to the sound-track center-line. Projection types are slow in threading; and require a darkened room. The release print laboratory requires a small quick-threading device which gives a direct reading of sound-track position.

A device that fulfills these requirements has been built, and consists of a curved film-gate in which the film is held against a guiding edge by means of a spring parallel. This gate is mounted in *V*-slides which permit motion in a direction perpendicular to the length of the film. Motion is provided by a hand-lever-operated cam, and the position of the gate is measured by a one-ten-thousandth dial indicator.

The gate has in it a hole directly under the sound-track, and beneath is mounted a small incandescent lamp. Directly above the gate is an optical system consisting of a standard 32-mm microscope objective and a 10-power Huygen's eyepiece The normal cross-hairs of the eyepiece have been replaced with a parallel hair device consisting of two very fine hairs whose mounts slide in *V*-ways perpendicular to the direction of the film. Both hairs operate together and are operated by a common cam and lever which cause them to move; and as they separate or close, they always remain parallel to each other and equidistant from the optical center of the instrument.

The operation is as follows: With film in the gate the operator places a hand on each of the two levers, which are moved simultaneously until the two cross-hairs are directly over the bias lines or over corresponding peaks of modulated variable-area track. The one-ten-thousandth dial indicator then indicates the track center-line position to the nearest ten-thousandth of an inch. With the instrument, a film may be inserted and a reading taken in ten seconds.

Volume Distortion; S. L. Reiches, Cleveland, Ohio.

The contention that a linear recording and reproducing system represents the ideal, and that sound handled by such a system will be exactly represented, is not borne out by experience. Systems have been built which meet this requirement within limits that are not detectable by the ear and yet these systems do not reproduce sound as it actually is produced. In many cases a definite non-linear response curve is provided to compensate for some factor that is not covered by the above contention. It is the author's thesis that this discrepancy is due to the ear sensitivity to frequencies as a function of loudness.

Using the ear sensitivity curves presented by Fletcher and Munson of the Bell Telephone Laboratories (which have been verified by other observers) it is shown how the ear introduces frequency distortion to a linear system when the sound is reproduced at a level other than the level at which it is produced. It is shown how a sound reproduced above the incident sound level introduces excessive low frequencies. The case for a sound reproduced at a lower level is also examined and the conclusion is drawn that this case accentuates the high frequencies.

It is further shown that the possibility of correcting for the limited volume range of all sound systems may lie in the type of amplifier response curve.

A description is given of three methods used to achieve the desired amplifier characteristics: (*1*) a mechanical method, (*2*) a linear-non-linear system, and (*3*) a selective by-pass system. Circuits are given and the important operating points of each are discussed. The objections to each system are also given.

Further, a brief summary, with diagrams, describes the various set-ups used to record with these amplifiers. This covers work for radio, disk record, and sound-film.

Television Control Equipment for Film Transmission; R. L. Campbell, *Allen B. DuMont Laboratories,* Passaic, N. J.

A television film chain with particular reference to amplifier, sweep, and power circuits in the film pick-up unit is described.

Many improvements in television circuits have been made possible by recent advances in circuits and circuit components in radio and allied electronic fields. Application of some of the newer ideas to motion picture film pick-up equipment has resulted in improved performance and simplicity of operation.

Circuit arrangements which permit flexibility in transmission standards are considered and their application discussed. Also the anticipation of possible future improvements in picture quality is indicated in some circuit capabilities.

Simplification of controls from the television projectionist's standpoint is discussed.

The Production of a Three-Dimensional Motion Picture; J. A. Norling, *Loucks and Norling,* New York, N. Y.

Some problems involved in the production of satisfactory three-dimensional motion pictures have not received much mention in the literature dealing with stereoscopy. Their practical solution has contributed marked improvements to the three-dimensional picture of today.

The fundamental problem in projecting three-dimensional pictures is that of providing a "right-eye" picture that will reach only the right eye and be prevented from reaching the left eye, and to do the same for the "left-eye" picture. To attain this result two methods have been employed with success, namely: the "anaglyph" in which substantially complementary colors are employed in the viewing devices, and polarized light.

The screen surface upon which three-dimensional pictures are projected by polarization methods is of extreme importance. The selection of the proper type of screen raises real problems but these also have been overcome in a practical way.

Considerations Relating to Warbled Frequency Films; E. S. Seeley, *Altec Service Corp.*, New York, N. Y.

Some warbled frequency films, intended as signal sources for acoustical response measurements, appear to have been made and used without full realization of the true nature of the warbled signal and the manner in which such a signal is affected by a non-linear transmission system. It is pointed out that the warbled signal is a frequency-modulated signal; hence the signal may be represented by a carrier frequency and a series of side-frequencies, all of which are steady and discrete. It is pointed out, and substantiated experimentally, that the signal must be regarded in this light when considering the effect on it of a non-linear transmission system. The frequency structure of one "warble film" in use is calculated and shown graphically. Fundamental requirements for a suitable warbled frequency film having sinusoidal modulation are discussed and values for modulation rate and for modulation depth are recommended. The side-frequency array provided by the recommended modulation constants is shown in graph form. Expressions are derived giving the frequency relationship and relative amplitudes of the side-frequencies resulting from the non-sinusoidal frequency modulation which contains two components of modulation rate, one component having an associated phase constant. The side-frequency structures corresponding to some assumed combinations of two rates are calculated and illustrated. Certain assumptions are made for distortion or departure from sinusoid of a modulating frequency and the effects on the side-frequency structure are shown. From the latter calculation recommendations are derived for tolerances of departure from sinusoidal modulation for a warbled frequency film.

A Transmission System of Narrow Band-Width for Animated Line Images; A. M. Skellett, *Bell Telephone Laboratories*, New York, N. Y.

A new method of transmission and reproduction of line images, *e. g.*, drawings, is described which utilizes a cathode-ray tube for reproduction, the spot of which is made to trace out the lines of the image twenty or more times a second. The steps of the complete process are: (*1*) the transcription of the line image into two tracks similar to sound-tracks on motion picture film; (*2*) the production from these tracks of two varying potentials by means of photoelectric pick-up devices; (*3*) the transmission of these potentials; and (*4*) their application to the cathode-ray deflector plates to effect reproduction. Satisfactory transmission of fairly complex images, *e. g.*, animated cartoons, could be effected within a total band width of 10,000 cycles.

Science and the Motion Picture; H. Roger, *Rolab Photo-Service Laboratories*, Sandy Hook, Conn.

The motion picture is a product of science. There is ample historical material available for those who wish to convince themselves of this fact, but a brief review is given of the work of Muybridge and Marey in order to clarify the cause of their inventions. The ensuing discussion centers around the question, "Has science maintained its interest in the motion picture and has it utilized its advantages to its full extent?"

In this paper the word "science" is taken broadly and includes research, dissemination of knowledge, and industrial application. Motion picture's application to science is divided into two distinct categories and are discussed in detail:

(*1*) The motion picture as an aid to scientific research;

(*2*) The motion picture as a medium for the dissemination of knowledge.

The paper concludes with descriptions and demonstrations of interesting material from the files of the Rolab Photo-Science Laboratories. Also an inside view is given of production activities of an unusual character.

The Problem of Distortion in the Human Ear; S. S. Stevens, *Harvard University*, Cambridge, Mass.

The amount of distortion produced by the ear upon a simple sound-wave has been measured by analyzing the electrical output of the ears of animals and by indirect experiments with human ears. The amount of distortion in a sound-wave which the human ear is just able to detect has also been determined, and it is found that the threshold of audible distortion is intimately related to the amount of distortion occurring in the ear itself. Hence the transmission characteristics of the ear determine the tolerances for distortion in sound reproduction.

Report of the Standards Committee; E. K. Carver, *Chairman.*

Proposals have been received from the ISA Secretariat for International Standardization of raw-film cores; 16-mm sound-film; projection reels; projection reel boxes; 8-mm film dimensions; and definition and marking of safety film.

Most of these proposals differ from the SMPE standards only in tolerance. Some of the tolerances appear to be unimportant and some important. The European practice for projection reels differs so widely from the American practice that it is deemed impossible to come to an international agreement. Standardization of 16-mm projection reel boxes appears to be outside the range of useful standardization.

The international standard definition of safety film has been cleared up in all points except the question of nitrogen content.

The question of sound-track dimensions for 35-mm and 16-mm film was clarified, to a considerable extent, at the Hollywood meeting of the Committee but no definite conclusions have yet been reached.

No satisfactory standard for 16-mm sound-film sprockets has yet been attained.

The publication of the Academy standard 2000-ft release print has been delayed pending further questions by the Academy.

Some Industrial Applications of Current 16-Mm Sound Motion Picture Equipment; W. H. Offenhauser, Jr., and F. H. Hargrove, *The Berndt-Maurer Corp.*, New York, N. Y.

Sixteen-mm sound motion pictures are potentially one of the most effective means through which industry can develop a broad, cost-cutting communication system within the organization itself.

Many latent applications for internal films exist; the cases in business where the improved transfer of ideas afforded by films can be most profitable are almost unlimited. Several specific instances are cited.

Sixteen-mm equipment is simple, easy to operate, reliable, and economical. With it, a member of the industrial organization who knows his company's products, policies, and structure can readily produce films that are, in every respect, profitable internal communications media.

Future Development in the Field of the Projectionist; A. N. GOLDSMITH, New York, N. Y.

The highly diversified activities required for the production of a motion picture find their effective culmination in the work of the theater projectionist. The unusually concentrated value embodied in the reels of film corresponding to a feature picture can be brought to the theater audience and made the basis for commercial returns only through the activities of the projectionist.

Nevertheless the public is little aware of what goes on in the projection room.

The projectionist is in part compensated by the likely stability of his activities. His present position in the theater is important. Future developments in the motion picture field, such as three-dimensional sound, wider use of color, and the like, will make his work even more important. The possible inclusion of television projection in theater programs will require his mastery of the new field which is sufficiently similar to his present activities in its broad outline to enable its handling by the theater projectionist.

The Projectionist's Part in Maintenance and Servicing; J. R. Prater, *Congress Theater*, Palouse, Wash.

It is the duty of the projectionist to see that all projection equipment is kept in condition to give excellent service dependably and efficiently. It is impossible to accomplish these results by depending upon memory alone. The projectionist must establish and keep written records of all necessary maintenance data. He must follow a written schedule in making inspections and in doing maintenance work. He must establish a reliable system for checking and ordering supplies and spare parts at regular intervals.

The projectionist should do as much of actual service work as his knowledge, ability, tools, and available test equipment will permit. At least nine-tenths of trouble shooting should be done before any trouble exists. He should obtain detailed drawings of internal and installation wiring of all electrical equipment, besides identifying the points at which tests may be made. He should prepare a written outline of all tests that could be made if various troubles existed. Then he should actually make all possible tests in advance, wherever possible, without causing damage, by deliberately creating the trouble and then correcting it. He should immediately record the exact results of each test in the written outline. In this way, simple tests may serve as well as or better than elaborate ones.

The professional service engineer with special test equipment is a necessity to the finer and more difficult parts of modern servicing, but the projectionist who makes the best of what resources he has can also do a very valuable part of the job.

Suggestions for Encouraging Study by Projectionists; F. H. Richardson, *Motion Picture Herald,* New York, N. Y.

This paper stresses the great importance of expert work in theater projection rooms and points out that pride in performance is essential to high excellence. If the status of projection were elevated to a higher plane there would be as a result improved excellence in results both on screen and through loud speakers. It offers a suggestion concerning the contacts of the Society with the projectionists' organizations.

The Production of 16-Mm Sound Pictures for Promoting Safety in the Mineral Industries; M. J. Ankeny, *Bureau of Mines, U. S. Department of the Interior,* Pittsburgh, Pa.

The paper deals chiefly with experience in developing 16-mm direct sound recording technic in producing safety educational films. Attention is called to the fact that direct 16-mm recording and photography have a great potential usefulness in the field of education, not as a competitor of 35-mm, but as a means of extending the use of sound motion pictures into fields that 35-mm is unable to serve.

Some of the difficulties encountered in underground motion picture photography and how these difficulties were met are described; also the types of film used and the various printing methods that have been employed in order to arrive at a most satisfactory procedure.

The method employed in recording sound directly on 16-mm film, in which the double-system variable-area is used, is described in some detail.

Artificial Reverberation for Motion Picture Studios; P. C. Goldmark and P. S. Hendricks, *Columbia Broadcasting System,* New York, N. Y.

An electroöptical method of producing reverberation synthetically will be described and the latest model of the equipment will be demonstrated. The method employed consists basically of recording the original program on the rim of a phosphor-coated disk by means of a modulated light-source and then picking up the continuously decaying sound images after a predetermined time interval by means of photocells.

The exponential decay curve of the phosphorescent substance will produce an infinite number of secondary sound impulses to which any desired decay characteristic can be applied. This reverberation signal is then mixed with the original program in the proportion required.

This new reverberation device has been successfully employed in radio broadcasting and can be used in phonograph as well as in motion picture sound recording, where the scenic effect or script requires a type of sound which, due to the deadness of the sound stage, might not readily be available.

This synthetic reverberation device would replace the use of so-called echo chambers, at the same time introducing an appreciable amount of flexibility without degrading the quality of the original sound.

Delivering Laboratory Results to Theater Patrons; J. R. Prater, *Congress Theater*, Palouse, Wash.

A discussion emphasizing the importance of actually delivering the benefits of laboratory research and developments to the theater patrons who furnish the financial support for practically the entire motion picture industry.

Accomplishments in photography, sound recording, projection, and sound reproduction are discussed briefly. Examples are given of various ways in which theater screen results may suffer regardless of the excellence of films and equipment.

It is pointed out that whatever can be done to increase the projectionist's technical knowledge, ability, and pride in good workmanship will ultimately benefit the entire industry. To this end, it is suggested that if possible, information from the JOURNAL of the Society of Motion Picture Engineers be made easily available to projectionists.

A New Non-Intermittent Motion Picture Projector; F. Ehrenhaft and F. G. Back, New York, N. Y.

The authors have designed a projector wherein the optical compensation is effected by means of a rotating glass prism. The problem was originally attacked from the viewpoint that by eliminating the errors inherent in the rotating glass prism, a projector could be designed that would be both simple and practicable. The dimensions of the rotating glass prism and its optical placement result from basic optical laws, and the arrangement depends upon the size of the image and on the materials. Errors inherent in the rotating glass prism are (*1*) Nonlinear displacement on the screen causing a lack of definition: (*a*) errors of the center rays, (*b*) errors of the corner rays, (*c*) errors caused by shrinking of the film; (*2*) Chromatical errors; (*3*) Spherical errors: (*a*) caused by the size of the prism, (*b*) caused by the deviation of light in glass; (*4*) Astigmatism caused by the movement of the prism; (*5*) Side images (projection of more than one frame on the screen); (*6*) Limited focus; (*7*) Defects by reflection.

Elimination of these errors was achieved by: (*1*) (*a*) Limitation of the effective rotation angle, (*b*) use of a curved gate, (*c*) establishing the tolerable limits of film shrinkage; (*2*) Calculating size and displacement of the colors at the extreme position of the prism; (*3*) (*a*) Use of special lenses or additional lenses corrected for glass instead of for air, (*b*) compensation by a curved gate; (4) Slip-shaped diaphragms; (*5*) Use of diverse diaphragms; (*6*) Use of special lenses or additional lenses; (*7*) Diaphragms for the condenser and screening off the edges of the rotating prism. Relation between amount of light on the screen, absence of flicker, and arrangement of condenser and lamp-filament.

These factors will be treated by means of illustrations and diagrams. A working model will be shown and test-films projected to illustrate what has been accomplished up to now.

A Flexible Time-Lapse Outfit; W. W. Eaton, *Eastman Kodak Company*, Rochester, N. Y.

An apparatus is described which has been designed to enable single movie frames to be made automatically at intervals conveniently adjustable over a wide range. It is known as the Electric Time-Lapse Outfit, and is designed primarily for the Cine-Kodak Special. It consists of an electromagnet which mounts on the camera and interacts with the one-frame shaft, and suitably housed condenser-resistance circuits which supply impulses to the electromagnet and cause pictures to be taken. By expanding basic times through an interval multiplier, pictures may be made automatically at intervals throughout a range of $^1/_4$ second to 24 hours. The exposure time is completely independent of the time between pictures and may be set throughout a range of $^1/_{100}$ second to 6 seconds. In addition, where artificial illumination is required, a lamp control is provided which automatically turns the lights on and off for each exposure, regardless of the time between pictures. The whole outfit operates on self-contained batteries, and is entirely portable.

Automatic Slide Projectors for the New York World's Fair; Fordyce E. Tuttle, *Development Dept., Eastman Kodak Co.,* Rochester, N. Y.

Special slide-changing projectors were designed and built for the Kodachrome exhibit in the Eastman building at the New York World's Fair. The individual screen images are seventeen feet wide and twenty-two feet high. Eleven machines are synchronized so that panoramic scenes one hundred and eighty-seven feet long may be shown. Indexing of the slides is controlled by notches in a sound-film so that the entire program is automatic.

The slides in each machine are arranged in two rows, and each machine has two gates and two complete optical systems. All the slides in one row are rigidly bolted to a ring-gear forty-eight inches in diameter. For each new picture the ring-gear is spring-indexed into a new position. While one gear is being moved the other is stationary, and the picture being projected is in the stationary row. An optical compensator geared to the ring-gear corrects for any inaccuracies in indexing, and the image is optically "dowelled" on the screen. The accuracy of registration is such that one slide may be substituted for another without movement on the screen.

The light-source used is a 2500-watt, high color-temperature tungsten lamp. Water-cells and refrigerated air are used to cool the film in the gates. The shutter system is located between the lamp and the gate in order to minimize the heat at the gate. Shutters in the two beams are interlocked in such a way that while they are being moved the light to the screen is constant. The cross-dissolve may be rapid or slow depending on the type of transition desired.

Slide projectors similar in structure are also being used in the Perisphere Building. There the slides are projected in rapid enough succession to show motion.

Motion Picture Theater Auditorium Lighting; B. Schlanger, New York, N. Y

The various functions of motion picture theater auditorium lighting are discussed. Particular analysis is made of the lighting which is used during the period in which the motion picture is projected. Past and present lighing practices in this respect are explained. The advantages and disadvantages of these practices, and a new type of lighting are discussed. It is proposed that the illumination levels of the interior surface of the auditorium be at greater levels than have been heretofore found to exist. A definite relationship between the screen brightness and that of the auditorium surfaces is indicated as desirable. Recent tendencies toward higher screen brightnesses have made a very low intensity lighting in the auditorium much more undesirable, and therefore have made it more important to arrive at a new solution for motion theater auditorium lighting. The realism of the projected picture can be considerably heightened by proper surface illumination. Controlled reflected light coming from the screen and re-reflected from the interior surfaces is discussed as a medium for lighting.

Lenses for Amateur Motion Picture Equipment (16-Mm and 8-Mm); R. Kingslake, *Eastman Kodak Company*, Rochester, N. Y.

In all motion picture photography and projection, lenses of high relative aperture must be used. However, on account of the small size of the amateur frame, the focal length is short, and the linear aperture of the lens is therefore small, resulting in considerable depth of field. Thus in cine work, great lens speed is not automatically associated with small depth, as is the case in ordinary photography.

Moreover, as the entire motion picture frame must be seen by the eye at a glance, the angular field covered must be much smaller than in still pictures which may be examined critically and deliberately. This fact is of the greatest assistance to the lens designer because high aperture and field are inevitably somewhat incompatible, and types of lens construction which favor aperture generally cover a relatively small field.

Perspective considerations usually require a projection lens covering only about half the angular field covered by the taking lens, which fact enables projection lenses of very high relative aperture to be made. Some of the types of construction commonly used in amateur cine lenses are described, including an account of the Kodak line of 16-mm and 8-mm lenses.

Tape Splicers for Film Developing Machines; J. G. Capstaff and J. S. Beggs, *Eastman Kodak Co.*, Rochester, N. Y.

The splicers described make a strong, waterproof tape splice for sprocketless developing machines, and have proved very successful. The ends of the films to be spliced are placed one at a time in a punch and die, where three holes are punched on the centerline of the films, the ends of which are then trimmed. The two holes away from the ends are placed over two pairs of pegs, which are in a straight line and spaced so that the abutting ends of the film are separated by $^1/_{16}$ of an inch. A piece of 1-inch wide waterproof adhesive tape, previously placed adhesive-side up and symmetrically under this space, is now wrapped around the film. The tape sticks to itself through the two holes near the ends of the film, thus preventing the tape from loosening when the emulsion swells. The splice is quite thin, and there is nothing about it to catch in the machine or blow-off. It is also very dependable and will not mar film in taking up or make the roll out of round.

An Investigation of the Ground-Noise of Photographic Sound Prints; O. Sandvik and W. K. Grimwood, *Eastman Kodak Co.*, Rochester, N. Y.

This paper deals with the effect of the negative sound-track on the ground-noise of the print. Data are presented showing the influence of negative density and negative gamma on print ground-noise for fine, medium, and coarse-grain negative emulsions.

The Backward Perspective—a Résumé of Three Years of Progress in the Film Library of the Museum of Modern Art; Douglas L. Baxter, *Museum of Modern Art Film Library,* New York, N. Y.

In 1936 a paper was read before the Society outlining the organization and aims of the Museum of Modern Art Film Library, then in its first year of existence.

The present paper deals with the activities of the Film Library during the intervening three years, giving a brief résumé of its growth in the local, national, and international fields, and tracing its development from the position of an unrecognized institution with rather limited headquarters to one where the opening of its permanent headquarters in its own $2,000,000 building was considered of sufficient national importance for the President of the United States to make it the occasion of a nation-wide broadcast.

In international circles the importance of the Film Library has won such recognition that in response to its invitations representatives of twelve foreign nations as well as representatives of the Library of Congress and the Division of Cultural Relations of the State Department attended the first annual Congress of the International Federation of Film Archives held in New York in July, 1939.

The present activities and future plans of the Film Library are explained. The paper is amplified by the showing of *The Movies March On,* a recent issue of the "March of Time," devoted to the work of the Museum of Modern Art Film Library.

Statement of the Ownership, Management, Circulation, *Etc.*, Required by the Acts of Congress of August 24, 1912, and March 3, 1933, of *Journal of the Society of Motion Picture Engineers*, published monthly at Easton, Pa., for October 1, 1939.

State of New York }
County of New York } ss.

Before me, a Notary Public in and for the State and County aforesaid, personally appeared Sylvan Harris, who, having been duly sworn according to law, deposes and says that he is the Editor of the *Journal of the Society of Motion Picture Engineers* and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), *etc.*, of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, as amended by the Act of March 3, 1933, embodied in section 537, Postal Laws and Regulations, printed on the reverse of this form, to wit:

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5. That the average number of copies of each issue of this publication sold or distributed, through the mails or otherwise, to paid subscribers during the six months preceding the date shown above is: (This information is required from daily publications only).

SYLVAN HARRIS, Editor, Business-Manager.

Sworn to and subscribed before me this 19th day of September, 1939.

(Seal) Wm. J. Miller.
Notary Public, Clerk's No. 180, New York County. Reg. No. OM 104

(My commission expires March 30, 1940)

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OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

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A DIRECT POSITIVE SYSTEM OF SOUND RECORDING*

G. L. DIMMICK AND A. C. BLANEY**

Summary.—*One of the fundamental advantages of the variable-area system is that the original negative may be reproduced directly without appreciable wave-shape distortion. One printer operation can be eliminated and the film noise considerably reduced by originally recording a track in which the transparent area diminishes as the recorded level is decreased. A direct positive recording system has been so designed that the recording and noise-reduction light-beams are separated in the direction of the film motion. This allows the noise-reduction system completely to anticipate a coming signal, thereby eliminating clipping. When the sound volume is less than is required to fill the track, the noise from the direct recording is reduced further by additionally exposing those portions of the track not needed for the sound-waves. A single shutter vane automatically controls both the transparent area and the additionally exposed area.*

A model of the direct positive optical system has been on test in Hollywood for several months. The exposure has proved to be less critical than on the negative-print process. Densities from 0.80 to 1.60 produced only minor quality differences. A good print of a negative compares favorably in quality with a direct positive record, but because of the variations always present in the printing operation, it is believed that a higher average of quality can be maintained from the direct record.

One of the fundamental advantages of the variable-area system is that the original negative may be reproduced directly without appreciable wave-shape distortion. Although this advantage has been recognized from the start, no use could be made of it as long as all or part of the final release film was printed from the original recorded negative.

The present practice, which has been almost universally followed by the motion picture industry, is to record a negative, print this to a master positive, re-record from the positive to a final negative, and print to a release positive. This involves two printer operations with the attendant problems of printer contact, slippage and noise. One of the printer operations can be eliminated and the film noise considerably reduced by originally recording a track in which the trans-

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 14, 1939.

** RCA Manufacturing Co., Camden, N. J., and Hollywood, Calif.

parent area diminishes as the recorded level is decreased. The final negative can then be re-recorded from this direct positive.

The exposed areas of a direct recording are opaque and therefore relatively free from noise, whereas the exposed areas of a print have a large number of minute transparent or partially transparent holes which result from opaque particles and abrasions nearly always present in the clear areas of a developed negative. When the sound volume is less than is required to fill the track, the noise from the direct recording is decreased still further by additionally exposing those portions of the track not needed for the recorded waves. The width of the additionally exposed portion is automatically controlled by the same shutter and noise-reduction amplifier which control the transparent area of the track. The density of the recorded waves is usually held to about 1.4 in order to prevent excessive spreading of the image and the loss of high frequencies. The additionally exposed areas are given a density of about 2.2.

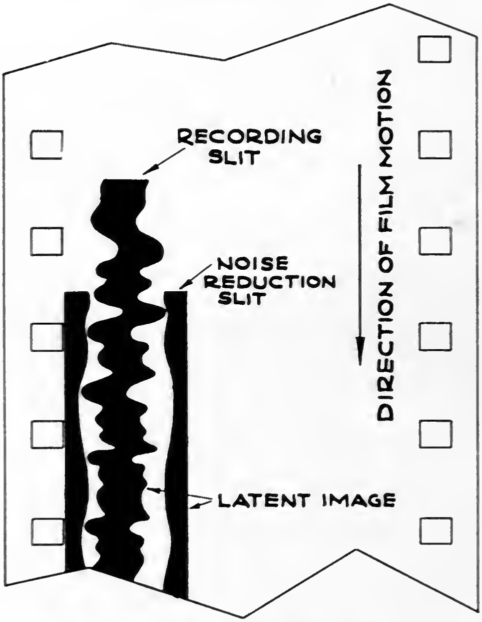


FIG. 1. The sound-waves and corresponding noise-reduction waves are recorded simultaneously but may be separated any distance in the direction of film motion.

The width of a standard variable-area sound-track is 76 mils and the reproducing slit length is 84 mils. The present practice in printing is to blacken a strip on both sides of the sound-track so that the beam will not hang over into clear film. In making an original recording for direct reproduction, the recording light beam must be longer than 84 mils for the same reason. A total track width of 100 mils provides enough tolerance to take care of track misplacement and film weave. It is desirable, of course, to expose the portions outside the normal track width to a high density.

With the exception of the class *B* system, all the noise-reduction systems in commercial use at the present time are limited in their effectiveness by virtue of the fact that both the sound waves and the noise-reduction waves are recorded at the same instant and at the same point along the film. This makes it necessary to clip the first few waves of a rapidly increasing train of waves such as occurs at the start of a word or a musical sound. The reduction of noise from the print is accomplished by subtracting from either the intensity or the length of the recording light-beam. Obviously, the subtracting process can be applied only at the light-beam. Schemes have been proposed for causing an acoustical or electrical delay of the sound-waves so that the noise-reduction system might anticipate the coming signal, but so far, practical difficulties have prevented their use.

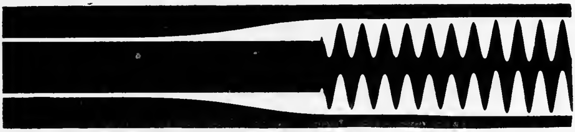
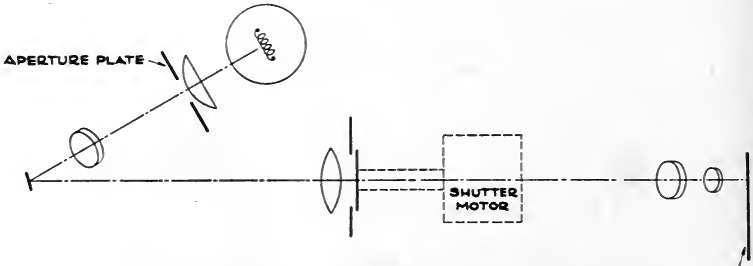


FIG. 2. Enlargement of sound-track.

The direct positive recording system offers a simple and effective method of obtaining anticipation and complete freedom from clipping. In this system, noise-reduction is accomplished by auxiliary light-beams which darken those portions of the track not needed for modulation. Since this is an additive process, the noise-reduction light-beams may be separated any desired distance from the recording beam in the direction of the film motion. The sound-waves and the corresponding noise-reduction waves are recorded simultaneously in time, but anticipation in space results from the separation. Fig. 1 shows the order in which the two waves are recorded. The dark area represents the latent image and the clear area represents unexposed film. The sound-track enlargement in Fig. 2 shows the action of the noise-reduction system when a 1000-cycle signal is suddenly applied and indicates the point at which the shutter vane started to move. The displacement of the vane was completed at the point where the recording of the sine wave began, so that no clipping occurred. The sudden application of a full amplitude signal is a very severe test of clipping, and a system designed to meet this condition should be capable of handling all sounds occurring in nature.



FIG·3

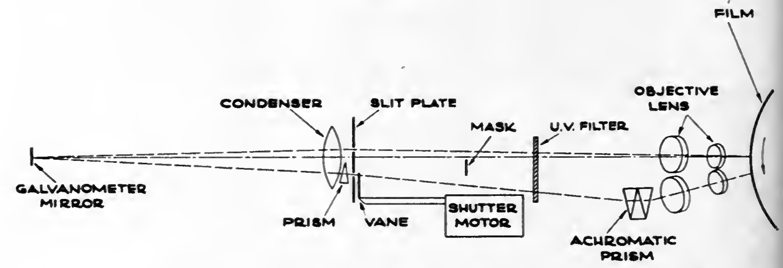


FIG. 3 (*Top*). Layout of recording optics.
FIG. 4 (*Bottom*). Vertical section through axis of galvanometer mirror and objective lenses.

Fig. 3 shows a layout of the recording optics and Fig. 4 is a vertical section taken through the axis containing the galvanometer mirror and objective lenses. In addition to the usual recording slit, a noise-reduction slit is placed behind the condenser and spaced 200 mils below the optical axis. This slit is illuminated constantly along its full length and a shutter with triangular vane is placed behind it to limit the length of the light-beams reaching the film. The noise-reduction slit is made wider than the modulation slit in order to obtain the additional exposure needed for the double density feature.

The greater width of this slit is not detrimental since it is required only to record low frequencies proportional to the envelope of the sound-waves. Two objective lenses are rigidly fastened in a single mounting so that they may be moved together and are simultaneously focused upon the film. A narrow prism at the noise-reduction slit causes the light from this slit to be deviated from its normal path and to fall upon the lower objective. An achromatic prism in front of the objective again changes the angle of the light so that it passes along the axis of this lens and to an image of the slit upon the film. Light from the modulation slit converges to an image of the galvanometer mirror upon the upper objective and then to an image of this slit upon the film. A narrow opaque mask placed about midway between the slit and the objective lens serves to reduce stray light by making only one slit visible from each objective. An ultraviolet filter placed in the path of both slits restricts the exposing energy to the 3560 Å band. The distance between the two slit images at the film is 180 mils in the present design. This results in an anticipation of 10 milliseconds. Longer or shorter values of anticipation may be obtained by changing the separation distance.

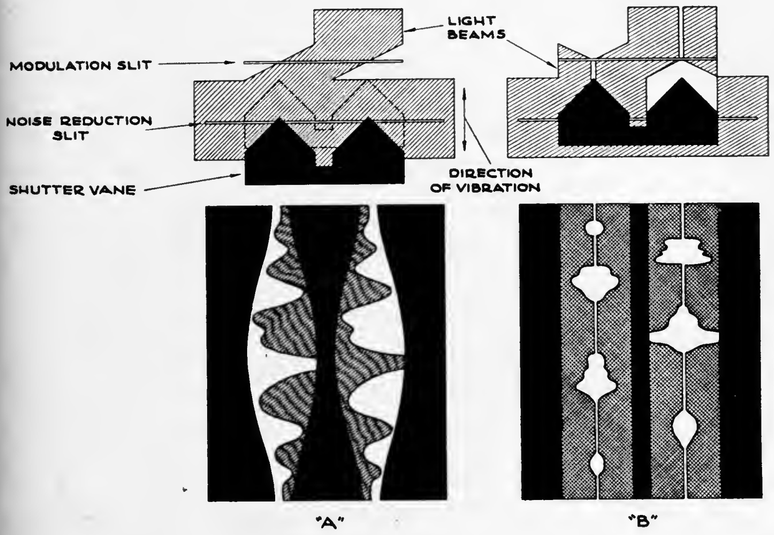


FIG. 5. Shapes and relative positions of recording light-beam, shutter vane, and slits for class *A* and class *B* push-pull systems.

Fig. 5 shows the shapes and relative positions of the recording light-beam, shutter vane, and slits for both a class *A* and a class *B* push-pull system.[1] A short section of sound-track is also pictured below each diagram. The class *A* recording aperture is made in such form that the sloping edges modulate the light from the recording slit, but the noise-reduction slit is illuminated constantly, for signal amplitudes below that corresponding to 200 per cent of the track overload.

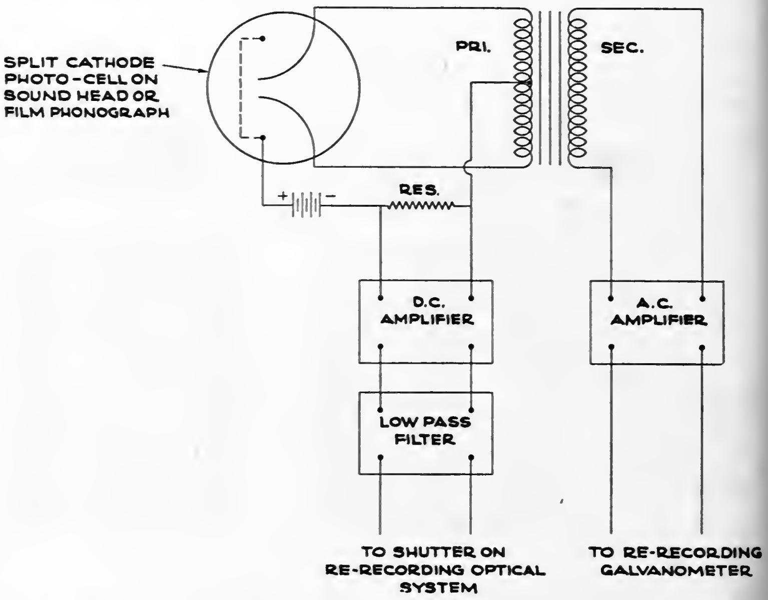


Fig. 6. Method of transferring noise-reduction anticipation provided in the direct positive system to the master negative.

The length of the image of the recording slit at the film is 76 mils, while the noise-reduction slit-image length is 100 mils. The shutter vane and the recording slit are the same length. When the modulation is near 100 per cent, the shutter takes the position shown by the dotted line in Fig. 5 *A*, giving maximum coverage of the noise-reduction slit. The two ends of this slit remain uncovered, thus providing the black strips along each edge of the track. When there is no modulation, only the tips of the triangular shutter vane cover the noise-reduction slit and provide the zero lines. The apex of each triangle is in line with the corresponding intersection of the recording light-beam and the modulation slit. It is apparent that the portion of the track beneath the uncovered center section of the noise-reduction slit receives exposure from both slits. The portion of the track beneath the uncovered outer sections of the noise-reduction slit receives exposure from only this slit. The portion of the track beneath the covered sections of the noise-reduction slit receives either the full exposure from the recording slit or no exposure at all, depending on the position of the recording light-beam at any instant.

Fig. 6 shows a method by which the noise-reduction anticipation provided in the direct positive system may be transferred to the master negative and therefore to the release print. A d-c amplifier with low-pass filter is utilized to make the current in the middle leg of the push-pull reproducing transformer control the motion of the shutter vanes in the re-recording optical system. This current is proportional to the motion of the shutter vanes on the direct positive optical system and is independent of the recorded sound-waves. The re-recording amplifier which drives the galvanometer, obtains its signal from the secondary of the push-pull transformer, which responds to the recorded sound-waves but not to the shutter wave. Complete separation of the noise-reduction and the modulation waves is therefore accomplished without changing the time interval between them. If the recording film phonographs were provided with two reproducing optical systems spaced apart in the direction of the film motion, the final negative could be given the advantage of anticipation by picking off the signal for the noise-reduction amplifier ahead of the regular scanning beam. The advantage of the method shown in Fig. 6 is that it can be applied to the present film phonographs or sound heads.

The class *B* variable-area recording system is the simplest and most effective noise-reduction system yet devised. Direct positive recording opens new possibilities for the class *B* system by eliminating the principal source of difficulty, namely, the printer. Past experience with class *B* recording under production conditions has shown considerable variation in quality, due to the effect of printer contact upon the resolution of the two narrow zero lines. The correct rotational adjustment of the aperture to obtain a smooth cross-over between tracks was found to depend upon the condition of the particular printer. The direct positive class *B* recording tests made to date indicate that a smooth cross-over and therefore good quality may be obtained under varied laboratory and exposure conditions.

At the present time it is not advisable to extend the direct positive method to include the standard type of variable-area track. Image spreading in variable-area sound records gives rise to a rectification component at high frequencies, which if not eliminated, results in sibilant distortion and a general loss in quality. High-frequency rectification may be brought under complete control in the printing process, because of the fact that the resultant distortion due to the negative and the print are of opposite signs and will completely cancel under certain conditions of negative and print density. High-frequency rectification also may be eliminated in the original recording by choosing the proper density, but for the films which are now available, this cancellation density is too low to be usable.[2] The push-pull method is ideal for direct positive recording because the rectification component is eliminated in reproduction. This increases the processing tolerances, and, with the absence of the printer variable, should considerably reduce the risks involved in obtaining high-quality original recordings.

There are a number of ways in which a direct positive recording might be duplicated to provide a sound-track for the "dailies" and for editing purposes. For these purposes, it is assumed that the ultimate in quality and noise-reduction is not required. The original record could be re-recorded to another positive; it could be printed twice to obtain a positive; it could be printed once and reversed; or it could be printed once on the new auto-positive film and developed in the normal manner. The last method would be most desirable, provided this type of film could be made sensitive enough to be exposed in a commercial printer. For musical scoring, the direct positive system would lend itself to the present technic without any added complications. Two recorders are nearly always used to cover a musical session because of the added protection. One of these could record a direct positive and the other a standard negative track. A print from the negative could be used for "dailies" and for editing, and the direct positive could be used for re-recording.

A model of the direct positive optical system has been on test in Hollywood for a number of months. During this period all types of material have been recorded. Most of the recordings were made on the class *A* push-pull type of track; however, the class *B* push-pull proved to be practicable and, of course, offered greater noise reduction.

Standard negative sound recording stocks were used. The exposed film was developed in either the sound negative or the print developer, the exposure being adjusted to compensate for the difference in density speed of the solutions. There was no apparent quality difference with respect to the type of development.

The exposure has proved to be much less critical than on the negative-print process. Densities from 0.80 to 1.60 have been used, resulting in only very minor quality differences. This factor and the omission of the variations in printing no doubt account for the practical performance of the class *B* track.

In general, the chief benefit seems to be a lower noise level. A good print of a negative compares very favorably in quality with the direct record. However, since variations are always present in the printing operation, it is believed that a higher average of quality can be maintained from the direct record. This is, of course, advantageous from an operation standpoint.

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THE POLYRHETOR—A 150-CHANNEL FILM REPRODUCER*

G. T. STANTON,** F. R. MARION,† AND D. V. WATERS†

Summary.—*At the New York World's Fair 150 versions of a fifteen-minute story are carefully sorted to bring each to only four persons seated in comfortable chairs on a moving conveyor.*

A verbal description of a diorama along the edge of which the conveyor progresses, carefully synchronized with the motion of this conveyor, is given each group of persons and is repeated to each succeeding group with approximately a six-minute lag. In telling the fifteen-minute story, approximately 150 versions are being repeated simultaneously, each version differing only in its starting time.

In considering possible ways of meeting the elaborate requirements established for this sound system, various combinations of disk, film, and steel-tape reproducing apparatus were considered, a novel form of film reproducer being selected primarily on the basis of proved operating reliability over long periods of time.

The Polyrhetor consists essentially of a rotating steel drum eight feet in diameter capable of carrying 24 continuous film loops past 168 optical scanners and associated amplifiers mounted on seven posts equally spaced about the drum. A multiple system of sectionalized trolleys conveys the sound through sliding contactors to small speakers in the cars, around which sufficient acoustical partitioning is provided to avoid program interference from car to car.

The creation of a modern Babel might appear to be the purpose of the Polyrhetor, or 150-channel film reproducer, recently completed for use at the World's Fair in New York. Actually, 150 versions of a fifteen-minute story are carefully sorted to bring each to only four persons at a time seated in comfortable chairs on a moving conveyor.

The apparatus is a twenty-ton magnification of the "Call Announcer," the first model of which is satisfactorily operating in telephone plants after nine years of continuous service. The Polyrhetor consists essentially of a rotating steel drum eight feet in diameter, machined to watch-like precision, capable of carrying 24 continuous film loops past 168 optical scanners and associated ampli-

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 17, 1939.

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

† Western Electric Company, New York, N. Y.

fiers mounted on seven posts equally spaced about the drum. A multiple system of sectionalized trolleys conveys the sound through sliding contactors to small speakers in the cars, around which sufficient acoustical partitioning is provided to avoid program interference from car to car.

The need for this unique sound system came into being with Norman Bel Geddes' concept of a gigantic diorama to portray the development of highway systems of the future and their influence on civic planning. Sponsored by the General Motors Company and known as *Highways & Horizons*, it provides the central theme in their New York World's Fair exhibit. Owing to the size of the panorama, over 35,000 square-feet, and the third of a mile of travel required to view it, a conveyor was needed to permit spectators to ride in comfort and view the scenes in proper sequence. To explain the significance of the panorama a verbal description and explanation was needed which must of necessity begin for each spectator at the same point of the ride and must at all times tell that part of the story appropriate to his position with respect to the diorama. The plans called for seats for approximately 600 spectators who are transported sidewise around the panorama. The conveyor took the form of 322 cars approximately 5 feet in length, coupled together in a continuous chain, each car carrying two chairs, except that every 14th car carries, instead of chairs, an electric propulsion motor picking up power from a four-wire trolley system. The conveyor system is in continuous operation approximately 14 hours a day, access to and egress from it being obtained by means of moving platforms. Provisions were included for quickly stopping the conveyor in event of difficulty, and on being restarted, the sound must still be in correct relation to the spectators' positions.

Many types of systems were reviewed in the preliminary study and three distinct methods were planned in some detail, before a final decision was made. These were, first, a series of self-contained disk systems, with automatic replaying attachments, housed under the chairs, on each alternate car, with a small amplifier serving four seats. Synchronizing pulses at the start of each panorama sequence would serve to maintain approximate synchronism. Second, a special steel tape reproducer was considered, having 150 pick-ups at intervals along a 1400-foot spirally wrapped tape. This would be mounted on the train and speech distributed through a flexible cable. The third plan was a film system at a central location.

All considerations of maintenance, rapid service restoration, flexibility of program material, and ability to make announcements to the passengers, pointed to a central station installation with the minimum of apparatus on the cars. The most serious disadvantage to central station equipment appeared to be the fact that some 150 communication channels must be provided from the central station to the individual groups of cars. Radio and guided carrier offered theoretical possibilities which, however, appeared impracticable. The logical method appeared to be some form of multiple trolley system with contactors mounted on each car. With the extremely limited space provided these parts would, of necessity, be so minute as to represent severe design difficulties and almost impossible maintenance requirements.

In addition, conventional film systems involved moving contact with or flexure of the film, with consequent wear. However, a method is embodied in the Call Announcer[1] eliminating this difficulty. In principle, this device consists of a series of small rotating drums, carrying sound-film past a conventional scanning system, the digits and party letters being repeated four times on each film. By a system of relays the desired sequence of digits is selected and repeated to the telephone operator in manually completing a dialed connection. Some of this apparatus, in continuous use for nine years in telephone plants, had repeated the digits over 100,000,000 times with the same film and photoelectric cells without failure or replacement. However, the 15-minute playing time indicated an impossible drum diameter, which at 36 feet per minute would have been approximately 170 feet.

Sectionalizing proved the key that unlocked the door to a solution which met all the requirements: merely sectionalize the length of the conveyor and the time of the sound. This adapted itself admirably to the conveyor design, eliminated excessive numbers of trolleys, and required lengths of film which could conceivably be handled on the Call Announcer principle. From this sectionalizing method arose the first concept of the Polyrhetor.

Spacing the traction motors at regular intervals throughout the conveyor divided it into a series of 23 sections, each containing 13 cars with chairs and one with the motor. There are, therefore, only seven separate groups of spectators to receive sound in each section, six groups of four and one group of two, there being no sound required for the motor car. The cars being 5 feet long, established the length of each conveyor section as approximately seventy feet. Likewise, the time of sound in each section at a conveyor speed of 100 feet per minute is approximately forty seconds.

On a continuous loop of film providing forty seconds of playing time, the story for the first seventy foot section of conveyor travel is recorded. A reproducer scanning this loop is associated with a length of trolley rail installed along the first seventy feet of panorama. The loud speaker of the first sound group in each successive conveyor section is connected to this rail through a contactor drawn by the car. When properly synchronized, this contactor first touches the trolley rail as the story is commencing, and as it finishes is carried from this trolley, entering a second trolley section, as the appropriate sound commences on a second loop of film. By spacing six more scanners (seven in all) equally around the loop, the start of the story reaches each scanner with a proportionate delay. These other six scanners are connected with trolley rails paralleling the first, and the following six sound groups in each conveyor section have contactors which progressively are carried into contact with the appropriate rail, just as the start of the sound reaches the associated scanner (Fig. 1).

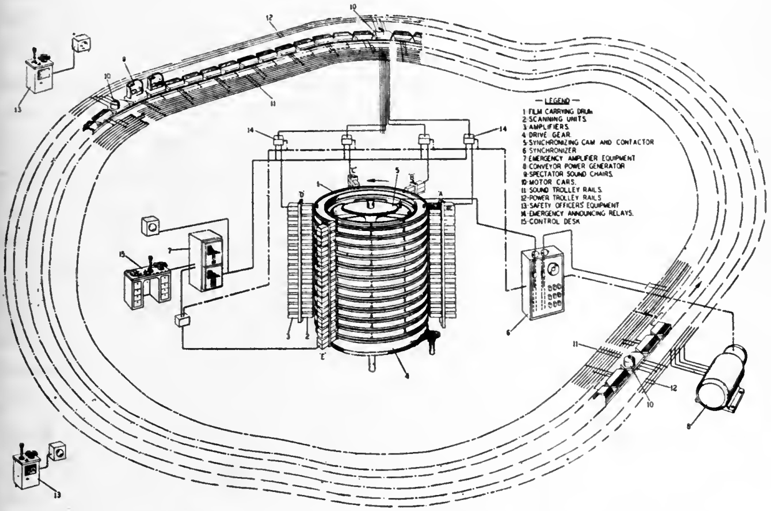

FIG. 1. The Polyrhetor: General Motors exhibit at the New York World's Fair; Spectator Sound System.

The Polyrhetor now took form. At a film speed of 36 feet per minute, a film length of 24 feet or drum diameter of approximately eight feet was required. Only 21 sections of the conveyor required sound simultaneously, since two sections lay between the unloading and loading platforms. One film loop was assigned to emergency announcements as described later, and two loops reserved for spares, requiring 24 film tracks, in total. Seven scanning points were required on each loop as previously brought out. Computation showed and experiment established that with a particular lens assembly and an 0.0007-inch scanning image an axial deviation of plus or minus 0.0015 inch in location of the film was completely tolerable. Of this total 0.001 inch was assigned to the machine, and 0.0005 inch to the deviation of the film. By suitably masking the track 0.005 inch lateral wobble could be tolerated. Flutter limits were set at 0.5 per cent per second for gradual speed changes and 0.2 per cent per second for high speed. Obviously, vibration of all parts must be at a minimum, and the whole assembly must be capable of withstanding the strains of shipment and installation, including the ranges of temperature likely to be encountered, without loss of accuracy beyond the tolerances of the specifications. These represented the principal requirements to be met in the film-propulsion machine.

To find a means of rotating 24 film loops approximately 8 feet in diameter within the tremendously small tolerances of permissible cam action was the first problem. Several radical forms of rotating system were considered, one being an extremely interesting and novel rotor suspended at its top from a central shaft much like a carousel. A conservative design based on electric generator practice was adopted. A vertical mounting was utilized to avoid deflection of the central shaft under load, to gain the advantage of a bearing at the bottom of the shaft which would be preloaded by the mass of the drum to eliminate radial play and the ability to carry off heat generated by the exciter lamps, thus avoiding possible misalignment caused by unequal heating. In the formation of the drum consideration was given to the use of dished rings pressed on the central shaft, spaced to permit placement of photocells behind overhanging soundtracks located on the surface of the disks, a solid drum with scanner rings and recess for the photocells turned into the surface, and a fabricated cylinder with built-up scanner rings pressed on.

Fig. 2 shows a sectional assembly of the machine and drum. A $7^1/_4$-inch central steel shaft carries three large bosses which support steel disks approximately 82 inches in diameter, which are reinforced by six radial plate steel ribs. The outer cylinder of $^3/_4$-inch plate steel, is closely fitted to the machined surfaces of the three disks and welded to them only. Twelve circular ring-like disks were machined and fitted to the outside diameter of the cylinder. These were machined at their outside diameters to carry 12 stainless steel hoop-like rings, the outside diameters of which were properly machined, ground, and polished to provide seating surfaces upon which the sound-films are located. The seven rigid posts provided for mounting the scanners were made sufficiently heavy to carry the supporting spider. An eighth post was added for the support of a precision grinding machine, when and if required due to accidental deformation of the rings. It also provides support for the equipment used to mount and demount the films. The great weight of the drum, approximately 14,000 pounds, and the proportionate massiveness of the scanner and top bearing supports, required a base and bearings that would not only support the revolving drum satisfactorily, but would have sufficient rigidity to maintain proper alignment of various machine members during testing and shipment.

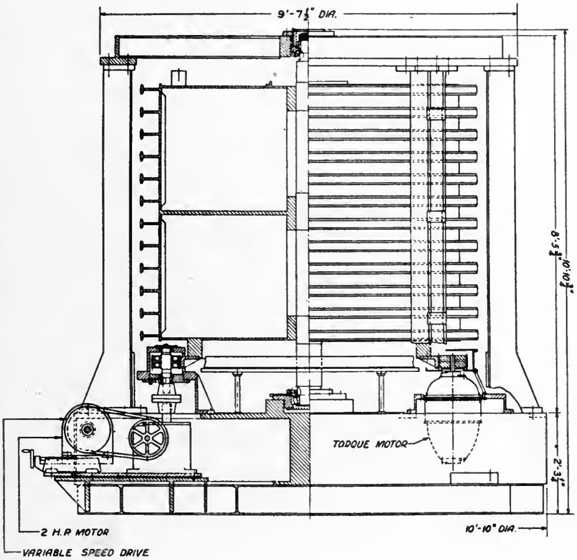

FIG. 2. Sectional assembly of machine and drum.

For scanning the sound-film the stainless steel rings were formed to provide surfaces for mounting singly perforated 16-mm sound-film with the sound-tracks projecting beyond the edges of the rings. The assembly took the form of double units for scanning film on the top and bottom of the rings simultaneously. The scanning mechanisms were designed so that displacements of the film with respect to the scanning-beam could be held within the 0.001-inch tolerance, even with severe cam action of the ring. This was accomplished by arranging the scanners so they could be mounted to slide into sub-bases, to which were attached compression springs forcing the scanner inward toward the ring. Precision rollers bear upon the central portion of the film mounting ring, thus maintaining the clearance between optical assembly and film surfaces even with large relative motion of ring and post. A small number of the scanners were so built and tested in service, their performance being satisfactory, although some vibration due to friction of the roller in its bearing and contact with the ring established a background noise level slightly higher than is obtained with the stationary scanner. These scanners, as shown in Fig. 3, are mounted vertically on the right-

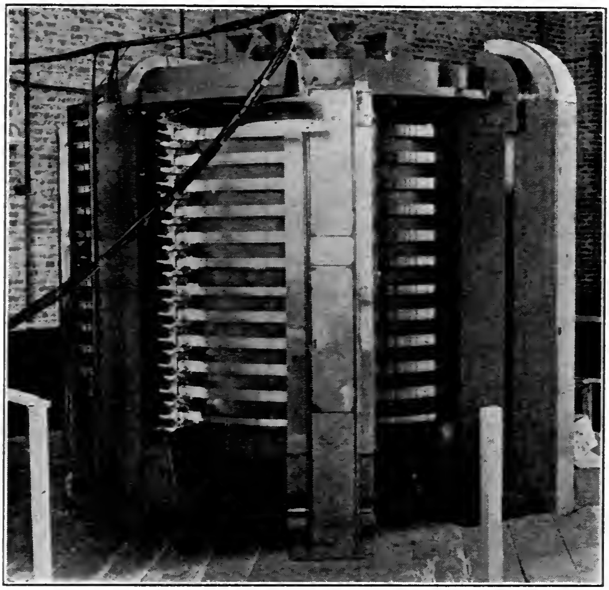

FIG. 3. Showing amplifier and scanner cabinet bolted to the wiring trough.

hand side of each of the seven columns. A vertical heat flue is provided with individual flues to each exciter lamp, these flues acting also as light-shields.

As it was desirable to maintain short leads from the photocell to the amplifiers, it was arranged to mount the latter directly on the face of the seven supporting columns. All wiring to the exciter lamps, for amplifier filament and plate supply and the speech circuits, was installed in preformed sheet metal troughs bolted to the column faces. A simple two-stage amplifier is employed having its connections in a jack mounted on the end of the chassis and arranged to plug into the machine receptacles. In the illustration, the amplifiers are shown in place within the enclosing metal work on the left column. On the column is a selector switch which is at mid-height of the supporting column. All 24-speech circuits on the column are multiplied to this selector switch, the latter being equipped with a jack for the insertion of head-phones or testing meter, permitting rapid monitoring of the circuits as a check of operating efficiency.

Sheet-metal cabinets for housing the amplifiers and scanners were built up and bolted to the wiring troughs as shown partially completed in Fig. 3. Two large doors may be opened to give access to the amplifiers which are mounted in individual pockets carefully jigged to provide ready alignment of the amplifier jack with its associated receptacle. The heat flues from the exciter lamp are carried upward over the top spider of the machine, terminating above its center in wide-mouthed outlets. In the final installation the approximately 6 kw of heat generated in the machine is largely drawn off through these flues by means of a giant anemostat located in the ceiling of the room housing the machine. At the same time cool air is admitted to the outer vanes of the anemostat and circulated downward to the outside of the machine. Temperature and humidity are automatically controlled. A sketch of the completed assembly is shown in Fig. 4. In view of the large power requirements for the 150 systems, distribution of the exciter lamp and amplifier filament currents is effected by four copper busbars arranged in circles concentric with the top of the machine. Special connectors were designed to accommodate the termination of 24 wires to each bus at each column. Connection from these to the power transformers is by overhead busses. All speech connections to the machine are carried from the terminal strips located at the base of each column and through raceways cored into the circular concrete base.

Study of types of film and methods of mounting to insure a smooth surface free from waves or wrinkles indicated the desirability of stiffness in the film stock and uniform contraction on both surfaces. A 10-mil stock, singly perforated film, gelatin-coated on both faces, was selected, using a standard emulsion. An *RA-258* high-quality 16-mm recorder is employed, making a "toe" negative, with 6-db noise reduction. Original recordings were on standard 35-mm film pre-equalized slightly at the high end. Background music and sound effects were dubbed with the edited speech to a master negative, a print from which is used to re-record the 16-mm "toe" negatives. The "toe" negative was employed in preference to prints because commercial printers could not satisfactorily handle the heavy stock without considerable readjustment. The film is run onto the drum from a special reel having a minimum hub diameter of 3 inches to avoid wrinkling the film. This reel, with a brake and drum contact roller, is mounted on the tool post carriage, and by revolving the drum the film is smoothly drawn around the steel mounting ring. A

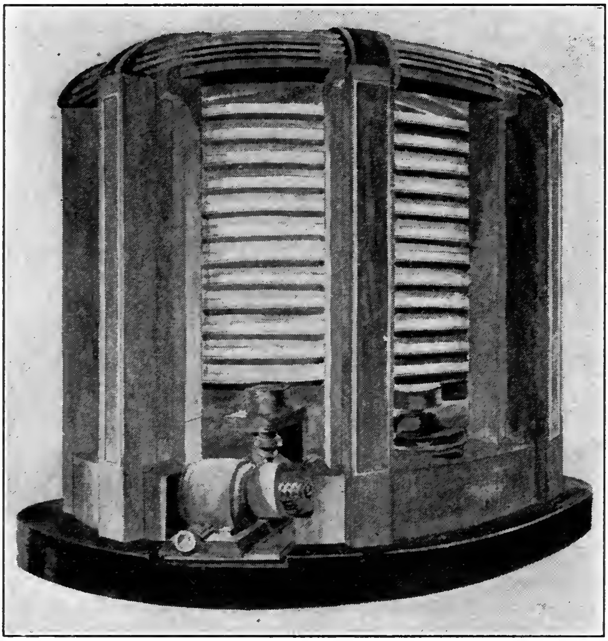

FIG. 4. *RA-301* film reproducing machine.

steel ribbon is then run onto the drum from the same machine, and fastened by special spring clips to hold the film firmly in place.

Synchronizing the sound and conveyor travel is a straightforward process accomplished by apparatus adapted from automatic elevator control. An interrupter cam is located on the rotating drum of the film machine which actuates a make-and-break contact, advancing a mechanical contactor or "selector" in step with the drum's rotation. A contactor mounted on one car in each conveyor section makes and breaks contact with a special synchronizing rail, located in one of the sections between the unloading and loading platforms, advancing a "selector" step by step with the car's progress. At each step these two selectors pick up relays, so arranged that a premature arrival of the car selector functions to slow the conveyor, a tardy arrival to speed it up. The relays produce a temporary speed correction, and a motor-driven rheostat provides a semipermanent speed correction occurring at a slow rate. This double correction prevents "hunting" in the system. In event of stoppage of the conveyor, the sound machine continues to rotate, and picks up the conveyor at a synchronous point after the latter's controls are set to restart it. Light signals at the operator's position indicate correct synchronous operation, any departure from which is immediately flashed on an indicating board showing whether the sound system or the conveyor impulses are at fault.

An integral part of the system design was the means of transferring speech signal to the moving cars. Seven speech channels were required, which must at their terminals be open wire or rail, untransposed and in close parallelism with the conveyor power-supply rails. An investigation of possible inductive disturbance indicated the possibility of employing a single common return, grounded at the section midpoint. Thus only eight trolley rails were required, one being added for a spare. The problem of transferring speech signals through moving contacts without the introduction of noise was exhaustively investigated. The best solution that appeared was the use of silver-bearing graphite, about 80 per cent of silver by weight, with contact pressure of three pounds per square-inch.

The trolley rail construction finally selected consisted of special copper shapes resembling conventional rail sections $^3/_4$ inch high with $^1/_4$-inch top bearing surface. Nine rails were employed in each trolley section spaced $^7/_8$ inch. Steel brackets and phenol-fiber insulators support the rails. The collector consists of a relatively heavy sled form of structure towed by a freely pivoted link from the car. This sled is supported on impregnated fiber pads riding on the surface of the outermost rails and laterally guided by similar pads from the central rail. Brush-holders of insulating material are employed which bear directly on the rail surface and have side flanges on each side of the rail. These holders are loosely supported in the carriage permitting them sufficient freedom of motion to compensate for possible inequalities of spacing of the rails and to adjust themselves to the radii encountered. Two silver-bearing graphite brushes are installed in each holder, their faces projecting slightly below the holder bearing surfaces and forced against the rail by long steel spiral springs.

Since the story furnished to one group of chairs is different at any given time from that in adjacent groups, special precautions were required to avoid acoustic interference. The conveyor tunnel was heavily treated with acoustic absorbing material. The seats for two occupants of each car were built as a unit, and considerable testing was done to establish the amount of acoustic shielding or barrier needed between chairs. The loud speakers are mounted at head height between the two seats, and enclosed in the structure of the chair. A design was used which would direct the maximum energy sideward toward the ears of the listeners, and a minimum outwardly from the chair. A small cone speaker was employed, mounted in a double horn-like structure, the radiation being cancelled to a considerable extent in the plane normal to the horn axis. Matching transformers are mounted on the support of the speaker as well as pads providing an adjustable transmission loss. As there is a margin of gain in the amplifiers over the system requirements, the use of these pads at the terminal is effective in minimizing noise or disturbance in the transmission circuits or trolley contacts.

As previously indicated, one of the requirements was the ability to address all passengers on the conveyor at one time from the central point, or to select a particular section to which an address or other form of program material could be given. To accomplish this, all speech circuits are carried through a selector switch panel and multiple contact relays of the crossbar type normally used in telephone plants. Each relay is capable of accommodating a total of 60 circuits, 6 relays being employed. Operation of these relays is such as to open all speech circuits from the machine and put them in common with the output of a 50-watt amplifier, thus permitting simultaneous transmission to all circuits. The selector switch panel consists of 11 multi-deck rotary switches. Operation of these switches is such that any two adjacent conveyor sections may be switched from their normally associated circuit to a common circuit. In addition, in event of damage to any of the film-carrying drums, the circuit associated with that drum may be transferred to the spare drum provided on the machine by suitable operation of the selector switches. This selector panel involved over 7600 soldered connections and considerable complexity of wiring, which is shown in a rear view of the panel (Fig. 5).

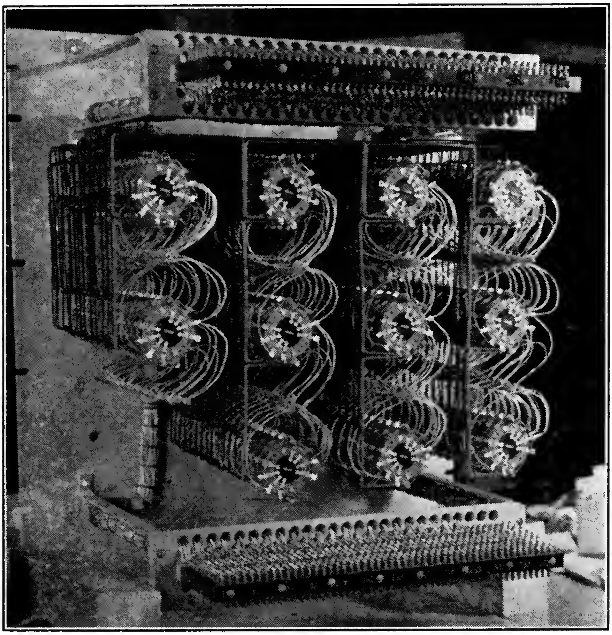

FIG. 5. Rear view of the selector panel.

One of the safety features of the conveyor system is the ability to stop the conveyor instantly from any one of the 12 positions at which attendants will be located during operation, and such stoppage is indicated to the control operator by a light signal on his control desk. To insure that a message is immediately conveyed to all passengers on the conveyor in the event of such stoppage, use is made of a film on the spare ring which will carry a brief continuously repeated message, such as "Please Keep Your Seats." This message is picked up by one scanner and constantly supplied to the 50-watt amplifier. Immediately upon stoppage of the conveyor the crossbar relays function to interrupt the story and to associate all chairs with the emergency announcement mentioned above. After a brief interval the control operator, by pressing a key, can deliver any desired message or information by means of a microphone, or associate the power amplifier with the turntable carrying a record of music or other desired program.

The effectiveness of the system in meeting the general requirements has been well borne out in the operating tests conducted on the ground. The requirements for ease of operation, maintenance, and service restoration are readily met, since all parts of the system requiring attention are compactly located in a central air-conditioned room. Here the controls for the conveyor system and the sound system are centralized on a single desk from which the operator may start or stop the conveyor system, converse with any of the 12 attendants situated at various points around the panorama, address a message to all occupants of the conveyor or to those in any desired section, or furnish recorded program music. The only equipment outside the room is the loud speaker and trolley collector located on the conveyor, which apparatus inherently requires very limited attention.

This project involved the fundamental solution of a large number of varied problems, in a three-month period, and the design and construction in four months of a quantity of equipment, many pieces of which had no counterpart and many of which required high precision. Moreover, without opportunity for preliminary assembly, testing or modification, all parts had to operate harmoniously in their first installation. Its success was possible only by the subdivision into component parts and careful coördination of the work of the engineers in the various design groups. While the subdivision and coördination of the problem remained with ERPI and the detailed design, manufacture, and test were handled by the Western Electric Co., acknowledgment is due to many others whose assistance proved invaluable. A great deal of advice was received from members of the staff of the Bell Telephone Laboratories, with respect to physical possibilities of certain design concepts, information on inductive interference, and design of moving contacts for noiseless transmission of speech. The Westinghouse Electric &

Manufacturing Co., in whose shop the rotating drum and supports were fabricated and who assembled the driving elements, were also responsible for the detailed design of the parts of the structure. The difficult problem of manufacturing the large precision ring gear was overcome by Gould & Eberhard, while the Timken Roller Bearing Co. offered invaluable suggestions and furnished and adjusted the high-precision bearings required. The Westinghouse Electric Elevator Co., who furnished the conveyor system, also constructed and installed the novel synchronizing mechanism. The special film was developed for this application by the Eastman Kodak Company. Acknowledgment is made of the services of Professor Karelitz of Columbia University, who acted as consultant on the mechanical features of this machine.

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EFFECT OF ORIENTATION OF THE SCANNING IMAGE ON THE QUALITY OF SOUND REPRODUCED FROM VARIABLE-WIDTH RECORDS*

DONALD FOSTER**

Summary.—*This paper gives a general analytical theory of reproducing variable-width records with oblique images. Two types of records are considered. In each case the effect of obliquity is to introduce non-linear distortion and loss of power; but the amount of distortion produced and its dependence on the modulation are different in the two types of records. The loss due to the width of the image is practically independent of the orientation of the reproducing image. Curves are given which show the amount of distortion produced by an error of orientation of 43 minutes when the width of the sound-track is 0.080 inch.*

It is well known that the effect of the width of the image in reproduction of photographic sound records is to cause a loss of power which increases with the frequency. There is no non-linear distortion when the image is at right angles to the sides of the film; and the effect is the same for all types of records that have been devised.

If, however, due to an imperfect adjustment, the reproducing image is not properly oriented, additional loss of power occurs, and also a non-linear distortion is introduced, the nature of which depends on the type of record reproduced.

These effects will be considered first in relation to a type of record which may be called the *symmetrical* type. In this type of variable-width record, the middle of the sound-track is an axis of symmetry. The appearance of a positive print of such a record is seen in Fig. 1. The more familiar unsymmetrical type of variable-width record looks like the upper or lower half of the record shown in the figure.

It is shown elsewhere[1] that while the variable-width type of record varies in density as well as in width, it is equivalent, when properly exposed and developed, to an ideal variable-width record of lesser amplitude which varies in width only. This freedom from non-linear

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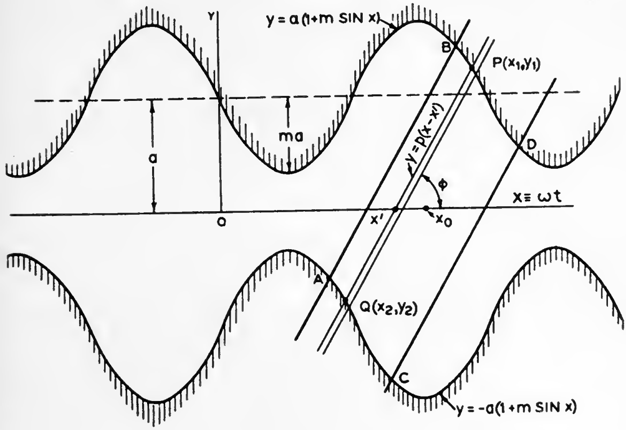
* Received June 2, 1939.

** Stevens Institute of Technology, Hoboken, N. J. (The work reported here was done in 1932 while the author was at Bell Telephone Laboratories.)



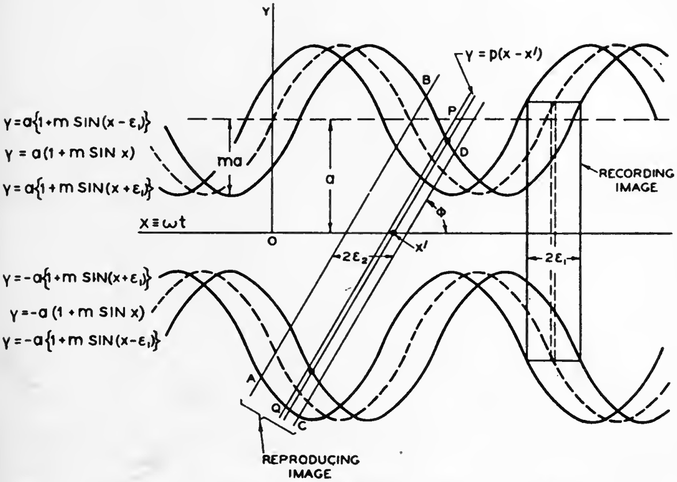


FIG. 1 (*Upper*). Ideal variable-width record reproduced with oblique image.

FIG. 2 (*Lower*). Practical variable-width record reproduced with oblique image.

distortion in the record exists only when the reproducing image is at right angles to the direction of motion of the film. When the reproducing image is oblique, non-linear distortion is introduced even for reproducing images of infinitesimal width. The finite width of the reproducing image contributes additional distortion.

In order to solve the problem simply it is convenient first to develop certain equations regarding the reproduction of ideal variable width records by means of an oblique reproducing image of finite width.

By an ideal record is meant one in which the density of the exposed portion is uniform. Such a record would be generated by a recording image of infinitesimal width. The theory of the ideal record is a useful mathematical preliminary in the solution of the problem of the complex record which occurs in practice.

THEORY OF IDEAL VARIABLE-WIDTH RECORDS

Ideal Symmetrical Record.—In Fig. 1, let *AB*, *CD* be the sides of the image, which for the present is assumed uniform in illumination. Let the difference in phase of the two sides of the image be 2ϵ. This quantity, for the sake of brevity, will be called the *width* of the image. The narrow strip of the image, *PQ*, cuts the axis of phase at x'. The height of this parallelogram is $(y_1 - y_2)$ and the width of the base is dx. In this representation, the "area" S of the part of the record covered with light is, therefore

$$S = \int_{x_0-\epsilon}^{x_0+\epsilon} (y_1 - y_2)dx \tag{1}$$

where x_0 is the phase of the middle of the image.

The function $(y_1 - y_2)$ is expressible in terms of x by solving simultaneously the two pairs of equations

$$\begin{aligned} y &= a(1 + m \sin x) \\ y &= p(x - x') \end{aligned} \tag{2}$$

and

$$\begin{aligned} y &= -a(1 + m \sin x) \\ y &= p(x - x') \end{aligned} \tag{3}$$

where $p = \tan \phi$ and m is the modulation.

The x coördinate for the point determined by the first pair of equations* is[2]

$$x_1 = \left(x' + \frac{a}{p}\right) + \sum_1^\infty \frac{2}{n} J_n\left(n\frac{am}{p}\right) . \sin n \left(x' + \frac{a}{p}\right) \tag{4}$$

and for the lower point, we have

$$x_2 = \left(x' - \frac{a}{p}\right) + \sum_1^\infty \frac{2}{n} J_n\left(-n\frac{am}{p}\right) . \sin n \left(x' - \frac{a}{p}\right) \tag{5}$$

in which the *J's* are Bessel functions.

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* The problem is mathematically identical with Kepler's famous problem in celestial mechanics.

Then since

$$y_1 - y_2 = p(x_1 - x_2) \tag{6}$$

after some reduction we obtain

$$y_1 - y_2 = 2a + k_1 \sin x' + k_2 \cos 2x' + \ldots \tag{7}$$

in which

$$k_1 \equiv 4\ p\ J_1\left(\frac{am}{p}\right)\cdot\cos\frac{a}{p} \tag{8}$$

$$k_2 \equiv 2\ p\ J_2\left(\frac{2am}{p}\right)\cdot\sin\frac{2a}{p} \tag{9}$$

Integrating

$$S = \int_{x_0-\epsilon}^{x_0+\epsilon} (y_1 - y_2)dx' \tag{10}$$

$$= \int_{x_0-\epsilon}^{x_0+\epsilon} (2a + k_1 \sin x' + k_2 \cos 2x')dx'$$

$$= 4a\epsilon + 2k_1 \sin\epsilon\cdot\sin x_0 + k_2 \sin 2\epsilon\cdot\cos 2x_0$$

Dividing by the width of the image, the apparent height of the reproduced record is seen to be

$$y_r = 2a + k_1\frac{\sin\epsilon}{\epsilon}\sin x_0 + k_2\frac{\sin 2\epsilon}{2\epsilon}\cos 2\ x_0 + \ldots \tag{11}$$

Inspection of this equation shows that the loss given by the *k's* is due to orientation alone, since that due to the width alone is known to be of the form $(\sin n\epsilon)/n\epsilon$. It should be noticed, however, that ϵ here is equal to the ϵ of the restricted theory multipled by $1/\cos\psi$, where ψ is the angular error of orientation. Strictly, therefore, the second factor implies a certain very small additional loss due to the greater phase-width caused by an error in orientation.

Ideal Unsymmetrical Record.—For this case, the function S is given by

$$S = \int_{x_0-\epsilon}^{x_0+\epsilon} y_1 dx' \tag{12}$$

$$= \int_{x_0-\epsilon}^{x_0+\epsilon}\left(a + 2p\sum_1^{\infty}\frac{1}{n}J_n\left(n\frac{am}{p}\right)\cdot\sin n\left(x' + \frac{a}{p}\right)\right)dx'$$

$$= 2a\epsilon + 2g_1 \sin\epsilon\cdot\sin\left(x_0 + \frac{a}{p}\right) + g_2 \sin\ 2\epsilon\cdot\sin 2\left(x_0 + \frac{a}{p}\right) + \ldots$$

where

$$g_1 \equiv 2\, p\, J_1\left(\frac{am}{p}\right) \tag{13}$$

$$g_2 \equiv p\, J_2\left(\frac{2am}{p}\right) \tag{14}$$

Dividing by 2ϵ, the apparent height of the reproduced record is given by

$$y_r = a + g_1 \frac{\sin \epsilon}{\epsilon} \cdot \sin\left(x_0 + \frac{a}{p}\right) + g_2 \frac{\sin 2\epsilon}{2\epsilon} \cdot \sin 2\left(x_0 + \frac{a}{p}\right) + \ldots \tag{15}$$

It is understood, of course, that in comparing symmetrical and unsymmetrical records of the same unmodulated width that the quantity a in the expression just derived is twice as large as it is in the corresponding expression for the symmetrical case.

The factor by which the total amplitude is reduced in the symmetrical case is

$$L_s = \frac{1}{2am} k_1 \frac{\sin \epsilon}{\epsilon} \tag{16}$$

and the ratio of the amplitudes of the second and first harmonics is

$$R_s = \frac{k_2 \dfrac{\sin 2\epsilon}{2\epsilon}}{k_1 \dfrac{\sin \epsilon}{\epsilon}} = \frac{k_2}{k_1} \cos \epsilon \tag{17}$$

while for the unsymmetrical case

$$L_u = \frac{1}{am} g_1 \frac{\sin \epsilon}{\epsilon} \tag{18}$$

and

$$R_u = \frac{g_2 \dfrac{\sin 2\epsilon}{2\epsilon}}{g_1 \dfrac{\sin \epsilon}{\epsilon}} = \frac{g_2}{g_1} \cos \epsilon \tag{19}$$

In calculating these numbers it will be remembered that the slope p is a function of the wavelength because the abscissa in Fig. 1 is the *phase*. The slope of the image in this representation is given by

$$p = \frac{4a}{\dfrac{2\pi}{\lambda} q} = 2\frac{a\lambda}{\pi q}; \quad \text{(Symmetrical case)} \tag{20}$$

$$p = \frac{2a}{\dfrac{2\pi}{\lambda} q} = \frac{a\lambda}{\pi q}; \quad \text{(Unsymmetrical case)} \tag{21}$$

in which the quantity a is the amplitude of a single wave when fully modulated, λ is the wavelength and q is the relative displacement along the film of the two ends of the image due to the obliquity.

For purposes of computation the expressions derived now become

$$k_1 = 8\frac{a\lambda}{\pi q} J_1\left(\frac{\pi mq}{2\lambda}\right)\cdot\cos\frac{\pi q}{2\lambda} \qquad (22)$$

$$k_2 = 4\frac{a\lambda}{\pi q} J_2\left(\frac{\pi mq}{\lambda}\right)\cdot\sin\frac{\pi q}{\lambda} \qquad (23)$$

$$g_1 = 2\frac{a\lambda}{\pi q} J_1\left(\frac{\pi mq}{\lambda}\right) \qquad (24)$$

$$g_2 = \frac{a\lambda}{\pi q} J_2\left(\frac{2\pi mq}{\lambda}\right) \qquad (25)$$

and the expression for the apparent height of the reproduced unsymmetrical record becomes

$$y_r = a + g_1\frac{\sin\epsilon}{\epsilon}\sin\omega\left(t + \frac{q}{2v}\right) + g_2\frac{\sin 2\epsilon}{2\epsilon}\sin 2\omega\left(t + \frac{q}{2v}\right) + \ldots \qquad (26)$$

where v is the velocity of the film. In this form it is apparent that there is no phase-distortion caused by an error in orienting the reproducing image.

THEORY OF PRACTICAL VARIABLE-WIDTH RECORDS

Symmetrical Record.—In Fig. 2 the record has been generated with a recording image whose width in phase is $2\epsilon_1$ and whose ends execute simple harmonic motion. The sides of the reproducing image are represented by the lines AB, CD. Consider how much light is transmitted by the narrow element PQ of the reproducing image. If the record has been properly exposed and has been developed to an overall gamma of unity the transmission of the positive is proportional to the exposure of the negative. Thus the light-flux transmitted by the record due to one infinitesimal strip of the recording image is

$$dF_i = dT_i\,(y_1 - y_2)_i\,dx \qquad (27)$$

where y_1, y_2 are the y coördinates of the intersection of the reproducing image with the sine curves traced by the i-th element of the *recording* image, and dT_i is the part of the transmission contributed by that element. The total flux transmitted by an infinitesimal reproducing image is therefore to be obtained by summing dF_i for all the elements i of the recording image. This would require integration with respect to the epoch of the sine curves. But it is simpler to vary the phase

x' of the reproducing image than it is to calculate $(y_1 - y_2)$ in terms of the epoch of the sine curves. The results must be identical.

Therefore

$$F = dT \int_{x'-\epsilon_1}^{x'+\epsilon_1} (y_1 - y_2) dx' \tag{28}$$

Then because

$$\frac{dx}{2\epsilon_1} = \frac{dT}{T} \tag{29}$$

where T is the transmission of the uniform part of the record, we obtain

$$F = T\,dx \left[\frac{1}{2\epsilon_1} \int_{x'-\epsilon_1}^{x'+\epsilon_1} (y_1 - y_2)\,dx' \right] \tag{30}$$

Comparing the expression in brackets with (10) and (11), it is seen that

$$F = T\,y_r\,dx \tag{31}$$

This result may be expressed in the following theorem:

The apparent height of a practical variable-width record as observed with an oblique reproducing image of infinitesimal width is the same as that of an ideal record as observed with a finite oblique reproducing image having the same phase-width as the image with which the practical record was produced.

For a finite reproducing image of width $2\epsilon_2$ the reproduced record is given by

$$y = \frac{1}{2\epsilon_2} \int_{x_0-\epsilon_2}^{x_0+\epsilon_2} y_r\,dx \tag{32}$$

which becomes for the symmetrical record

$$y = 2a + k_1 \frac{\sin \epsilon_1}{\epsilon_1} \frac{\sin \epsilon_2}{\epsilon_2} \sin \omega t + k_2 \frac{\sin 2\epsilon_1}{2\epsilon_1} \frac{\sin 2\epsilon_2}{2\epsilon_2} \cos 2\omega t + \ldots \tag{33}$$

Unsymmetrical Record.—In like manner it is easy to show that the reproduced unsymmetrical record is given by

$$y = a + g_1 \frac{\sin \epsilon_1}{\epsilon_1} \frac{\sin \epsilon_2}{\epsilon_2} \sin \omega \left(t + \frac{q}{2v}\right) +$$

$$g_2 \frac{\sin 2\epsilon_1}{2\epsilon_1} \frac{\sin 2\epsilon_2}{2\epsilon_2} \sin 2\omega \left(t + \frac{q}{2v}\right) + \ldots . \tag{34}$$

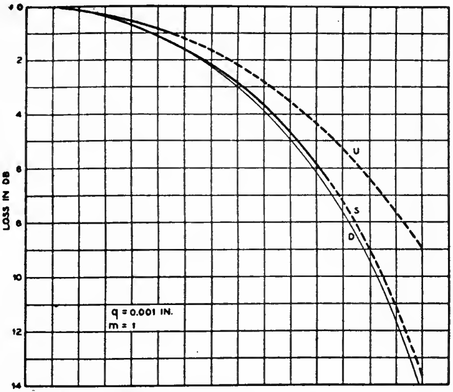

FIG. 3. Loss of the fundamental due to obliquity. Modulation = 1. The lower curve *D* for variable-density is given for comparison here and in Figs. 4 and 5.

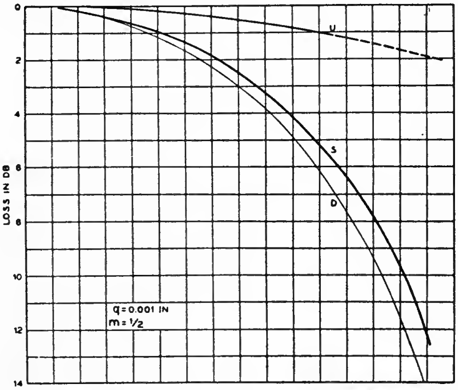

FIG. 4. Loss of the fundamental due to obliquity. Modulation = $^1/_2$.

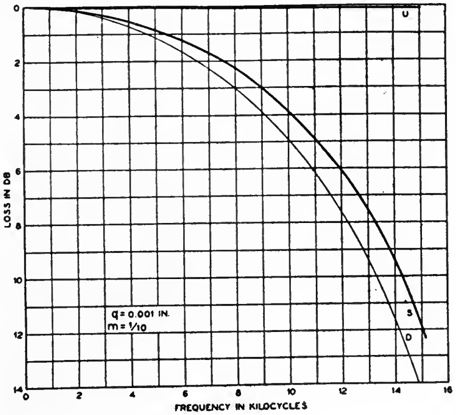

FIG. 5. Loss of the fundamental due to obliquity. Modulation = $^1/_{10}$.

Application to a Particular Problem.—Let the width of the recording and reproducing images be 0.001 inch, the speed of the film 18 inches per second, and suppose that the angular error of orientation of the reproducing slit is 43 minutes. The useful width of the sound-track is taken as 0.080 inch, so that for the symmetrical record $a = 0.020$ inch, while for the unsymmetrical record $a = 0.040$ inch. The linear orientation error q corresponding to 43 minutes is then 0.001 inch.

The letters S and U which appear in the figures refer to symmetrical and unsymmetrical records, respectively. The loss of the first harmonic due to *obliquity alone* is given for different values of the modulation in Figs. 3, 4, and 5. Figs. 6, 7, and 8 show the ratio of the second harmonic to the first; and the part of this ratio which is independent of image width is given in Figs. 9, 10, and 11.

Limited Application of the Analysis.—Due to mathematical difficulties the analysis up to this point has been confined to the consideration of what happens to a pure tone in recording and reproducing. The above theory does not apply to recording any wave-shape except a simple harmonic wave. In the general case of recording an arbitrary function the loss of the first harmonic and the amount of non-linear distortion produced depend not only on the amplitude and frequency of the first harmonic but also on the amplitudes and phases of all the other harmonics. *This is true of any non-linear system.* The effect therefore depends on the particular wave-shape recorded. The general theory for an input wave of arbitrary shape will be found in the appendix. The value of the theory lies in the fact that it is possible by means of it to estimate the tolerance in adjusting the orientation of the reproducing slit and to compare the effects in the two different types of variable width records considered.

The frequency range over which the theory is valid is limited due to the fact that above a certain frequency, which depends on the linear obliquity q and the modulation, the sides of the image intersect the boundaries of the record more than once. Above this frequency the imaginary pairs of roots of equations *2* and *3* become real and these roots are not given by the solutions *4* and *5*. The frequency above which multiple roots occur is given by

$$\frac{am}{p} = 1 \tag{35}$$

and for the symmetrical case this is equivalent to

$$\lambda = \frac{\pi}{2} qm \tag{36}$$

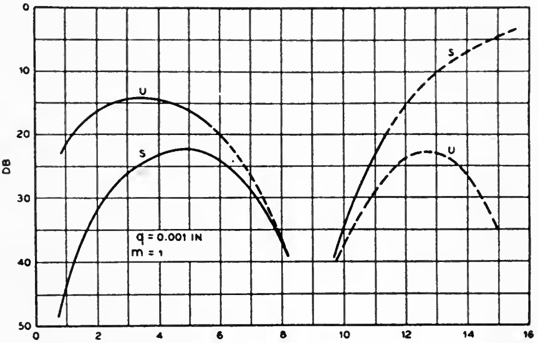

FIG. 6. Ratio of the second harmonic to the first harmonic. Modulation = 1.

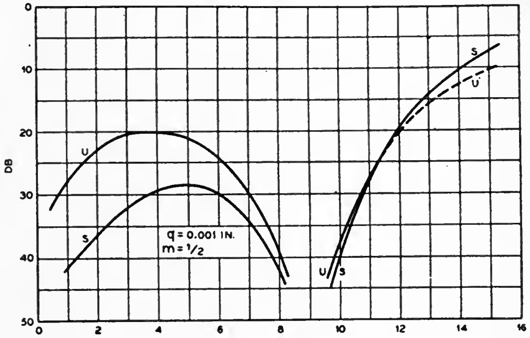

FIG. 7. Ratio of the second harmonic to the first harmonic. Modulation = $^1/_2$.

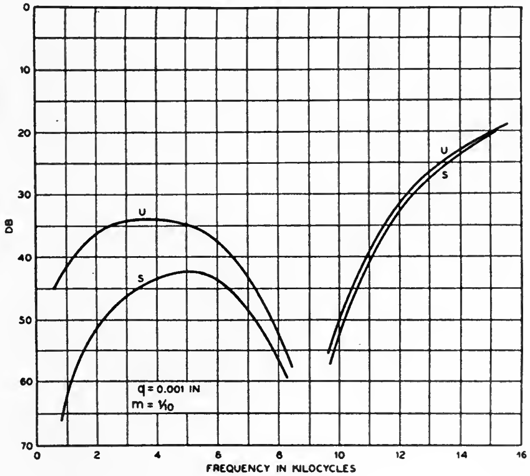

FIG. 8. Ratio of the second harmonic to the first harmonic. Modulation = $^1/_{10}$.

while for the unsymmetrical case

$$\lambda = \pi q m \tag{37}$$

For example, for standard film speed of 18 inches per second and $q = 0.001$ inch the frequencies are

$$\left.\begin{array}{ll}\text{Symmetrical} & f = 11{,}460 \text{ cycles/sec.}\\ \text{Unsymmetrical} & f = 5{,}730 \text{ cycles/sec.}\end{array}\right\}\text{when } m = 1.$$

For smaller values of the modulation than 1 these frequencies are proportionately higher.

For higher frequencies than that determined by equation *35* the solution may be obtained graphically. However, this is not required except for larger errors of orientation than are likely to occur in practice.

The results of a *graphical* solution of this problem for the *unsymmetrical* type of record expressed in terms of the *wave-shape* and *klirr factor* (coefficient of non-linear distortion) have been published by Frieser and Pistor.[3] A solution for both types of variable-width record was given by E. D. Cook[4] who obtained the coefficients of the Fourier series by a mechanical method.

A graphical construction of the wave-form for both kinds of variable-width records with modulations of $^1/_2$ and 1 is given in Fig. 12 The reproducing image is of *negligible width* so that the effect is that due to obliquity alone. The parallel oblique lines represent various phases of the reproducing image and the slopes correspond to the orientation given in the earlier example and a frequency of 5000 cycles per second. For convenience in plotting, the sound-track of the symmetrical record is drawn twice as wide as for the other record, but they will be compared for the same width and frequency. For this reason the slope of the image for the symmetrical record appears in the figure twice as great as for the unsymmetrical one.

If the width of the image is constant *in the direction of motion of the film* the amount of light that gets through the record is proportional to the vertical distance between the intersections of the boundaries and the image. By projecting these points on the vertical line through the intersection of the image and the line *OX*, the reproduced waves are constructed.

The reproduced symmetrical and unsymmetrical waves are marked *S* and *U*, respectively, and the subscripts refer to the modulation. The figure serves to illustrate certain facts, previously indicated in the analysis. For the unsymmetrical type the wave-form is more

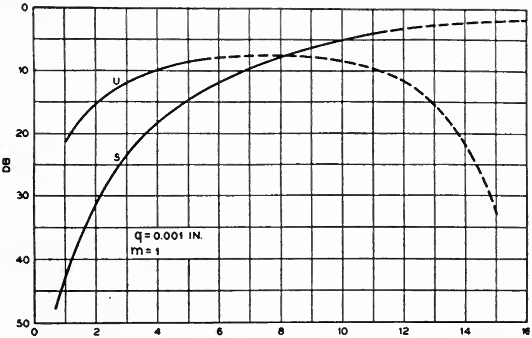

FIG. 9. Second harmonic/first harmonic for oblique reproducing image of negligible width. Modulation = 1.

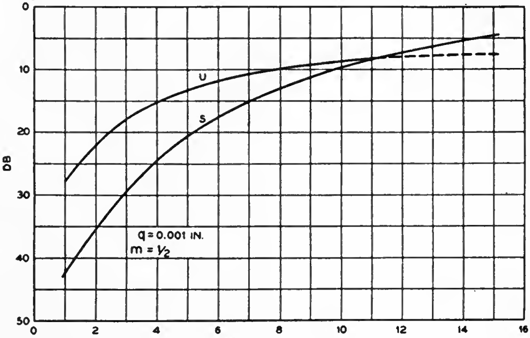

FIG. 10. Second harmonic/first harmonic for oblique reproducing image of negligible width. Modulation = $^1/_2$.

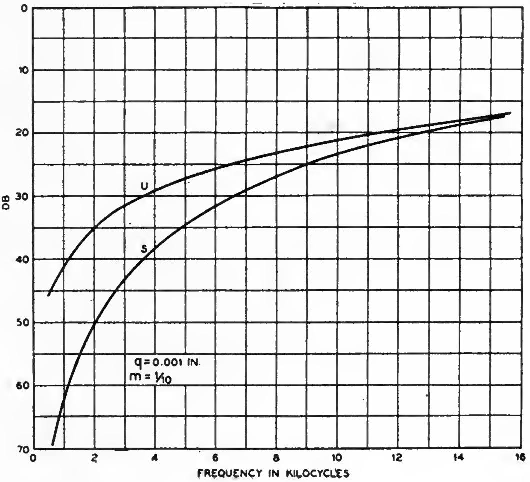

FIG. 11. Second harmonic/first harmonic for oblique reproducing image of negligible width. Modulation = $^1/_{10}$.

dependent on the modulation than it is for the symmetrical type. While the amplitude of the fundamental for the unsymmetrical type is less attenuated, especially at small modulations, the symmetrical type is superior because relatively much less second harmonic is generated.

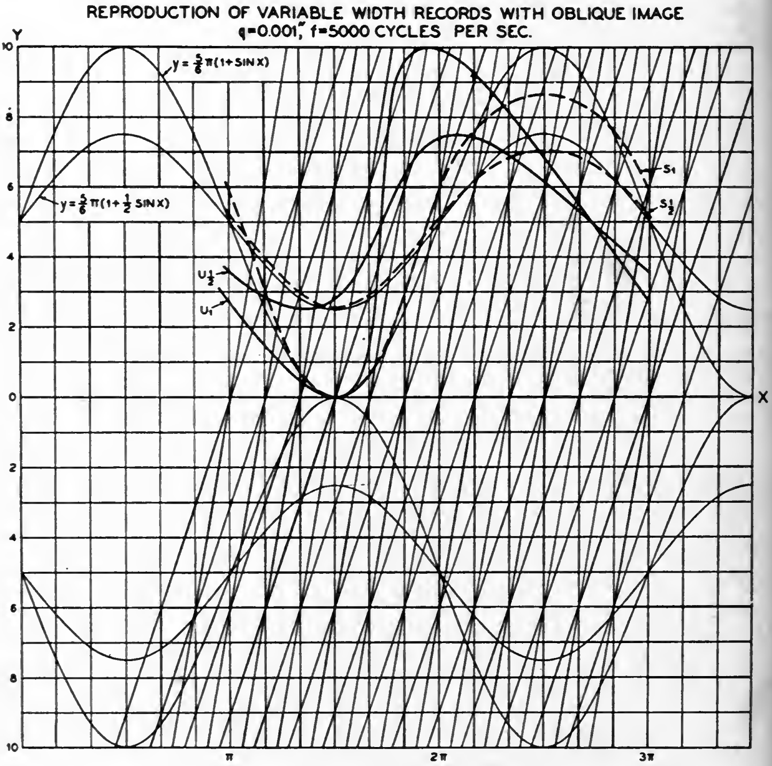

Fig. 12. Wave-form of symmetrical and unsymmetrical records reproduced with oblique image of negligible width. Modulations 1 and $^1/_2$.

APPENDIX

General Case.—Let us inquire now what happens in the case when the wave applied to the recorder is arbitrary.

Following the plan of analysis used in the simpler case, equations *2* are replaced by

$$\begin{aligned} y &= a + am\,\phi\,(x) \\ y &= p\,(x - x') \end{aligned} \tag{38}$$

Eliminating y,

$$x = x' + \frac{a}{p} + \frac{am}{p}\,\phi(x) \tag{39}$$

Let $\phi(x)$ be developable in a Fourier sine-series which is of such rapid convergence that it will be sufficient to consider only the first two terms, thus

$$\phi(x) = \sin x + \alpha \sin 2x + \ldots \tag{40}$$

Equation *39* is of the form

$$E = M + e\,\phi(E) \tag{41}$$

the solution of which is[5]

$$E = M + e\,\phi(M) + \frac{e^2}{2!}\frac{d}{dM}\,\phi^2(M) + \frac{e^3}{3!}\frac{d^2}{dM^2}\,\phi^3(M) + \ldots \tag{42}$$

which gives

$$\begin{aligned} E = M + \sin M&\left\{\left(e - \frac{e^3}{8}\right) - \frac{e^2}{2}\,\alpha - e^3\left(\alpha - \frac{21}{12}\,\alpha^2\right) + \ldots\right\} + \\ &\sin 2M\left\{\frac{e^2}{2} + e\alpha - e^3\left(5/4\,\alpha + \frac{1}{2}\,\alpha^3\right) + \ldots\right\} + \ldots \end{aligned} \tag{43}$$

The solution of *39* is thus

$$\begin{aligned} x_1 = \left(x' + \frac{a}{p}\right) + \sin\left(x' + \frac{a}{p}\right)\cdot&\left[\left\{\frac{am}{p} - \frac{1}{8}\left(\frac{am}{p}\right)^3\right\} - \frac{1}{2}\left(\frac{am}{p}\right)^2\alpha + \ldots + \right. \\ &\left.\sin 2\left(x' + \frac{a}{p}\right)\cdot\left[\frac{1}{2}\left(\frac{am}{p}\right)^2 + \frac{am}{p}\,\alpha + \ldots\right] + \ldots\right. \end{aligned} \tag{44}$$

whence

$$\begin{aligned} y_1 = a + \sin\left(x' + \frac{a}{p}\right)\cdot&\left[\left(1 - \frac{1}{8}\frac{a^2m^2}{p^2}\right) - \frac{1}{2}\,\frac{am}{p}\,\alpha + \ldots\right]am + \\ &\sin 2\left(x' + \frac{a}{p}\right)\cdot\left[\frac{1}{2}\,\frac{am}{p} + \alpha + \ldots\right]am \end{aligned} \tag{45}$$

Putting

$$\eta \equiv am\left[\left(1 - \frac{1}{8}\,\frac{a^2m^2}{p^2}\right) - \frac{1}{2}\,\frac{am}{p}\,\alpha + \ldots\right] \tag{46}$$

$$\psi \equiv am\left(\frac{1}{2}\,\frac{am}{p} + \alpha + \ldots\right) \tag{47}$$

45 becomes

$$y_1 = a + \eta \sin\left(x' + \frac{a}{p}\right) + \psi \sin 2\left(x' + \frac{a}{p}\right) \tag{45'}$$

so that the equation for the reproduced record is evidently

$$y = a + \eta \frac{\sin \epsilon_1}{\epsilon_1} \frac{\sin \epsilon_2}{\epsilon_2} \sin \left(x' + \frac{a}{p}\right) +$$

$$\psi \frac{\sin 2\epsilon_1}{2\epsilon_1} \frac{\sin 2\epsilon_2}{2\epsilon_2} \sin 2 \left(x' + \frac{a}{p}\right) \qquad (48)$$

Here η and ψ are analogous to g_1 and g_2 of equation *34*. In fact if g_1 and g_2 are developed in series we have by definition

$$g_1 = am \left\{1 - \frac{1}{8} \frac{a^2m^2}{p^2} + \frac{1}{192} \frac{a^4m^4}{p^4} - \dots\right\} \qquad (49)$$

$$g_2 = am \left\{\frac{1}{2} \frac{am}{p} - \frac{1}{6} \frac{a^3m^3}{p^3} + \dots\right\} \qquad (50)$$

Thus it is seen that η and ψ contain the g's plus additional terms which depend on α, the ratio of the two harmonics in the applied wave. For the symmetrical case the corresponding equations may readily be derived by adding to equation *48* the same equation *48* with the sign of p reversed.

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THE CHEMICAL ANALYSIS OF HYDROQUINONE, METOL, AND BROMIDE IN A PHOTOGRAPHIC DEVELOPER*

H. L. BAUMBACH**

Summary.—*The usefulness of chemical analysis as a supplement to sensitometric data is emphasized. Distribution ratios for hydroquinone and metol between water and ether are given as functions of sulfite concentration and pH. A new analytical method is presented for the determination of metol and hydroquinone in a photographic solution where the developing agents are "salted out" of the solution at the proper pH by means of sodium thiosulfate and determined volumetrically by titration with iodine. A modified Volhard method is presented for the determination of soluble bromide where the interfering substances are removed by treatment with hydrogen peroxide.*

The value of chemical analysis to determine the constitution of a photographic developer has been demonstrated by Evans[1,2] and others to the extent that periodic tests are recognized as essential to any photographic establishment. While chemical analyses can in no way supplant the more direct sensitometric tests, considerable advantage is secured by the supplementary information. There are many combinations of metol, hydroquinone, bromide, sulfite, and *p*H which yield sensitometric data that are practically indistinguishable but which cause considerable variation in the stability and the behavior of the solutions. Hence, unless periodic checks can be made, the developing solution that is constantly being replenished may become greatly out of balance. In addition, few research and development problems can be undertaken without rapid and accurate analytical methods.

The procedures described in this paper are the result of research carried on in this laboratory to develop analytical methods for the quantitative determination of hydroquinone, metol, and bromide that are readily adaptable to any type of developer, whether positive or negative, new or old. These procedures have been used actively for over a year and thousands of analyses have been made. The

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methods are volumetric and accurate to 2 per cent. With slight modifications this accuracy can be increased, but such procedure is not considered to be worthwhile, since deliberate variations of this extent, when produced in a developer, are without significance sensitometrically.

Analytical methods for the other important ingredients of the developer have been published[2,3] and are used with excellent results.

It has been demonstrated by Pinnow[4] and by Lehman and Tausch[5] that a photographic developer may be analyzed for metol and hydroquinone by so adjusting the *p*H that the molecular forms exist in solution and extracting the agents with an organic solvent immiscible with water, such as ethyl ether or ethyl acetate. Thus, in acid solution only hydroquinone is extracted because the methyl amino phenol forms an acid salt under these conditions, while at a *p*H of 8.5 both agents are removed. On the basis of the two analyses it is a simple matter to determine the amount of each agent present.

Lehman and Tausch used a continuous extraction device for removing the developing agents from solution which, because of the great physical size of the solvent particles, necessitated an extraction period of several hours. In order that the analysis be useful for control purposes, it must be conducted in a much shorter time than this apparatus permits.

It had been hoped originally to analyze a developer simply by shaking a known volume of the sample with a known quantity of ether and using the amount of the agent extracted as an indication of its true concentration, even though the entire quantity can not be removed from the developer in one separation. Accordingly, experiments were made to determine the effect of variables present in the developer upon the distribution ratio of the agents between the two solvents. For hydroquinone in pure water solution, the distribution ratio was found to be independent of the concentration of hydroquinone in the water layer, but such was not the case when other salts were present.

The effect of concentration of sodium sulfite in the water layer upon the distribution ratio is shown in Fig. 1. In this test, the individual volumes of the water layer and the ether-layer were 100 ml and the total amount of hydroquinone present was 0.500 g. The solutions were shaken vigorously for 2–3 minutes at 22°C, allowed to stand until separated, and the contents of the ether layer determined gravimetrically.

Similar tests were made with hydroquinone and metol with the distribution ratio as a function of *p*H, and the results are shown in Figs. 2 and 3. *p*H measurements were made by means of the glass electrode upon the water layer after equilibrium had been reached. The figures show the *p*H values at which the greatest proportion of the agents may be removed in a single extraction.

As the result of these tests it became evident that in order to perform an analysis by this method, it would be necessary to have either a rather complete analysis of the other constituents present in the developer as well as the predetermined effect of each constituent, or else some sort of a calibration curve for each particular developer in question. The latter method is satisfactory only where there are a few basic formulas to be checked repeatedly, but it is in error for otherwise unknown developers or those in which there is considerable variation in salt concentration.

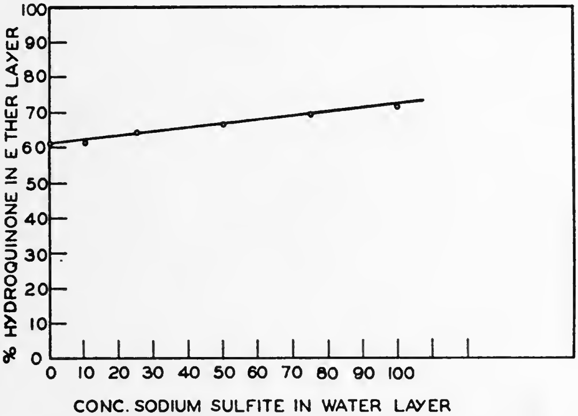

FIG. 1. The effect of concentration of sodium sulfite upon the distribution of hydroquinone between water and ether.

Reference to Fig. 1 shows that, as the concentration of sulfite is increased in the water solution, more of the hydroquinone is removed by the ether layer. This is the familiar "salting out" effect. Other more soluble salts were tried to enhance this effect. Of those possible to use in the developer, sodium thiosulfate proved to be the most satisfactory. Saturation of the water layer with this salt caused the removal of over 95 per cent of both agents by an equal volume of ether in a single extraction. Two extractions are therefore all that are necessary in order to make the separation quantitative.

Developer samples were analyzed for a time by this method, using a gravimetric measure of the quantities of the agents removed. The accuracy was better than 1 per cent on 100-ml developer samples but the necessary drying and weighing operations were so time-consuming that a volumetric method was sought.

Attempts were made to perform quantitative oxidations by using potassium permanganate, hydrogen peroxide, and iodine; only the last was found to be adequate. Lehmann and Tausch used such an iodimetric method by employing a CO_2 saturated bicarbonate solution as a buffering agent, but had difficulty in securing a satisfactory end point, unless the iodine solution was added in excess and the solution back-titrated with sodium thiosulfate because of the polymerization of the metol oxidation products into highly colored substances.

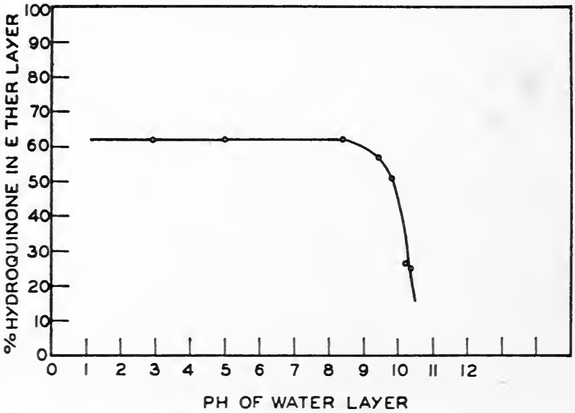

Fig. 2. The distribution of hydroquinone between water and ether expressed as a function of the *p*H of the water layer. The sudden drop in extraction percentage at a *p*H of about 9 is due to the formation of ionic hydroquinone which functions as the developing agent.

The polymerization was found to be entirely prevented simply by having the solution sufficiently diluted with water and adding an alkaline buffering agent, such as disodium phosphate, only as needed to cause the reaction to progress in the first stages of the titration. The titration is as simple and direct under these conditions as any normal iodimetric method. The complete analysis for metol and hydroquinone is performed in 45 minutes. This time can be shortened if desired by duplicating the distillation equipment.

DETERMINATION OF HYDROQUINONE AND METOL

Procedure.—To a 25.00-ml portion of the unfiltered developer sample in a 300-ml separatory funnel, add first 0.5 ml of 0.04-per cent thymol blue indicator, then concentrated hydrochloric acid dropwise until a salmon red color of the dye has just formed. Add a 50-ml portion of ether and enough granular sodum thiosulfate (25 ml of commercial rice hypo) to saturate the water layer.

Stopper the funnel and shake it vigorously for two minutes. Remove the stopper and allow the funnel to stand for several minutes or until separation of the two layers has occurred. Drain the water layer into a clean beaker and pour the ether layer into a clean 250-ml Erlenmeyer flask. Place the water layer back in the funnel and rinse out the beaker with another 50-ml portion of ether which is then added to the funnel.

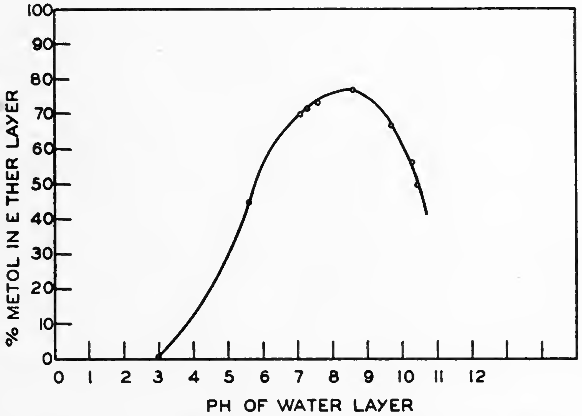

FIG. 3. The distribution of metol between water and ether as a function of *p*H of the water layer. *p*H values lower than 8.5 represent formation of the acid salt and those higher the basic salt. Probably both salts exist in equilibrium at *p*H 8.5.

The first ether extract is poured into a separatory funnel, the stem of which leads into a clean 250-ml Erlenmeyer flask, containing a bit of broken china, from which the ether can be distilled by the external application of a continuous stream of hot water. The second ether portion is treated exactly as the first and is used as a rinse for the surface of the containers that held the first.

When the ether has been distilled from the flask, the vapors are removed by blowing into the flask and the precipitated hydroquinone is washed into a 600-ml beaker by means of three 100-ml portions of distilled water. One to 2 ml of starch indicator and 20 ml of a 10-per cent solution of disodium phosphate are added and the solution titrated immediately with standard $0.1N$ iodine solution. Calculate the hydroquinone content as follows:

2.20 × N of KI_3 × ml iodine used in titration = no. grams hydroquinone per liter of developer.

To another 25.00-ml portion of the developer add the 0.5 ml of thymol blue indicator and conc. hydrochloric acid until the yellow color of the dye has just formed. Proceed exactly as in the first analysis when only hydroquinone was determined, with the exception that the 20 ml of disodium phosphate solution must be added in small portions at first, only as needed to allow the titration reaction to proceed and to allow the methyl amino phenol to be oxidized by the iodine rather than by the oxygen of the air.

Calculate the metol content of the developer sample as follows:

3.44 × N of KI_3 × $(V_2 - V_1)$ = No. grams of metol per liter of developer.
Where V_1 = volume KI_3 for first titration and V_2 = volume KI_3 for second titration.

Notes.—(*1*) It is very important that the flask from which the ether is distilled be absolutely clean. It is necessary to use chromic acid cleaning solution every time the flask is used for distilling a solution of the metol base, otherwise the sample may be oxidized by the air to a dark tar-like product and the determination ruined.

(*2*) All stop-cock greases should be removed from the separatory funnels and water used as the lubricant.

(*3*) A solution of sodium thiosulfate will decompose in acid solution if there is no sulfite present. Practically all developers contain sufficient sulfite to prevent this decomposition and none need be added.

(*4*) Entrance of any of the water layer into the distillation flask would cause an error in the analysis because of the high content of thiosulfate. For this reason the ether layer is poured first into an empty flask, then into the distillation chamber to catch any water particles that may be carried over.

THE ANALYSIS OF SOLUBLE BROMIDE IN A DEVELOPER

The customary method for determining a soluble bromide is that of Volhard,[6] in which the bromide is precipitated by the addition of an excess of silver nitrate. The excess silver salt is determined by titration with a thiocyanate, using a ferric salt as the indicator. When the attempt is made to analyze a developer in this fashion, the silver salt is simply reduced to the metal. Nitric acid can be used to oxidize the sulfite and the developing agents, but the resulting solution is so highly colored that the end point is very difficult to recognize. If hydrogen peroxide is added to the alkaline developer and the solution boiled, both the hydroquinone and the sulfite form colorless oxidation products. The metol is oxidized to a lemon-yellow colored compound which also becomes colorless when the solution is made acid. Under these conditions the regular Volhard method can be applied without interference. The end point is moderately easy to recognize, especially under "daylight" type illumination.

Procedure.—Pipette a 25.00-ml portion of the unfiltered developer sample into a 250-ml Erlenmeyer flask. Add 5 ml (10 ml for negative developers high in sulfite) of 30-per cent hydrogen peroxide and heat the contents of the flask to boiling. The solution becomes amber and finally lemon-yellow in color. Continue the boiling for a few minutes until the excess peroxide is decomposed.

Cool the flask under the tap and add 100 ml of distilled water. Add freshly boiled nitric acid (1:1) dropwise until the solution becomes colorless, then add 5 ml more of the acid.

Pipette 10.00 ml of $0.1000N$ silver nitrate solution into the sample, add 3 ml of ferric alum solution (sat.) and titrate to a salmon colored end point with standard $0.1N$ potassium thiocyanate solution.

Calculate the volume of silver nitrate equivalent to the thiocyanate used, subtract this from 10.00 ml. Multiply by 0.476 to find the amount of KBr in grams per liter present in the developer.

Notes.—(*1*) Some developers contain so little alkali that it is difficult to decompose the excess peroxide by boiling. Such solutions should have 1 to 2 pellets of sodium hydroxide added to the measured solution.

(*2*) Certain developers receiving exceedingly hard use contain so much gelatin that the solution foams when the sample is boiled. It is convenient in this case to have a cold water tap handy to cool the outside of the flask to avoid mechanical loss.

The bromide analysis is relatively simple to perform and can be accomplished in less than ten minutes. The quantities given cover the range of 0–4.75 grams/liter of potassium bromide and may be adjusted to secure the greatest accuracy for the bromide content.

Acknowledgment.—We wish to express our gratitude to the Eastman Kodak Co., West Coast Division, and especially to Messers. Atkinson and Huse of that company for their many helpful suggestions.

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NEW FRONTIERS FOR THE DOCUMENTARY FILM*

A. A. MERCEY**

Summary.—*The motion picture today is the legacy of experimentation of the past. From the still camera to the movie camera, man moved into new realms of record and drama. Thus was evolved the fade-out, the close-up, special lighting, dissolves, and process shots. We had the Melies, the Lumières, the Griffiths, and the deMilles contributing to early production technics.*

The documentary is one of our oldest movie forms, for it means factual photography with the impact of drama. The documentalist takes real people in real places. The 15 years from Flaherty's Nanook of the North *to Lorentz's* The River *represent years of advance in engineering; but those working in the medium recognize many unsolved problems of sight and sound.*

The problems of modern life open exciting possibilities for both the producer and the engineer—problems that will mean new developments in the science of the motion picture. We have great frontiers ahead in the production of documentaries on housing, recreation, the business of food distribution, the problem of raising and obtaining food, communications, the conservation of natural resources, the backgrounds of war—all these offer a challenge to both the engineer and the producer, for in working together they will contribute much to a great art and a great science—the modern motion picture.

I

Any discussion of the "documentary" film should begin with a definition of the term. Unfortunately, defining the documentary is like trying to grasp an elusive piece of verbal ectoplasm. The term has been used both too generally and too narrowly; it has become endowed with all sorts of significance and devoid of any significance whatever.

Although it might seem too superficial to say that documentary film-making is factual photography with the impact of drama, there seems to be little else that is better. The documentary film takes real people in real places and shows factual events, real backgrounds; the entertainment film takes actors on stage sets and portrays a

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 13, 1939.

** United States Film Service of the Federal Security Agency, Washington, D. C.

fictional plot. Many an entertainment film has documentary importance because manners, customs, and social trends are enacted with an accurate sense of reproduction. *They Won't Forget, Dead End, Fury, I Am a Fugitive from a Chain Gang, Our Daily Bread, Street Scene,* and *The Citadel* are some of the entertainment films with documentary attributes.

To free ourselves from the fog of obscurantism we might go further and say that there can be "social" documentaries, "industrial" documentaries, and even "educational" documentaries.

To make any kind of documentary, the camera must be used to put reality on film. This use may result in a variety of methods of camera handling or supervision. The cameraman may combine the functions of the writer, the producer, and the cameraman; he may be producer and cameraman and collaborating writer; or he may participate in filming under the detailed supervision of a director-producer.

Since camera interpretation of social facts is so important in the successful production of documentary films, it is well to remember the flexibility and subjectivity of the camera. This subjectivity to the premise and end desired by the director is quite as important in documentary film-making as in the conventional type of story film, often of greater importance.

Use of the motion picture camera in documentary film-making is a succeeding stage of activity in which the engineer has made and may hope to add his contributions toward better documentaries. Since documentary is defined as reality on film, extraordinary thoroughness must be observed in research. Among other practices, such research may mean the use of manuscript photography and the extensive use of the still camera for field notes. In many cases, the still camera is used so extensively in taking field notes that the producer may have a fairly complete "motion picture" in a series of stills. Here again, the cameraman, using the still camera, must know the objectives of the producer.

Sound notes are often taken in the field preparatory to shooting. We may expect improvement in sound-recording instruments through compact devices, such as recording tape, easily used in editing sound notes for study or production. As the engineer perfects these new field-recording instruments, he will advance the cause of documentary by enabling the producer to study in research form actual sounds of actual places. Such sound-taking offers fascinating opportunities for the inventor, and offers promising material for the producer, anxious always to advance documentary to a state in which reality does not have to be compromised by simulated sounds produced by artificial means.

The job of editing, which may mean more than any other single process in the final interpretation of reality, presents both opportunities and difficulties for the engineer. He must enable the producer to get what he wants on film—photography, music, narration, and sound. The editor must know minutely the wishes of the producer and must adapt all the mechanical contrivances at his disposal to achieve those wishes in the form of a successfully edited film. New uses of music and sound are among the most important aspects in the domain of editorial opportunity.

Robert Flaherty, who made *Nanook of the North* in 1920, and later *Moana of the South Seas* (1925) and *Tabu* (1931), is called the father of documentary film production. Yet Flaherty would be one of the first to recognize the perception of earlier craftsmen who turned the camera on reality. The early films of Melies and the film showing the Lumière workmen leaving the factory were in a sense documentary. Newsreels which have brought us exciting moments in the world's history have high documentary value.

In the last ten years documentary film-making has had a considerable impetus in many parts of the world. People are finding that facts and reality are interesting and exciting and that the camera need not devote its use solely to the glamour and fiction of the entertainment film.

In this country documentary production was given a marked impetus as a result of the release in 1936 of Pare Lorentz's *The Plow That Broke the Plains*. The influence which that picture had on fact-film making was extended by the release of its successor, *The River*. Numerous direct results in terms of technic in film-making have been apparent since the release of *The Plow* and *The River*—the use of functional music, the use of poetic commentary, sequential development, and photography integrated with sound and music. Even Hollywood has felt the influence of these two films; *Variety* has reported that *Gold Is Where You Find It* and *International Settlement* bear the traces of Lorentzian technic. Moreover, Metro-Goldwyn-Mayer has announced that it proposes to produce "documentary" films in its schedule of fewer and better shorts for 1939 and 1940.

Joris Ivens in his *The Spanish Earth* and *The 400,000,000* and Herbert Kline in *The Crisis* have taken factual material and turned it into eloquent and interesting documentary films. *The City*, a story on city planning released at the New York World's Fair, promises to be a genuine contribution to documentary film-making. This production,* which is being made on an original treatment prepared by Lorentz, marshals facts and ideas on one of our current social problems in persuasive fashion.

In short, the documentary film in this country is assuming increased importance as a medium for use by the entertainment and educational screen. This growing importance invites the attention and the talent of the experimentalists from the ranks of the engineers and technicians.

No citation of documentary development is complete without mention of the *March of Time*. This screen treatment has earned a deserved reputation in reporting events and their background in contemporary affairs. The documentary attributes of the *March of Time* are especially emphatic in such releases as *Inside the Maginot Line, Prelude to Conquest, The Mediterranean: Background of War, Refugees—Today and Tomorrow, Uncle Sam—Good Neighbor,* and *G-Men of the Sea,* which depicts the United States Coast Guard. Even in the calling of these titles there appears a subtle gradation in the documentary aspects to be defined.

The question remains: what interest has the engineer in the development of the documentary form? How can he contribute to its progress? What can he do to assist the producer in translating his interpretation of reality into effective screen form?

The engineer has been the pioneer of new trends in the advance of the motion picture. He has been the trail-blazer for the producer, who has always been handicapped by the strictures of mechanical limitations. The excitement of new conquests in the realm of the scientific unknown has stimulated the engineers in the past to bring

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* Ralph Steiner and Willard Van Dyke, directors and photographers of *The City,* worked with Lorentz on his documentaries; Steiner as a cameraman on *The Plow* and Van Dyke as a cameraman on *The River.* Other credits for *The City:* presented by Civic Films, Inc.; produced by American Documentary Films, Inc.; scenario written by Henwar Rodakiewicz from original treatment by Pare Lorentz; narration written by Henwar Rodakiewicz and Lewis Mumford; original musical score by Aaron Copeland; associate cameramen Roger Barlow, Edward Anhalt, and Rudolph Bretz; edited by Theodore Lawrence.

movement to the still camera, to bring sound to the silent screen, to bring color to the black-and-white film. No one disputes the attraction of yet unconquered domains.

New devices, new instruments, new methods, resulting in continued emancipation of expression, will come from the unceasing efforts of the experimentalists. The meetings and discussions of the Society of Motion Picture Engineers are evidence that new and exciting contributions will continue as direct aids to better production technics. Moreover, as the documentary producer tackles hitherto untouched subjects, he will be confronted with new problems in translating technics, and here again the engineer will be his immediate ally.

II

What are some of the immediate opportunities for documentary production which will challenge the best efforts of both the engineer and the producer? The following topics are suggested:

Conservation of Natural Resources.—This general topic offers countless opportunities for creative expression. For example, someone might suggest in color-sound-film what the great Audubon did in his monumental *Birds of North America.* New technics in color photography and sound recording would be tested in getting on film some of the elusiveness of our migrant songbirds. Someone might complete the weaving of the pattern of the rivers of America begun by Lorentz with the Mississippi—for the Kennebec, the James, the Powder, and the Wabash too have their former glories, their traditions, their songs, their part in the life of the people.

Production and Distribution of Food.—Depicting, dramatizing, and disclosing the multiplicity of activities incident to feeding the nation give the most ingenious producers and engineers a challenge. For in these processes are found the essentials of machine-age living. Man's whole predisposition for survival is apparent in the modernized forms of obtaining food and placing it on the table of the ultimate consumer.

Communication.—The evolution of man's efforts to communicate ideas is a saga filled with endless fascination. To the simple methods of writing and printing we have added the telephone, the radio, the motion picture, and television. America has no great documentary on the telephone or the radio, nor, ironically enough, on the movie. We need a *Voice of America* for radio and telephone interpretation.

A real documentary on the growth of the motion picture would itself offer a challenging opportunity for originality in production and technics, for sound engineering and color photography.

Transportation.—Man's conquest of space and time through transportation has been an index to his civilization. Yet we have no great film epic in America on transportation. And America has developed transportation to extraordinary proportions in terms of the streamlined train, and the Yankee Clipper, the modern automobile.

Health and Medicine.—The story of the constant fight for survival on a hundred fronts is today one of our most fascinating undepicted dramas. In the laboratory unsung researchers anxiously watch the progress of experiments in test-tubes and peer intently at the slides under their microscopes—the spade work of the fight against disease and death. The development of micro- and *x*-ray photography makes accessible hitherto unknown worlds.

Scientific Research.—This is the age of science and the army of scientists moves forward in a constant battle to better the human race, to conquer time, to perfect new labor-saving technics, to discover new alloys, to perfect devices for the reproduction of voice and sound; to improve safety in transportation; to better our living conditions. The scientific field offers exceptional opportunity to utilize color, sound, photography, music, and production technics. Specifically, why should the film make a study of light refraction in terms of black and white when there is the fascinating possibility of showing color in the spectrum?

Economic and Trade Relations.—Unsettled trade relations and ill-adjusted economics in national and international affairs bring suffering, hardship, and war. The film can help the cause of peace by showing dramatically the maladjustments and some of the complexities of national and international trade; by suggesting what some of the remedies might well be. Sane economics mean peace; bizarre economics mean war. The film can do much for the accomplishment of peace through promotion of understanding. Increased interest in South America opens new vistas for documentary production on Pan-American topics. We should implement a "Good Neighbor" policy by the production of films which show us the life, music, customs, and activities of the Latin Americas. We in turn should show the South Americans documentaries on life in the United States.

Democracy.—America has a rich heritage of democracy, the result of the work and sacrifice of generations. With totalitarianism rampant throughout the world, the documentary film can do much to strengthen democracy through dramatizing its accomplishments in terms of today's problems. A philosopher* said in his own time that "The great problem of our time is the organization of the proletariat into social system." What medium has done more, what medium, directing its appeal to two senses, has more opportunity for achieving this integration and organization? The film is the instrument of evolution which affects both the minds and emotions of man.

Folkways and Folk Songs.—So few people know the rich and diverse heritage of America in song that one might well say that no one knows. But through the medium of the film—with sight and sound—the songs of Georgia and Tennessee and Kentucky can be known by the lumberjacks of Michigan and Wisconsin; the songs of New England—the *Jesse James,* the *Doggetts' Gap*—can be heard in Santa Fe. The disembodied voice of the radio is not enough; the Pennsylvanian miners must see the Texan's face as he sings, for through knowledge comes understanding, and we *know* what we *see* and *hear.* The film is the logical successor to the telephone and the automobile in establishing this cohesion of the people.

The Virginian in the spring of 1934 saw the layer of dust on his table, but *The Plow That Broke the Plains* showed him that there were people bereft by that dust, and it became more than an incident, it became more than a layer of dust on the table.

America is rich in festivals, native and adopted. To put on soundfilm some of America's most colorful festivals would be to give America a real contribution of native expression. The producer might go behind the panoply of the festival and examine the roots of these expressions, for in the background would be found ideas worthy of preservation and interpretation in the documentary film.

Labor.—How many of us know intimately, clearly, and well—how many of us *understand* the emergence of labor about which so many words are spoken and written and shouted from the dais? When we dramatize, we clarify, we point up, we catch the essence of—and by a dramatization of the Molly McGuires, by a faithful pictorialization of the automobile workers, by a portrayal of the timber

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* Auguste Comte, 1798–1857.

workers, we would contribute much to the understanding of all the people.

Television Shorts.—The field of television opens up an entirely new field for exhibition and use of documentary and short subject films. While sponsors of television have yet to determine the type of film most adaptable for television use, some have already said that the short subject is preferable. In this field the short subject of documentary type finds an especially good reception. Radio surveys are unanimous in voting dramatized news broadcasts among the most popular. If you couple reality (news) with film and exciting interpretation, you should have what would be an unmistakably effective contribution to television.

These suggestions are a few of the new frontiers for documentary production which have not been developed. The engineer has a tremendous stake in their conquest. He must continue his experimentation; he must take pride in his legacy from the great figures of the past. He must in the tradition of Daguerre, Edison, Melies, Pathe, the Lumières, Gaumont, and Cohl, push back the boundaries of the unknown, for in his wake will come the producer ready to work with and use the results of his efforts in bringing the motion picture to new heights of effectiveness and reality.

For "the man who makes the experiment deservedly claims the honor and the reward."*

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* Horace, *To Scaeva.*

SAFEKEEPING THE PICTURE INDUSTRY *

K. W. KEENE**

***Summary.**—The purpose of this paper is to deal with a very specialized phase of the motion picture industry; that is, its hazards of fire and consequent accident, as due not solely but chiefly to the prevalent use of nitrocellulose film. Consideration is given to the causes of hazards and an attempt made to show that they are real and what is being done about them.*

The many organizations and groups concerned with and supporting the cause of fire prevention and protection in the industry are described briefly as to their basic organization and methods, and are then correlated.

As distinguished from the recommended Regulations of the National Board of Fire Underwriters and the National Fire Protection Association, which in general specify the safe methods of installation and use of needed safeguards for apparatus and equipment in the field, the Standards of Underwriters' Laboratories specify the safe construction and performance of apparatus and equipment, and are applied and "policed" in the producing factories.

The paper concludes with a discussion of some of the underlying considerations affecting the Standards of Underwriters' Laboratories as applied to projectors, rewind machines, sound amplifiers, speakers, etc.

The United States of America is the most hazardous nation in the world—potentially. This is merely another way of saying that the United States is the most industrialized nation. Unfortunately there is a close tie-in between industrialization and hazards of fire and accident. An industrial nation produces and uses more articles, more in quantity and more in variety, among which are those capable of producing hazards; and second, once the fire starts, the industrial nation exposes to damage concentrations of high values both in life and property.

The motion picture industry is one of the more hazardous industries. The 1937–38 record of the N. F. P. A. on fires of over $50,000 damage shows three for studios and exchanges which total nearly $400,000 and five for theaters which total over $400,000. Actually this record is a very great improvement over the record of ten and

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** Underwriters' Laboratories, Inc., San Francisco Calif.

more years ago, and should be credited to the fine coöperation of yourselves, the Motion Picture Producers and Distributors of America, Inc., and other organizations.

If our country is not actually so very dangerous it is due to the successful efforts of the forces of fire prevention and protection. These forces are many and time will permit only brief mention of a few.

It will be obvious why insurance companies have been the pioneer discoverers and preventionists of hazards. It is their dollars that are burned up, and a costly insurance rate is recognized as not "good business." Back in 1866 the stock fire insurance companies organized and launched the National Board of Fire Underwriters. The National Board today is an educational, engineering, statistical, and public service organization. It publishes and makes available a large amount of material having to do with hazards; some 70 or 80 of their publications being known as the "Recommended Practices" for various industries or processes. Its engineers survey cities with regard to fire department personnel and equipment, alarm systems, building constructions, occupancy and zoning, water supply, *etc.*

Not the least important of the Board's activities, is its actuarial record of fires in the numerous classifications of insurance risks. Such records are of inestimable public benefit, especially with respect to the formulation of regulations for controlling hazards.

By 1894 the nation had become quite industrialized, and among the causes of the many fires were faulty design and performance of materials and equipment. Hence, the need arose for a testing laboratory, and the institution that was established, again by the stock fire companies, was Underwriters' Laboratories, Inc. Although in the course of time Underwriters' Laboratories became self-supporting, its sponsorship by and its coöperative relations with the stock insurance as well as with other groups having kindred interests remain. It is a non-profit organization whose function is to apply the scientific viewpoint and principles to the hazards of fire, casualty, and crime; to develop standards of construction and performance; to conduct examinations and tests for manufacturers and others under the appropriate standard and to make known the results therefrom. In short, it is the laboratory of Prevention, Detection, Protection, and all other fronts against Fire, Accident, and Crime.

In 1896 came the National Fire Protection Association: This is the popular organization whose membership or associate membership is open to anyone having an interest in fire prevention. Among its valued members are the Society of Motion Picture Engineers and the Motion Picture Producers and Distributors of America, Inc.

The purpose of the N. F. P. A. is to promote and improve the methods of fire prevention and protection, and to obtain and circulate information on the subject. To these ends, a staff of engineers surveys cities and the findings, good or bad, are publicized. Also functioning continuously are numerous technical committees. At the present time there are nearly 50 of these committees and all work toward the development of "Recommended Practices" so that this or that industry or process may be duly safeguarded. In any given committee, the personnel is made up of those best informed about the particular subject.

Nitrocellulose is the nightmare of the safety engineer. It ignites easily, even spontaneously, burns rapidly, produces much heat per pound, supplies of itself the chemicals needed for combustion and, especially when burning in a restricted supply of oxygen, produces lethal gases. There are different kinds of nitrocellulose having somewhat different characteristics, but the apparent ignition point may be taken as about 105°C. Film stock held in the beam of a high-intensity arc light will ignite with explosive violence in about $^1/_4$ second. A tightly wound reel will continue to support combustion even under water, but this is not to say that the cooling effect of plenty of water on a film fire is not very beneficial in retarding or stopping the spread.

With reference to the products used by the motion picture industry, what are some of the safety requirements that Underwriters' Laboratories applies to them before they leave the factory and before they can be listed or approved?

Projectors, installed in a booth which is itself sometimes quite hot, take nitrocellulose film stock and apply a hot beam of light to it. So the first step is to try to guard against ignition from the beam. The automatic shutter which closes down in case of subnormal machine speed is required. Also on the present-day machines, the placing of the shutter between the head and the lamp has been a decided advantage. This advantage, however, may have been partly or wholly neutralized by the use of higher-intensity lamps.

In dealing with projectors, the position is taken that film ignition may occur within the head due to film breakage or some mechanical or human failure. Thereafter, the most interesting parts of a projector are the upper and lower fire rollers. These are tested to see that a fire in the head will not communicate to the magazines. Twenty-five feet of film is placed within the head, with ends terminating within the magazines. The film is then ignited at the aperture and the doors are closed. The criterion is, of course, whether fire passes the roller into either magazine.

This is a stationary test and admittedly leaves something to be desired by our engineering idealism. However, in consideration of the satisfactory record of fire roller failures, the practical difficulties of designing rollers that will be effective under all conditions, and the third line of defense which is the vented fireproof booth, the present-day fire roller is probably good enough.

There are many other requirements of varying importance which are applied to projectors. Magazines are for protection of film. They must be of 22-gage steel or other approved metal; must not depend on solder; must fit a projector or sound-head so that film will not be exposed; and must have tight-fitting doors provided with a positive latch. Perhaps someday, it will be desirable to vent projector magazines into one of the existing ventilation systems so that products of decomposition or combustion can not be liberated into the booth.

Arc lamps must have housings not lighter than 24 gage which enclose all electrical parts; must have provision for ventilation; must be arranged to retain sparks within the housings; must prevent any possibility of "grounding" the carbons; must have doors hinged and latched; must have a douser to shut off the beam of light; must employ mica or other high-temperature electrical insulating material; must preclude the possibility of "bridging" dielectric spacings with carbon dust; must provide the flexible "motion picture cable" for connecting leads. Motors are investigated as are other applications of motors, under the Standard for Motor Operated Appliances.

Film-storage cabinets must provide a liberal ratio of vent area to storage capacity; must have an interior space not larger than ten cubic-feet; must not provide for storage of more than 375 pounds of film per cabinet; must provide individual doors or covers for each compartment which are practically smoke-tight; must be thermally insulated so as to prevent communication of fire from within one cabinet to others.

Inspection machines must have magazines and fire rollers as effective as those required of the projector. Inspection machines may expose not more than 5 feet of film. Simple rewind machines must fully enclose all film during the rewind process.

Motors and the various units of sound recording and reproducing systems are examined and tested under appropriate standards. The interest in all electrical equipment is to see that its design is such that fire will not start and to see that enclosures and housings protect the contained apparatus from outside damage and also protect persons from shock. Equipment must be capable of being installed in accordance with the rules of the National Electrical Code.

In addition to adequate housings and the electrical grounding thereof, materials of construction, both electrical and mechanical, must possess characteristics suited to the application; combustible materials must be kept to the practical minimum; wireways must be smooth; connections must be tight and workmanship in general good; spacings of uninsulated parts and the dielectric strength of materials must be sufficient to withstand the applied voltages plus a factor of safety; operating temperatures must not exceed the prescribed limits of materials used.

These brief capitulations of the salient interests in motion picture apparatus will serve to give some idea of what it is that Underwriters' Laboratories expects of apparatus before it can be listed or approved.

Here is one reason why this country is actually a safer place today than it was before the turn of the century—a fact proved by the downward trend of fire losses.

Perhaps some of you heretofore have known of "The Underwriters" as a far-away something or somebody doing things that are remote from your own world and affairs. If so, it will be hoped that these remarks will introduce to you forces for safety in our technological civilization whose influence is and always has been very close to you.

The methods employed in this endeavor are wholly coöperative and it must be agreed that the fundamental picture of volunteer associations, companies, departments, *etc.*, making common cause against the dangers of fire or accident is unique and American.

NEW MOTION PICTURE APPARATUS

During the Canventions of the Society, symposiums on new motion picture apparatus 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 NEW MAGNETIC RECORDER AND ITS ADAPTATIONS*

S. J. BEGUN**

The characteristics of magnetic recording have been frequently explained.[1] It may be well, however, to elucidate in which respects the method of magnetic recording distinguishes itself from film and disk recording methods. Briefly, film recording makes use of an optical process. The sound-track is photographed on the film and is reproduced by a suitable photoelectric device. The film method requires a development process and does not afford the advantage of immediate playback. Disk or mechanical recording requires either cutting or embossing a groove modulated with sound frequencies. Record materials have been developed which permit instantaneous playback of such recordings, but only in limited numbers. Film and disk recording do not offer facilities for canceling a record once it is made, and making a new record requires new material. If a mistake occurs while recording, the record material is lost. Disk records, as well as film records, have but a limited life. Only a definite number of playbacks can be made without noticeable effect upon quality.

In recent years, considerable progress in this respect has been made with disk recording. Pick-ups with very little needle pressures which lessen destruction of the record have been developed. Nevertheless, the acetate recordings which are chiefly used for direct recordings have a limited life for practical purposes because the acetate coating is soft and can be easily destroyed.

Forty years ago, long before the day of sound-on-film, Waldemar Poulsen conceived the idea of magnetic recording. However, the phonograph, which was already available, was simpler, and more adequately met the existing needs. In recent years, the inherent advantages of magnetic recording again aroused an effort to apply it to fields where other recording methods were unable to offer the same service.

It is interesting to note that in a short period of recent development work it has been possible to bring magnetic recording to a stage of quality which is compar-

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** Brush Development Co., Cleveland, Ohio.

able to that of film and disk recording. This foretells a future of further extensive developments in magnetic recording, both as to quality of reproduction and to variety of uses.

The principal distinction of magnetic recording resides in the fact that the record may be obliterated at any time and replaced by another one without any loss of material; and that the same record may be reproduced any number of times without noticeable effects on quality or level. It is easy to see that a magnetic record can be obliterated either by magnetic saturation or by demagnetization of the sound carrier. It is more difficult to understand that the same record can be reproduced over and over again without substantial loss in quality or level. Actual measurements of properly made magnetic recordings played over a quarter of a million times, show that after the first few thousand playings, the reproduction of the record reaches a permanent value, which for average speech, is about 5 decibels below the level of the first reproduction, without loss in quality. Thereafter no changes in quality or level can be observed. Fig. 1 is a graph showing the relation between level of reproduction and the number of playings. Magnetic recordings made as early as 1903 have suffered no appreciable change.

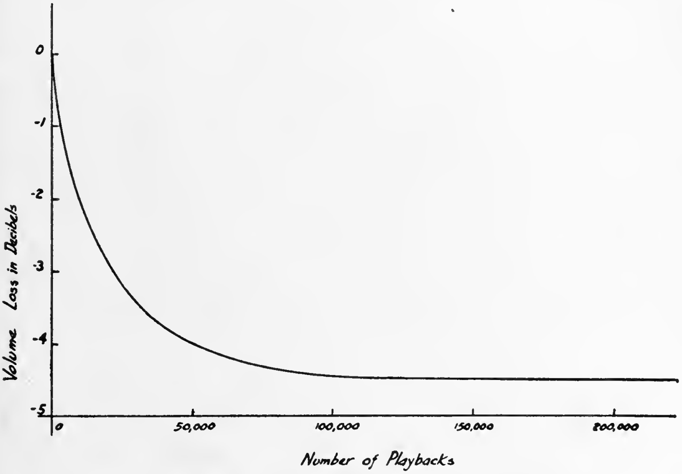

FIG. 1. Effect of continued playing upon volume.

Coiling of the magnetized tape does not affect the record if the tape is not excessively bent. Successive portions of the tape brought into actual contact do not affect the recordings. In fact, most of the magnetic recording machines now being used in European broadcasting stations have tape wound like film, layer upon layer. In spite of this handling no decrease in quality takes place.

The permanence of the record and the possibility of repeatedly recording on the same magnetic material are of particular value in applications where recordings either have to be frequently changed, or where it is desirable to reproduce the same record a great number of times. Among many others, the educational and the advertising fields appear to offer the most obvious applications of magnetic recording.

The impression which the external appearance of an individual makes on others is an important factor in his success. Almost every person living in the western hemisphere glances at a mirror at least once a day. We deem it worth great effort and expense to appear in correct attire and to make a good visual impression. And, almost of equal importance is the impression which one's voice makes on others. This realization is responsible for the great interest taken in speech and voice education.

At present, most persons know as little about their voices as they would about their appearances had they no opportunity to look into a mirror. The voice sounds very different to oneself from the way it sounds to others. A machine which immediately reproduces the voice, as a mirror reflects the appearance, can fill a great need. With such a machine it would be easy to cultivate pleasant voices. No one having a normal articulation mechanism need have an unpleasant voice.

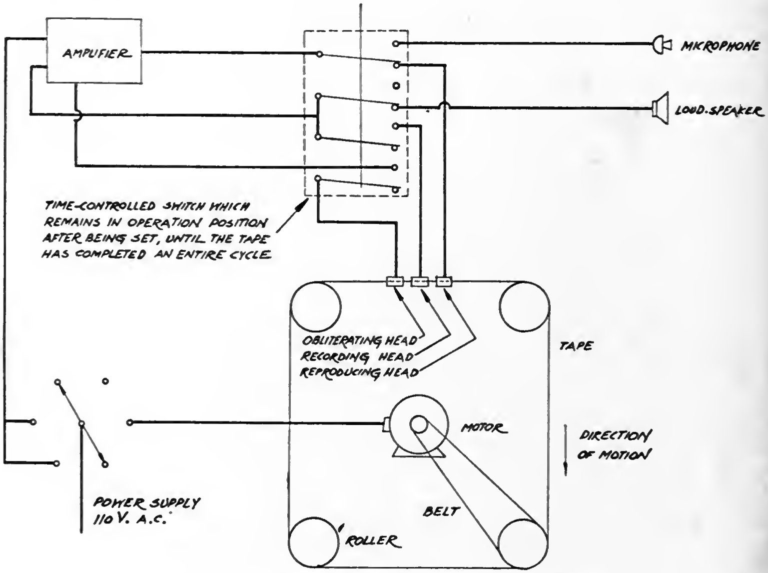

FIG. 2. Schematic diagram of tape recorder.

From this point of view, any instrument able to reflect the performance of our voices as simply as a mirror must have great educational value. Magnetic recording may be utilized to serve as a sound mirror. Such a sound mirror must, of course, be very simple.

Fig. 2 is a diagram of a practical sound mirror. An endless magnetic tape, good for a 30-second recording, is guided over four rollers. A motor drives one of the rollers through a belt. Magnetic heads for obliterating, recording, and reproducing engage one loop of the tape. The contacts of a control switch connect the magnetic heads, the microphone, and the loud speaker to the amplifier. In the neutral position of the control switch, the record is reproduced. When the control switch is rotated it establishes the recording connections and a recording is made. Upon completion of a 30-second recording, the reproducing connections are automatically reëstablished and the new recording is again continuously reproduced. The power switch in the *on* position energizes only the amplifier; in the *run* position it also energizes the motor. At the corners of a rectangular frame are mounted rollers upon which the long endless tape is wound as a helix. The last tape loop is connected to the first tape loop by a cross-over roller arrangement. The various magnetic heads are mounted on the cross-over roller bracket. Small guide bars evenly space the individual spirals of tape.

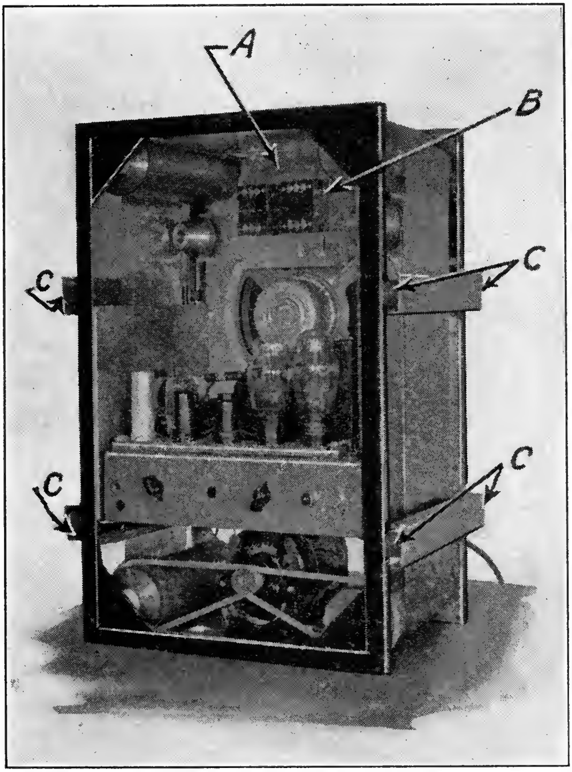

FIG. 3. Rear view of one type of tape recorder, showing location of parts.

Fig. 3 shows a rear view of the machine with the motor, amplifier, and speaker. The roller frame arrangement allows ample mounting space inside the frame for the amplifier, speaker, and motor. The cross-over bracket which connects the last layer of the helically wound tape with the first layer is indicated at *A* in Fig. 3. The recording and pick-up head is located on the cross-over bracket at *B*. The entire assembly is suspended on rubber blocks indicated at *C*, and floats freely within the cabinet. This method of suspension prevents external vibration from affecting the machine.

Fig. 4 shows the machine mounted in its cabinet. The amplifier control panel is exposed through an opening in the cabinet, as shown. The control switch handle is normally retained in its reproducing position, indicated by zero on the surrounding dial. The dial is calibrated in seconds, from zero to 30. A slight turn of the handle to "30" starts the recording, and its progress is indicated by the motion of the handle along its dial.

FIG. 4. View of tape machine in cabinet.

The magnetic reproducer herein described can be used for repeating announcements without any modification. After the record has been made, the machine will reproduce this record any number of times without attention.

Magnetic recording should be particularly applicable for advertising applications because of its flexibility and its practically unlimited capacity to repeat the record and thus draw continuous attention. It may also be mentioned here that without complications the machine may be readily synchronized with a picture-changing mechanism. Where repeated announcements are of value for moving vehicles, magnetic recording and reproducing are ideally suitable since mechanical vibration has no effect either on recording or reproducing, as will be pointed out later.

The machine can be used also for time-delay purposes. This application seems to be of some importance for broadcasting stations since speakers occasionally employ an objectionable phrase or statement. By providing a small time difference between speaking and transmitting, a supervisor could eliminate a phrase or a few sentences from the air without interrupting the speaker, and probably without the knowledge of the radio audience. In this particular case the tape passes successively through the reproducing head, the obliterating head, and the recording head. If recording and reproducing take place in natural sequence a word uttered by the speaker will be delayed for the time necessary for the tape to complete one cycle. This time can be made sufficiently long to give the supervisor a chance to eliminate the word or sentence or as much as he desires.

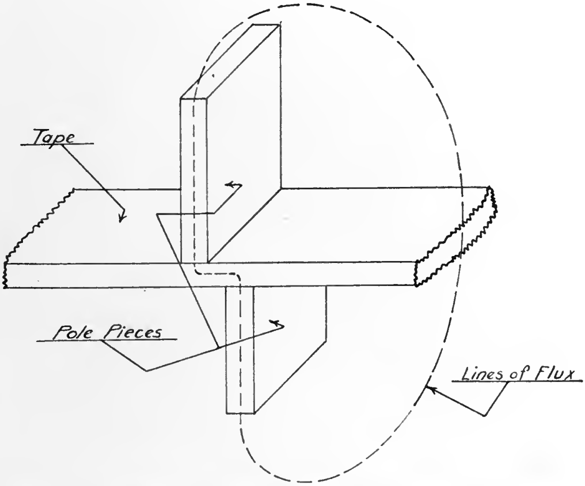

FIG. 5. Schematic view of section of tape and pole pieces, showing magnetic circuit

The machine may also be used for synthetic reverberation by providing any number of adjustable time-delays. This method of synthetic reverberation control has already been described in the JOURNAL by Wolf.[2]

Call systems of various kinds can also utilize magnetic recording to good advantage. For example, many hotels and factories call guests or employees to the phone by means of a call system. The tape recorder is ideally suited to paging the desired name or names at intervals until the individuals answer the phone. This system relieves the operator from the purely mechanical task of repeating the name or names, and leaves her free to attend to more exacting tasks.

Actually, it is impossible to enumerate the many varied applications of this type of machine. Almost everyday new uses are thought of.

This magnetic recording machine distinguishes itself by reason of its great simplicity, flexibility, and sturdiness. The steel tape is $^1/_8$ inch wide and 0.003 inch thick. It is highly polished and the edges are rounded to prevent injury to the operator should he bring his fingers against the moving tape. Breakage of the tape is almost impossible except when the tape is damaged by a very sharp bend. The elastic limit of the tape is in the neighborhood of 60 pounds and the breaking strength, even at the point where the ends of the tape are joined by welding or soldering, is 80 per cent of the tape strength. The tension of the running tape is actually less than two pounds, thus providing an enormous factor of safety. Life tests have shown that the same tape can be used millions of times. Finer tape could be used, of course, and is available on demand. This finer tape makes it possible for a longer length of tape with longer recording time to be accommodated on a given frame.

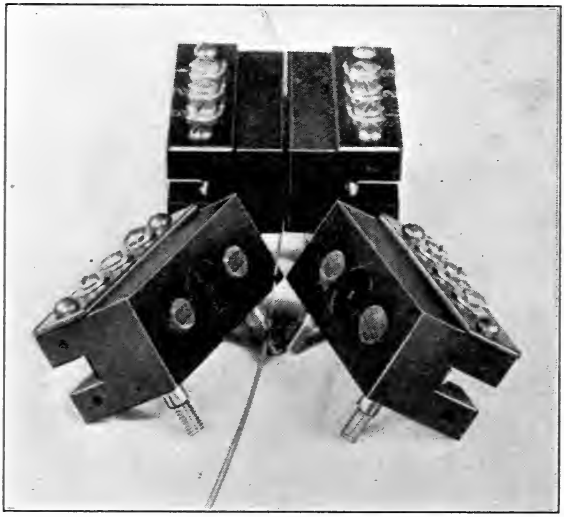

FIG. 6. Magnetic heads, showing how tape is threaded through them.

Another remarkable distinction of such magnetic recording machines is the fact that recording and reproduction may take place while the machine is subjected to severe mechanical vibration since none of the factors involved in the recording and reproducing process can be upset by mechanical vibrations. On the other hand, both disk and film recording require a delicately adjusted recording and pick-up system, which is directly or indirectly very sensitive to external mechanical vibration. In tests of this kind unbiased observers could not detect any difference in quality even when recording and reproduction were carried on while the magnetic recording machine was violently shaken and rocked about.

To protect the tape against moisture it is kept lubricated by being continuously passed over a bar of felt saturated with oil.

In a typical machine in which the tape is moving $3^1/_2$ feet per second, the frequency response is essentially flat up to 5000 cycles, and thereafter starts to drop slowly. The speed of the tape may be adjusted in accordance with the required quality. For many purposes sufficiently good quality may be gained with slower tape speeds, and consequently longer recording periods, with the same length of tape.

The machine described here uses longitudinal magnetization, in which the tape is magnetized in the direction of its motion. This is done by placing the two pole-pieces slightly offset on opposite sides of the tape so as to coerce the flux lengthwise of a tape element, as shown in Fig. 5. The flux, therefore, follows the path indicated by the dotted lines. Fig. 6 shows the magnetic heads, and indicates how the tape is threaded through the heads.

The machine is available with either a single channel or a push-pull amplifier. The push-pull amplifier, of course, results in somewhat lower harmonic distortion and better quality.

The ratio of signal level to noise level is in the neighborhood of 38 db. A 10-inch loud speaker is ordinarily used, but better quality may be obtained by employing a larger speaker in a larger cabinet.

Extensive tests have proved that the machine requires very little service. Once adjusted the magnetic heads remain in constant adjustment. The effective contact area of the pole-pieces in relation to the tape remains unchanged during prolonged use, and ordinarily they do not have to be changed more often than the tubes in the amplifier. Felt pieces provided along each guide bar keep the tape free from dust and dirt and prevent the magnetic heads from becoming clogged with foreign substances. Each part of the machine is easily accessible, and parts are interchangeable. Any required servicing is simple. Anyone, without the slightest technical knowledge, is able to operate the machine without danger of damage.

At the present time, two steel tape recorders are being marketed by two separate companies, under the trade-names "Sound Mirror" and "Voice Reflector."

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BEGUN, S. J.: "Magnetic Recording-Reproducing Machine for Objective Speech Study," *J. Soc. Mot. Pict. Eng.*, **XXIX** (Aug., 1937), p. 216.

[2] WOLF, S. K.: "Artificially Controlled Reverberation," *J. Soc. Mot. Pict. Eng.*, **XXXII** (April, 1939), p. 390.

DISCUSSION

MR. RYDER: Do I understand that the signal-to-noise relation is 38 db?

DR. BEGUN: Yes.

MR. JACK: What is the source of ground-noise?

DR. BEGUN: The vibration of the pole-pieces. This vibration can be caused by the roughness of the tape surface as the tape slips between the pole-pieces. By using a special method of securing the pole-pieces, this vibration can be very much reduced. Another reason for the background noise is lack of uniformity of the tape. The tape can be treated to overcome this effect, but the treatment is very critical and expensive. By the use of such treatment, and a better method of securing the pole-pieces, the dynamic range of the machine can be increased experimentally to approximately 60 db. In this particular application, however these procedures have not been applied. The tape is just as it comes from the mill, and is not quite uniform.

MR. KENNEDY: What is the frequency response of this machine as demonstrated?

DR. BEGUN: This machine has a frequency response of ±2 db between 150 and approximately 5000 cycles.

MR. KENNEDY: Have you made any measurement of the harmonic distortion?

DR. BEGUN: We have made recordings containing approximately three per cent harmonic distortion. The harmonic distortion can be suppressed by various methods.

MR. KENNEDY: Would not the amplitude distortion be greater at the higher frequency?

DR. BEGUN: No. Most of the harmonic distortion is in the lower range.

MR. SEILER: Is the tape in contact with the pole-pieces, or is there an air-gap to prevent wear?

DR. BEGUN: The pole-pieces are actually in contact with the tape. The tape is not subjected to any wear. The pole-pieces are made of very soft material, so if anything wears it will be the pole-pieces.

MR. STEVENS: What is the longest recording you can make with the models you now have?

DR. BEGUN: We can make three-minute recordings without any difficulty, on the same frame. On a little larger frame we can record up to fifteen minutes. Longer recording times can be accommodated on the same frame using a special method of winding the tape.

MR. MCRAE: Is it possible for this machine to reproduce 12,000 cycles by moving the tape faster?

DR. BEGUN: Yes.

MR. MCRAE: How fast must the tape move?

DR. BEGUN: That depends upon the character of the tape: perhaps about six feet a second.

MR. KENNEDY: Does the tape width influence the amplitude distortion?

DR. BEGUN: The amplitude distortion depends upon the thickness of the tape, not the width. The thinner the tape the better the quality.

MR. KENNEDY: Have you found that the recording and reproducing of high frequencies is a function of the angular relationship of the pole-pieces to the tape?

DR. BEGUN: Everything depends upon the adjustment of the pole-pieces. This instrument has a special fine adjustment for the pole-pieces.

MR. ROSS: What is the possibility of permanent or semipermanent records; in other words, after recording, can the tape be wound and left for any considerable length of time without possible distortion?

DR. BEGUN: Yes, the tape can be coiled on reels and stored for years without any danger of changing the quality of reproduction. The oldest record available to me was made in 1903. It was made of steel wire, and, of course, the quality was bad, but the reproduction was good and it could be repeated as many times as desired. The British Broadcasting Company has been using tape machines for all short-wave work and the records can be stored for years without any danger of changing the quality of reproduction.

MODERN INSTANTANEOUS RECORDING AND ITS REPRODUCTION*

N. B. NEELY AND W. V. STANCIL**

The history of disk recording is interesting and fascinating. In several phases of the history disk recording was the basis of musical entertainment. Yet each time it succumbed either to its own deficiencies or to some new development. The recording heads had peaks and droops and hardly ever reproduced above 5000 cycles. The records were noisy and if a good recording was made, the only reproducers available were small modified versions of a "plough"! But disk recording has now come back, equal or superior to any of our other recording methods. An instantaneous recording medium has been developed that is quiet and inexpensive, and a reproducer has been designed to play back the record efficiently.

In a survey of the papers that have been presented to this Society almost every technical aspect of cutters, processing, and reproduction had been covered. This paper therefore resolves itself into a short and simple discussion about a good cutter and a long-wished-for reproducer.

The Recording Head.—The cutter is compact and rugged, with a low distortion content throughout its range of from 50 to over 7000 cycles. So many of the cutters that have been on the market up to now have been little more than glorified versions of a standard rubber-pivoted reluctance pick-up, and in a few months of use the rubber deteriorated, necessitating its change and a realignment of the armature. Such construction was a vital factor in limiting the high-frequency responses due to lost motion.

This cutter is so designed that after it has been assembled and adjusted there are no parts that can disintegrate and deteriorate with use and age. To accomplish this and to prevent any lost motion, the armature has a *V*-bearing milled out along its longitudinal axis, and this bearing is pivoted on a knife edge (Fig. 1).

On the right of the armature is mounted the armature saddle, on which are fastened three springs. The center, or retaining spring, is fastened to screw *B* which holds the armature against the knife-edge. Two balance springs are used to center the armature between the pole-pieces. Each spring is controlled by its

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* Presented at the 1939 Spring Meeting at Hollywood, Calif., received April 19, 1939.

** Norman B. Neely Enterprises, Hollywood, Calif.

own screw, *A* and *C*, and when adjusted is locked by its set-screw, *A-1* and C-*1*. This is the entire adjustment of the cutter. Inasmuch as the cutter is designed for acetate recording, only a small amount of damping is needed. A block of Viscoloid, which is relatively unaffected by age, is mounted at the upper end of the armature. The cutter operates at a level of +16 to +18 db, or equivalent to about a third of a watt as referred to a 0.006 watt.

In acetate recording the main terminating impedance of the cutter is the disk itself, and Fig. 2 is taken from the recorded disk and not the air velocity of the needle point.

Below 400 cycles the curve of the cutter is a constant-maximum-amplitude characteristic, which has been conceded as necessary in the past. The rise that appears around 5000 cycles is due to the mechanical resonance of the stylus and its associated mounting. The peak of this rise can be shifted as much as a thousand cycles higher by lessening any of the weights of these members. For standard practice the rise as shown is beneficial in obtaining a higher signal-to-noise ratio. The post-equalized curve shown is from one of the major studios. In making the readings filters of commercial tolerances were used; hence the curve is not essentially a straight line.

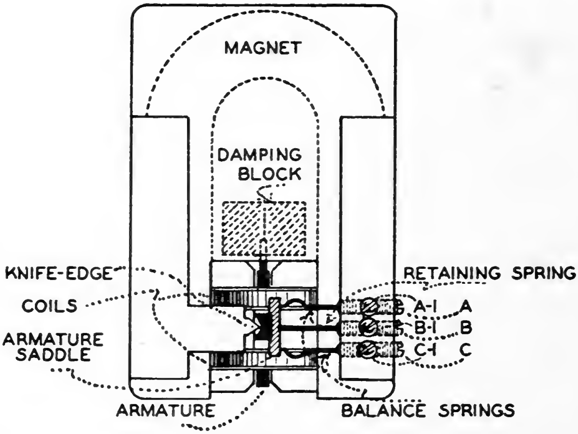

FIG. 1. The cutter.

The Reproducer.—The reproducer is of particular interest because of its design and application. Since in most recordings the largest portion of the recorded frequencies are at constant velocity, the designers confined their interest to a reproducer that would generate constant voltage output for constant velocity motivation. Two principles of reproduction manifested themselves—the commonly used variable-reluctance principle and the moving-coil, embodying the D'Arsonval principle. Because weight, mass, stability, distortionless output, and uniformity of response are of such importance in a reproducer, the obvious solution was the moving-coil system of generation.

One of the dominant features of the pick-up is the extreme lightness of its parts

(Fig. 3). A permanent sapphire needle point weighing 0.0000845 ounce is fastened to the apex of a cone weighing 0.000775 ounce. Around the base of this cone and in a magnetic gap of uniform flux-density is wound a coil which weighs 0.000352 ounce. The cone is about a quarter of an inch in diameter and about a fifth of an inch in altitude, with walls one-thousandth of an inch thick. To offer the least mechanical impedance to lateral movement the cone is suspended on a ribbon 0.004 inch by $^3/_{32}$ inch and under a spring tension of about 14.5 pounds. Due to the torsional flexibility of the ribbon the coil is free to move in a lateral plane, but because of stiffness of the ribbon under tension there is no freedom in the longitudinal plane. On the lateral axis, the mode of vibration is about 1300 cycles, whereas it has never been possible to excite a mode in any other axis. The weight of all the moving elements—coil, support, and needle—is only 0.00123 ounce or about one-eighth the weight of a steel phonograph needle. The effective mass at the needle point is but 0.000493 ounce. A tone-arm was designed to permit a controllable needle weight on the record of 0.2 to 1 ounce, though the needle will track at the lesser amount on a standard recording if the turntable is vibrationless. There is no variation in the frequency response over the entire recording range. The voltage generated is free from amplitude distortion inasmuch as the coil moves in a gap of uniform flux-density irrespective of the magnitude of modulation. Much has been written about distortion in both lateral and vertical recording due to the size of the point of the reproducing stylus and it has been demonstrated as well as calculated that the lateral cut has less distortion than the vertical.

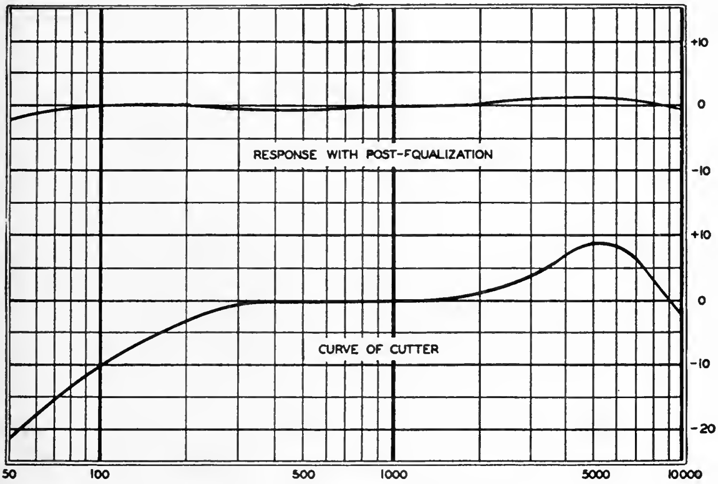

Fig. 2. Response characteristic.

Pierce and Hunt[1] state that the "stylus of an ideal reproducer should be positively driven by the groove walls. . . . ." They set forth, too, an important fact, that if this were executed, a lateral recording would have even-harmonic distortion cancellation and reduced surface noise. To do this, however, a reproducer must have vertical flexibility to comply with a double rise and fall for each fundamental wavelength. These authors stated further that a reproducer which failed to accomplish this would soon erase some of the higher-frequency modulation and also cause distortion. Though we have no extensive data as yet, apparently the pick-up has sufficient vertical compliance to satisfy this condition. This brings up an interesting point, too, that in a vertical excursion the coil moves in the same direction in both magnetic gaps. The current generated in one side of the coil is cancelled by the opposing side; hence there is no generation!

Now that we have a recording medium of such low surface-noise content and a reproducer suitable to this medium, we are in a better position to cope with the distortion due to the finite size of the reproducing stylus. Since the total distortion in this respect is a function of the square of amplitude, it at once appears obvious to record at a lower level. Naturally, there appears a limiting factor as to the amplification that can practicably be used in a reproduction, but even within these limits distortion can be minimized in lateral recording. In attaining this with a *1-B* cutter a dip filter is inserted at the peak previously shown. There would be no reason for not recording at constant velocity over the entire range although most cutters change over in the vicinity of 300 cycles.

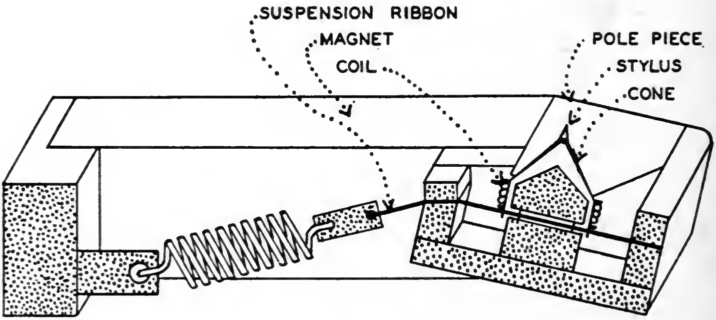

FIG. 3. Arrangement of the pick-up.

Numerous comparative runs have been made on acetate disks and this was the only pick-up that, after several playings, did not reflect wear on the record.

(Following the presentation a reproduction was given of a recording that had been made with this equipment at a session on the day before.)

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SALIBA, G. J.: "An Instantaneous Recording Head," *Communications and Broadcast Engineering* (March, 1937), p. 8.

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A NEWLY DESIGNED SOUND MOTION PICTURE REPRODUCING EQUIPMENT*

J. S. PESCE**

Purpose of Design.—There have been many developments in Sound Equipment during recent years which were a long step forward in the short but lively history of sound-on-film. However, as time went on, subsequent investigations revealed that certain refinements could be made in these developments which, together with other new improved features, would give to the exhibitor appreciably better overall performance. It was to reach this end that the new RCA *PG-140* series of equipments were designed. A set of specifications was prepared which can be summarized as follows:

General

(*a*) Simplicity in design, good overall performance, serviceability, and standby facilities at reasonably low cost.

(*b*) All parts of the equipment shall have Underwriters' approval.

Sound Head

(*a*) Isolate constant-speed sprocket-shaft drive.
(*b*) Simplify method of mounting projectors to sound head.
(*c*) Employ separate gear box for drive gears.
(*d*) Use double exciter lamp socket with pre-focused lamps.
(*e*) Provide adequate static shielding for phototube circuits.
(*f*) Make provision for push-pull operation.

Sound Head Selector and Volume Control System

(*a*) Provide a simple, rugged, and positive sound head selector switch.

(*b*) It shall be possible to select any one of three sound heads from any projector station.

(*c*) Make provision for complete control of volume on front wall at each projector station; also, provision for pre-selection where desired.

Amplifiers and Power Supply Equipment

(*a*) Adequate power with low distortion in amplifiers, particularly at the lower frequencies.

(*b*) Reliable standby facilities in case of failure of main channel. This to be accomplished with as little additional equipment as possible.

(*c*) Tube metering facilities.

(*d*) Low ripple in power supplies, together with the use of high-quality parts, particularly in high-gain stages to effect a low overall noise level. Standby for these power supplies.

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received May 18, 1939.

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

(*e*) Provisions on loud speaker dividing network for taking amplifier response curves and for standby operation of loud speakers.

(*f*) Conservative rating of components and tubes for long life.

(*g*) All units to be in one or more racks as required.

Loud Speakers and Overall Response

(*a*) The loud speakers employed on all equipments shall be of such design that the response-frequency characteristic of the complete system (including sound head, amplifier, and these loud speakers) shall be comparable to that desired by the Committee on Standardization of Theater Sound Reproduction Equipment Characteristics of the Academy of Motion Picture Arts & Sciences.

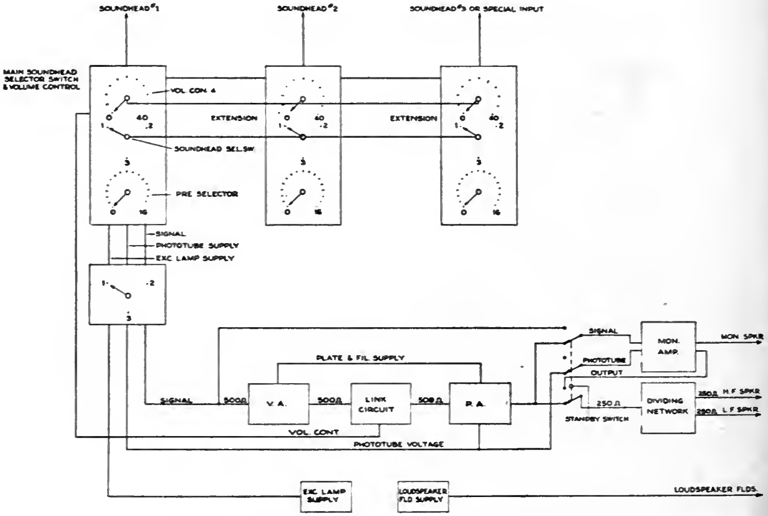

FIG. 1. *PG-140* block diagram layout.

(*b*) The design of the horns shall be such that proper distribution of both high and low frequencies can be obtained.

(*c*) The driving mechanisms shall be high enough in efficiency to produce an adequate sensation level without objectionably overloading or requiring the undistorted output of the amplifier to be exceeded. This shall hold at all frequencies within the desired range.

(*d*) Provide suitable monitor speaker.

Styling

(*a*) Each of the units making up this equipment shall be designed for good appearance and uniformity in resemblance. This styling shall be consistent with function.

GENERAL LAYOUTS

(*1*) *PG-140 Equipment, 25 Watts.*—Fig. 1 is a block diagram of the *PG-140* equipment. Starting at the sound heads, their respective outputs are brought to the main sound head selector switch and volume control box shown on the left-hand side of this diagram through pre-selector pads, if they are used. From this box, the signal of the sound head selected is conducted to the special input selector switch, if it is employed. From the special input switch, the signal is carried to the input of the voltage amplifier and a standby switch which is mounted on the monitor amplifier chassis, then to the 25-watt power amplifier through the link circuit, then on to the dividing network, and finally to the loud speakers, which consist of a high- and low-frequency horn with two mechanisms on each. Complete control of volume on the front wall is obtained by a variable *T*-pad which is connected in the link circuit between the voltage and power amplifier. In the position shown for the standby switch, which is its normal one, the monitor amplifier is bridged across the output of the 25-watt power amplifier. In the standby position, the monitor amplifier is bridged across the input of the voltage amplifier with its output replacing the output of the power amplifier across the input of the divider network. By further action of this switch in its standby position, a bleeder circuit in the monitor amplifier furnishes phototube polarizing voltage. The monitor amplifier is thus made to serve as a standby amplifier.

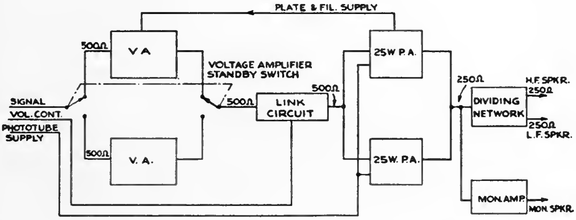

FIG. 2. *PG-141* block diagram layout.

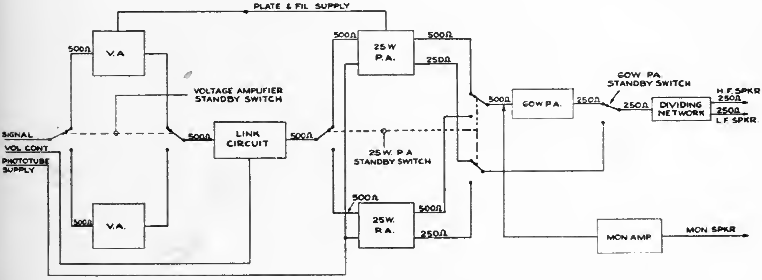

FIG. 3. *PG-142* block diagram layout.

A switch on the exciter lamp supply provides a-c standby for the exciter lamps. Standby field supply is obtained from the arc generators through the use of a switch installed at the time of installation. Loud speaker standby is effected by a switch on the dividing network.

(2) *PG-141 Equipment, 50 Watts.*—Fig. 2 is a block diagram of the *PG-141* equipment. This equipment is the same as the *PG-140*, with the exception that two voltage and two 25-watt power amplifiers are employed and standby is accomplished in a little different manner. Either of the voltage amplifiers may be used depending upon the setting of a standby switch. In case of failure of one of the power amplifiers, the output would drop slightly, but a sound outage would not occur unless the voltage amplifier receiving power from the power amplifier that failed was in use, in which case it would only be necessary to throw the standby switch to the other voltage amplifier. Thus complete standby of both voltage and power stages is accomplished.

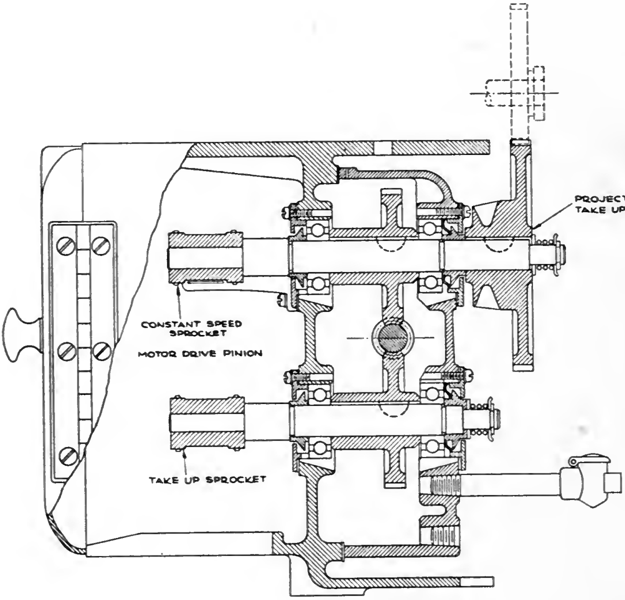

FIG. 4. Old gear drive.

(3) *PG-142 Equipment, 60 Watts.*—(Fig. 3.) This is the largest standard size equipment. It is similar to the *PG-141* with the exception of the addition of a 60-watt P. A. and its associated equipment.

Three standby switches are employed, giving two complete channels up to the 60-watt power amplifier and permitting the output to be taken from either of the 25-watt power amplifiers in case of failure of the 60-watt unit.

Although this equipment is rated at 60 watts, as compared to 50 watts for the *PG-141*, there is considerable difference in usable output due to the difference in shape between the respective distortion curves. This will be discussed later.

DETAILS OF DESIGN FEATURES

Isolated Constant-Speed Sprocket Drive.—In earlier type sound heads, the gear and pulley assembly, which drives the picture head and take-up mechanism, was keyed to the opposite end of the same shaft on which was mounted the constant-speed sprocket. This is shown in Fig. 4. Hence, any variations in load, from the sources just mentioned, affecting this assembly resulted in a corresponding variation in speed of the constant-speed sprocket.

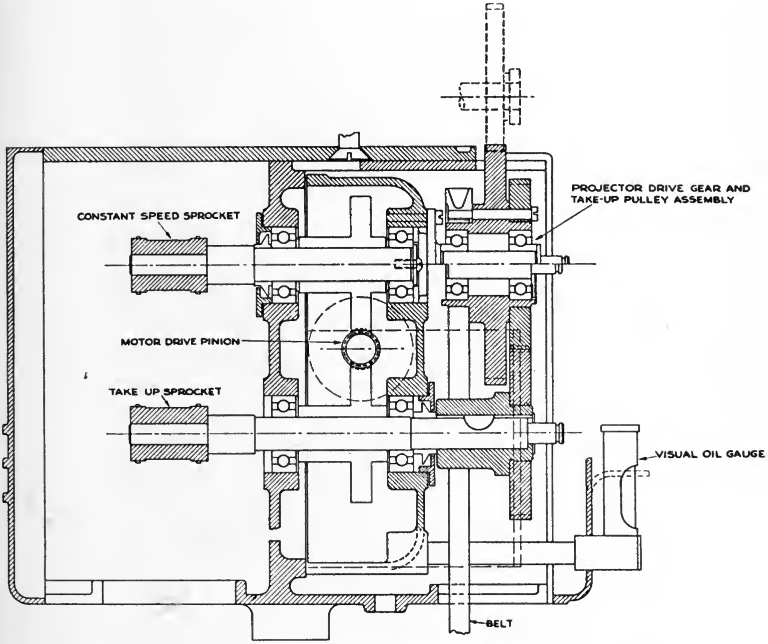

FIG. 5. New gear drive.

In the new sound head, this arrangement has been changed so that the gear and pulley assembly in question is no longer a part of the constant-speed sprocket-shaft assembly, as can be seen in Fig. 5. To accomplish this two spiral gears were added in the following manner: The gear end of the constant-speed sprocket shaft was shortened and terminated in a cap which acts only as a supporter member. The take-up sprocket's shaft, however, has been lengthened and one of the new spiral gears has been keyed to this extension. This spiral gear meshes with the second one which has been directly attached to the projector head drive

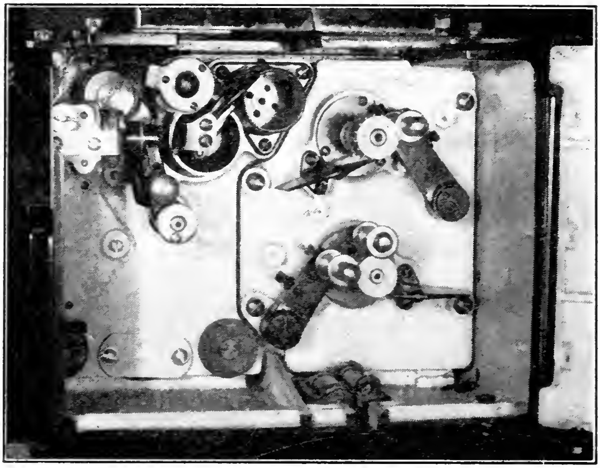

FIG. 6. Front view of new gear box mounted in place.

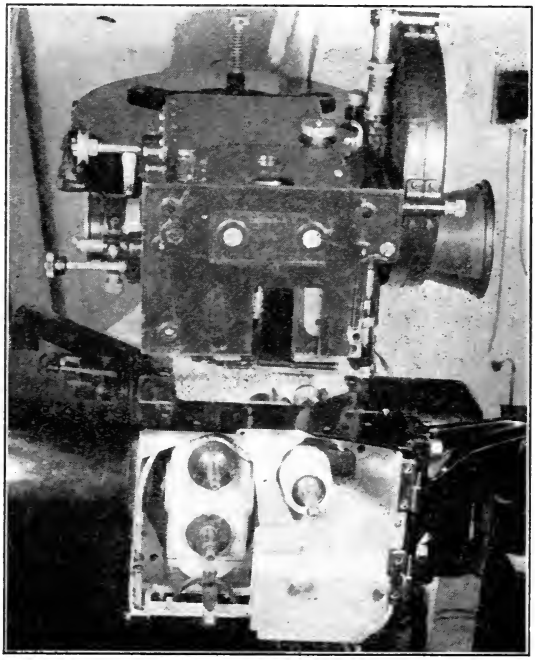

FIG. 7. Showing oil collection and projector adaptor plate mounted to bottom of projector head, the pins in the bottom of this plate, and the slots in the top of the sound head in which the pins fit.

gear and take-up pulley assembly. This new assembly rotates on a stationary study which projects from the back of the gear case housing.

Thus, it is evident that with this new arrangement, the varying loads from the take-up and projector mechanisms are transmitted to the take-up shaft to a much greater extent than they are to the constant-speed sprocket shaft. This is true because these variations can not readily go from the lower spiral through the motor pinion to the upper spiral due to the steep angle of these gears. Comparative measurements have shown a reduction in flutter.

Separate Gear Box.—The box for this new drive gear mechanism is assembled in a single unit and is removable as such (Fig. 6).

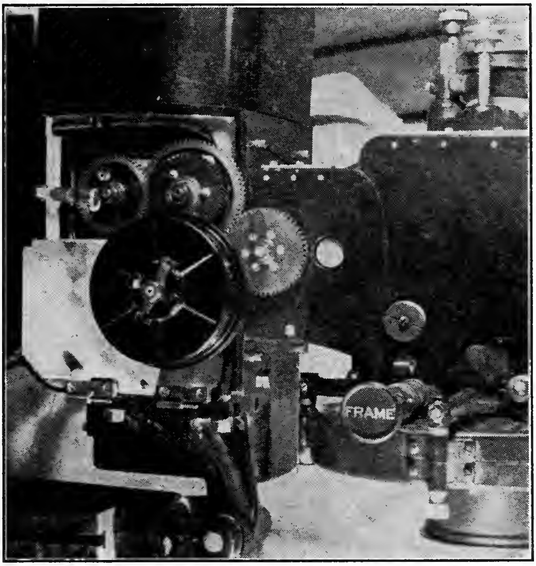

FIG. 8. Completed mounting of projector head oil collection and projector adaptor plate and sound head. Allen screws which hold the sound head to the projector adaptor plate can also be seen.

Projector Head Mounting Plate and Oil Collection System.—Another important feature of this new sound head is the simplification made in the method of mounting the projector head to the sound head and facilities for collecting excess oil.

With the new design, a separate $^1/_4$-inch thick mounting plate is attached to the bottom of the picture head by means of two $^3/_8 \times 16$ flat-head machine screws, which engage the two tapped holes in the bottom of the picture head as shown in Fig. 7. With this mounting plate securely attached to its base, the projector head is set upon the top of the sound head so that the three pins which project from the bottom of this plate are engaged with three corresponding slots in the top of the sound head. These pins and slots are also shown in Fig. 7. It is to be noted that it is not necessary to remove any parts from the sound head in order to complete the assembly. The mounting plate is attached to the top of the sound head by four Allen head screws, with a plate and a shakeproof washer under the head of each. The completed mounting is shown in Fig. 8.

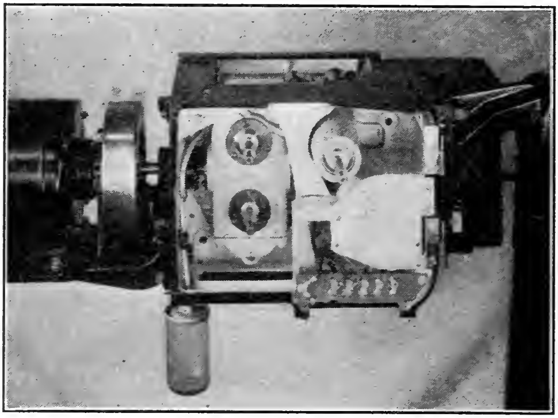

FIG. 9. Showing oil tube which conveys excess oil from this plate to the receptacle on the bottom of the sound head.

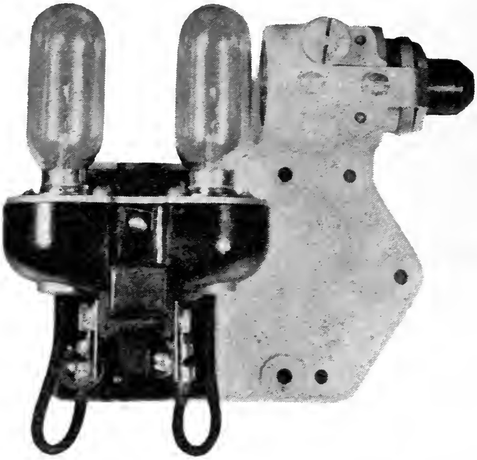

FIG. 10. Dual exciter lamp socket mounted in position with pre-focus lamp.

As can be seen from Fig. 7, two of the pins in the bottom of the mounting plate engage two slots which are parallel to the operating side of the sound head. These pins working in their respective slots permit motion toward or away from the screen, without permitting lateral motion. The slot in which the third pin engages is at right angles to the other two slots. This third pin is mounted on the plate eccentrically with relation to a large hexagon-headed cap screw. As this hex-headed screw is rotated, the complex picture head mechanism is moved either toward or away from the screen so that exact mesh of picture head drive gears may be readily accomplished.

In addition to acting as a picture head mounting plate, this same member acts as an oil-collection plate. Cast into its upper surface are a series of depressions into which the oil drips from the edges of the picture head. From this point the oil drains into a transparent removable receptacle (Fig. 9).

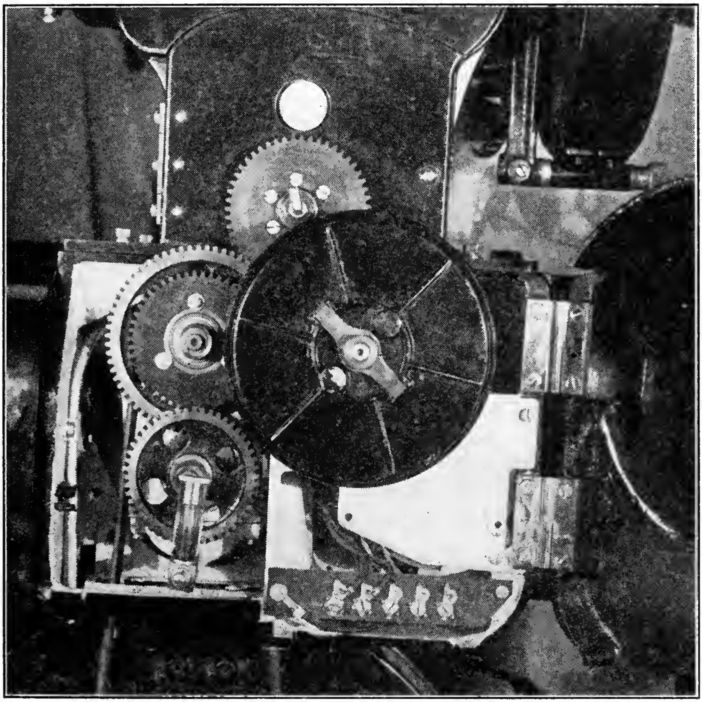

FIG. 11. Good accessibility to the photocell terminals.

This receptacle is not screwed to the end of the $^1/_4$-inch tube but instead mounts to the bottom of the sound head. This permits any excess oil in the bottom to drain into the receptacle through the same hole that the drain tube passes through.

Double Exciter Lamp Socket with Pre-Focused Lamps.—The new double exciter lamp socket with its mounting as shown in Fig. 10 is illuminated and the lamp which was originally in operation is not lit. This socket, in conjunction with the pre-focused lamps, makes it possible to very easily and quickly effect a replacement. In case of a burn-out of the operating lamp the double lamp socket is removed, rotated 180 degrees, and reinserted, electrical contact being automatically established to the lamp adjacent to the lens barrel. Neither vertical nor horizontal adjustment is necessary. Prefocused lamps are used.

Statically Shielded Phototube Circuit, Including Socket, Leads, Terminal Board and Transformer.—In the new sound head, the transformer is mounted in sponge rubber in an enclosed cast-iron chamber. The phototube socket, leads therefrom to the transformer, and the terminal board are also statically shielded in a cast-iron channel and suitable metal covers.

The terminal board is readily accessible for inspection by swinging the hinged gear cover out of its normal position and removing a small sheet-metal cover as illustrated in Fig. 11.

Styling.—The results of modern styling are shown in Fig. 12. This has merit for display purposes, and it is also felt that it is conducive to better operation, servicing, and maintenance.

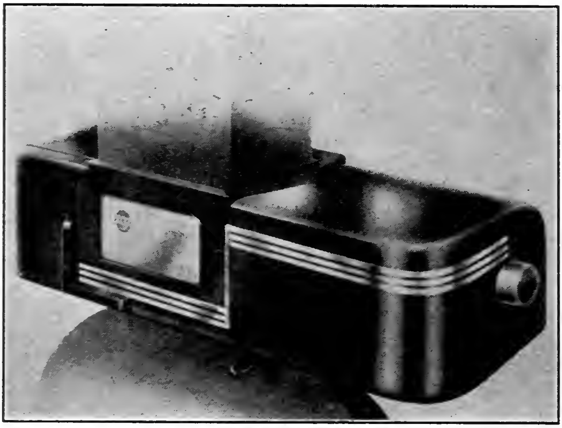

FIG. 12. Style view of sound head.

Sound Head Selector and Volume Control System.—It is possible to select the output of any sound head from any projector station for a three-projector installation, as well as for one having only two projectors. This is accomplished simply, conveniently, and at low cost by the use of extension rods. To meet the requirement that all controls should be front-operated, the associated operating knobs were coupled to these rods by miter gears.

"Mercury Kon-nec-tors" Employed in Selector Switch.—The sound head selector switch used in this new series of equipment is of the "Mercury Kon-nec-tor" type which has contacts sealed air-tight in glass tubes. Permanently low contact-resistance is assured, and the necessity for cleaning contacts is eliminated. In addition, all projectors or other input sources are connected in series. Those not being used are short-circuited by the mercury contact. In this way, even if a contact should fail to close, a completely closed circuit is still

available to the input of the amplifier (Fig. 13). The only indications of a failure would be a drop in level and possibly noise from the unused projector.

A maximum of three projectors is provided for on this switch. If only two projectors are used, the third position may be used for "Special Input." If three projectors are employed, a separate switch of the same type is available to be used in addition to the one just described, which connects one of the three sound heads previously selected or one of two other inputs to the voltage amplifier.

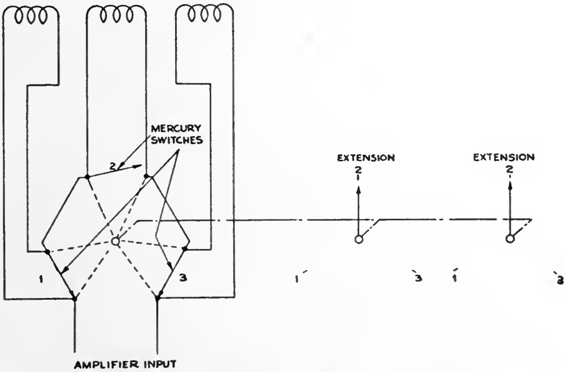

FIG. 13. Schematic of input circuit.

Either one of the two input sources not being used can be selected by throwing the switch through 120 degrees. A suitable detent is employed to insure positive action and the mercury tubes are cam-operated into short- or open-circuit position as required.

Complete Control of Volume on Front Wall at Each Projector Station.—The design employs a 500-ohm link circuit between the voltage and the power amplifier. This link circuit accommodates a 20-step 500-ohm T attenuator.

FIG. 14. *MI-9701* and *MI-9702* coupled by *MI-9703.*

The first fifteen steps of this pad are 2 db each, and the last four steps are progressively larger, being 4, 4, 6, and 9 db, respectively. There is also an off step which gives infinite attenuation. As this pad operates at a level which is 55 db above the input circuit, it can be placed on the front wall without danger of the effects of pick-up from stray fields. It can be controlled from any projector station by extension rods.

It is housed in the same box with the sound head selector switch but suitably shielded from the latter to prevent coupling. Also housed in this box is a network for controlling the polarizing voltage to the phototube and further space is provided for a second network for push-pull operation.

Provision for Volume Pre-Selection.—In addition to these parts, it is possible to install in this box a 16-db variable *T*-pad attenuator for volume pre-selection. This pad connects in the link circuit between the sound head and the voltage amplifier. This unit is not supplied as standard equipment.

The box which houses these parts constitutes the main sound head selector switch and volume control. It is commonly termed the "Main Fader." This main control unit, together with the extension unit and extension rods, are shown physically in Fig. 14. The interior construction of the main control unit and mercury selector switch is shown in Fig. 15.

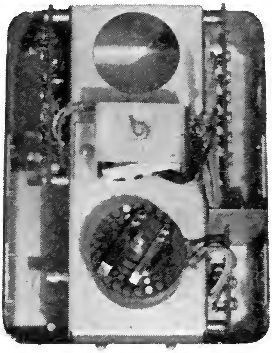

FIG 15. Interior of *MI-9701* showing mercury switch assembly and one of the mercury contacts.

Amplifiers and Power Supply Equipment

Voltage Amplifier.—The voltage amplifier employed in this equipment is a two-stage amplifier, using *RCA-1620* tubes as resistance-coupled pentodes in both stages with 18-db degenerative feedback on the second stage. Filament and plate power are both obtained from the 25-watt power amplifier with which it is associated. Its electrical characteristics are as follows:

Input Impedance 250 or 500 ohms
Load Impedance 250 or 500 ohms
Frequency Response ±1 db from 30 to 10,000 cycles
Gain 55 db
Maximum Output Level +6 db (0.006 w. ref.)
Output Noise Level −75 db (0.006 w. ref.)

25-Watt Power Amplifier.—The power amplifier consists of three stages, using one *RCA-1620* as a pentode in the first stage, one *RCA-1620* as a triode in the second stage, with a third *RCA-1620* operated as a triode phase inverter. The last stage is a parallel push-pull stage, using four *RCA-1622* tubes which are special tubes similar to the *RCA-6L6*. Two *RCA-5U4G* rectifiers provide the plate supply. In addition, one *RCA-874* regulator tube is used to regulate the polarizing voltage for the phototube which is taken from this amplifier. Inverse feedback is employed in the last two stages to reduce the distortion at all output values below maximum. It does not increase the maximum output of the amplifier, however. A second feedback circuit is employed on the first stage to increase its output, so that there will be sufficient margin between the undistorted output of the first stage and the required input to the second stage.

A plate current meter is supplied on the front panel of this amplifier which may be switched to measure individually the plate current of each of its tubes or to measure the combined plate currents of the tubes in the voltage amplifier.

The electrical characteristics of this amplifier are as follows:

Input Impedance	250 or 500 ohms
Load Impedance	7.5, 15, 250, or 500 ohms
Frequency Response	±1 db, 30 to 10,000 cycles
Gain	67 db
Rated Output at 2% Distortion (50 to 5000 cps)	25 watts (0.006 w. ref.)
Maximum Output	50 cps 33
	1000 cps 38
	5000 cps 36
Output Noise Level	−55 db (0.006 w. ref.)

60-Watt Power Amplifier.—The 60-watt amplifier is panel mounted, with the following electrical characteristics:

Source Impedance	500 ohms	
Input Impedance	500 ohms	
Load Impedance	250, 30, 15 ohms	
Rated Output	60 watts at 2% distortion (50 to 5000 cps)	
Maximum Power Output	100 watts at	50 cycles
	140	1000
	132	5000
Gain	15 db	
Frequency Response	±1 db, 30 to 10,000 cycles	
Noise Level	135 db (0.006 w. ref.)	

The tubes used are two *RCA-845*'s and two *RCA-866-A* rectifiers. Two separate plate current meters are provided, one in each of the amplifier tube cathode circuits. Since the rectifier tubes are of the mercury vapor type, and the filaments must be heated for thirty seconds before applying plate voltage, a manual time delay switch is provided on the front of the rack for this purpose. This switch will be connected so as to control all the amplifier and power supply equipment in the entire three racks, by means of the inter-rack wiring. A safety switch is provided to shut off the plate voltage, in case the front cover is removed from the rack, for the protection of those working on the equipment.

Monitor and Standby Amplifier.—The monitor amplifier is a three-stage unit with 16 db of feedback on the last two stages. Two *RCA-1620*'s are used in the first two stages, and one *RCA-1622* in the output stage. One *5Y4G* tube supplies plate voltage and an *RCA-991* is used as a regulator on the phototube polarizing voltage supply.

When used as a monitor amplifier, the input is connected across the output of the main amplifier through an 86-db *L*-pad. As previously described, when the standby switch is thrown to the standby position, the input and phototube polarizing voltage supply are paralleled across the corresponding circuits on the main amplifier, in order to avoid breaking the circuits of the main amplifiers. It is, however, necessary to break the output circuit of the main channel to switch the input of the loud speaker dividing network from the main channel to the standby amplifier. This is all accomplished by the standby switch which mounts on this amplifier chassis. The monitor speaker remains connected to the monitor amplifier at all times, and so functions as a monitor under either condition. The volume control on the front wall is inoperative when the standby channel is being used. Under this condition, the grid type volume control on the monitor amplifier is used.

It is felt that this feature is one which has considerable merit, particularly when cognizance is taken of the fact that the amplifier is normally required to serve only one purpose but by a judicious choice of circuits was made to give a dual service which is definitely desired.

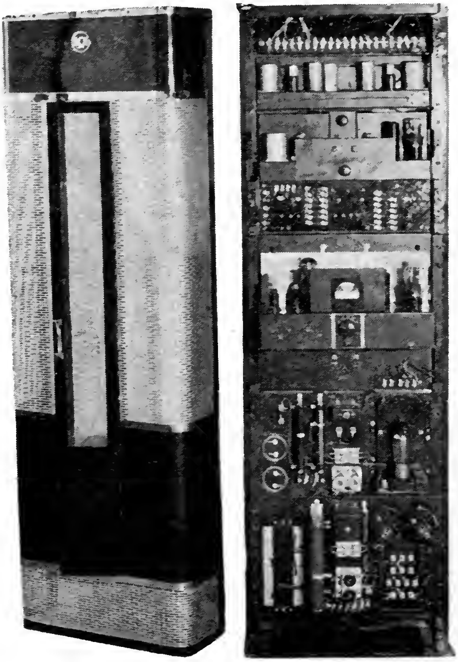

FIG. 16. *PG-140* amplifier rack cover for showing arrangement of units from top to bottom.

This amplifier has the following characteristics:

Input Impedance	unloaded transformer
Load Impedance	15 or 250 ohms
Frequency Response	30 to 4000 cycles + or − 1 db, 4000 to 8000 cycles +0–5 db
Gain	105 db
Feedback	16 db
Output	6 watts at 5% distortion
Noise Level	−20 db (0.006 w. ref.)

Loud Speaker Dividing Network.—The network used with this series of equipment is of the *M*-derived type, designed for input and output impedances of 250 ohms. A high-impedance line was decided upon because a more convenient arrangement of parts could be effected and line losses are materially reduced. While it probably would have been a little more desirable to standardize on a 500-ohm line, this could not very well be done because of the problem of wire size and insulation consistent with Underwriters' requirements, together with the dangers involved of exposing service engineers to high voltages. Moreover, the impedance decided upon is one which is widely used.

A standby switch is provided on this network by which the projectionist can switch the full output of the amplifier into the low-frequency speakers, in case of failure of the high-frequency speakers or any part of the network. A second switch is also provided to permit the service engineer to substitute a self-contained resistor load in place of the speakers for checking the frequency characteristic of the equipment. A jack is provided by which he can plug a power-level meter into the circuit across the resistor load.

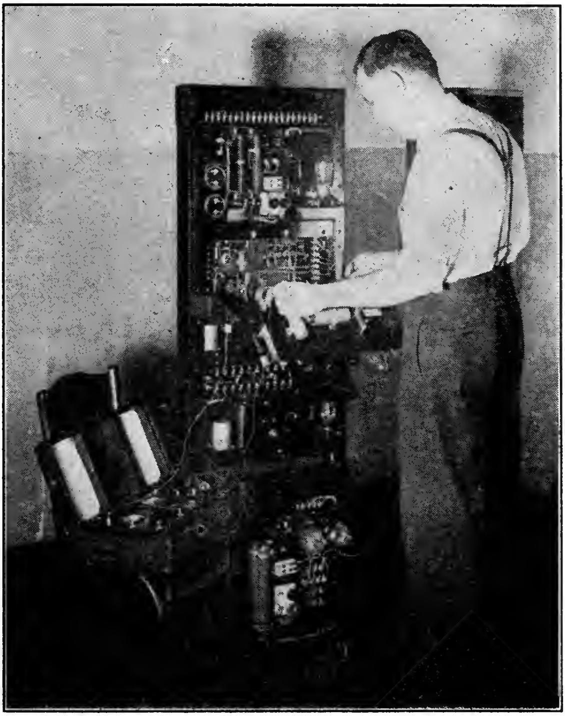

FIG. 17. *PG-140* rack cover off showing hinged construction of necessary components for accessibility.

Loud Speaker Field Supply.—The power-supply unit for the loud speaker fields utilizes a full-wave mercury vapor rectifier tube (G.E. cat. *16X897*). This unit supplies a maximum of 1.5 amperes at 120 volts, d-c, or enough power for six loud speaker fields. The ripple voltage is −54 db (0.25 v) below a 1.5-ampere load at 120 volts with a 60-cycle input.

Exciter Lamp Supply.—The exciter lamp supply employs two *RCA-2000* tubes, which are similar to 6-ampere Tungars and Rectigons, in a full-wave circuit. It supplies 9.0 amperes at a maximum of 12.0 volts for two 10-volt, 5-ampere exciter lamps operating in parallel at a reduced rating of 4.5 amperes. The ripple voltage is −62 db (0.01 volt) below its output voltage at rated load with a 60-cycle input. The regulation of this unit is such that if one of the exciter lamps burns out or is disconnected, the second will not burn out due to a greater supply voltage, nor will the volume of the operating machine be objectionably increased.

A standby switch supplies raw a-c taken direct from the power transformer.

PG-140 Amplifier and Power Rack.—The components of the amplifier and power rack for the *PG-140* equipment are arranged from top to bottom in the order shown in Fig. 16: (*1*) Voltage amplifier, (*2*) monitor amplifier, (*3*) link circuit, (*4*) 25-watt power amplifier, (*5*) loud speaker divider network, (*6*) field supply, (*7*) exciter lamp supply.

Fig. 17 shows how the necessary components have been hinged for good accessibility in servicing and inspection.

PG-141 Amplifier and Power Racks.—These racks are constructed similarly to the one employed for the *PG-140* equipment, but owing to the additional units used, two racks are required. All parts of the main amplifier are mounted on one of these racks as follows, in order from top to bottom: (*1*) Voltage amplifier, (*2*) standby switch, (*3*) voltage amplifier, (*4*) link circuit, (*5*) 25-watt power amplifier, (*6*) 25-watt power amplifier.

The second or power-supply rack used in this equipment mounts the following units: (*1*) Monitor amplifier, (*2*) loud speaker divider network, (*3*) exciter lamp supply, (*4*) field supply.

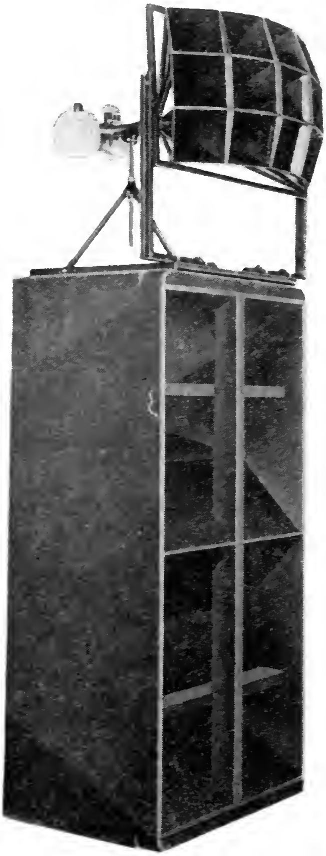

FIG. 18. *PG-140* speaker complement.

All the above units are the same as used in the *PG-140* equipment, with the following exceptions: The standby switch used on this equipment is mounted on a separate panel, and is a four-pole double-throw toggle switch. The monitor amplifier is not equipped with a standby switch, and is not used as a standby amplifier.

PG-142 Voltage and Power Amplifier Racks.—This equipment is similar to the *PG-141* equipment, with the addition of a third rack for supporting the 60-watt class *A* power amplifier with the other associated units.

Although this equipment is rated at 60 watts, as compared with 50 watts for the *PG-141*, there is considerable difference in usable power output, as shown by comparison of the 2-per cent ratings to the maximum power output ratings. Maximum power output of the *PG-141* amplifier at 1000 cycles is 76 watts (two 25-watt power amplifiers in parallel) as compared with 140 watts' maximum power output of the *PG-142* amplifier at the same frequency.

Where desired, a second 60-watt power amplifier can be employed increasing the amplifier capacity to 120 watts. When this second amplifier is added, the equipment is known as the *PG-143*. However, with this increase in power output, a change in speaker complement, together with other desirable changes are recommended and, consequently, no standard schedule has been prepared. Instead, each case requiring such equipment will be treated separately.

FIG. 19. *PG-141* and *PG-142* speaker complement.

Conservative Rating of Components and Tubes for Long Life.—All materials and parts used in these equipments are of the highest quality available. High-quality parts alone, however, will not give satisfactory and lasting service, unless properly used. Every effort has been made to see that all parts are used only under conditions conducive to long life.

Electrolytic capacitors were employed only after thousands of hours of test of representative samples at full rated values. In these equipments, they are employed under conditions of applied voltage, a-c ripple, and temperature which are well under the rated values.

By very close coöperation with the tube manufacturer, tubes have been obtained for this equipment which under the conditions of operation will have a life of several thousand hours. All the tubes used are specially selected and controlled in production for characteristics important in this particular application. The standard equivalents of these tubes can be substituted where necessary with a corresponding reduction in life and lower overall performance.

Underwriters' Approval.—All parts of these equipments have been submitted to the Underwriters' Laboratories for test and examination and have been approved.

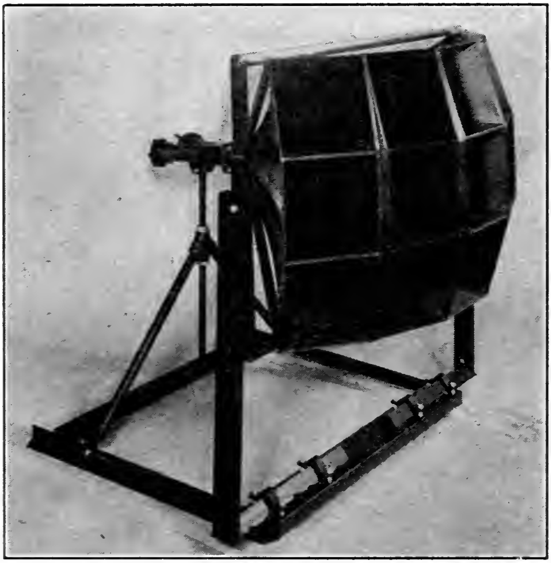

FIG. 20. High-frequency horn-mounting bracket.

LOUD SPEAKERS AND OVERALL RESPONSE

Loud Speaker Equipment.—The loud speaker complements employed with the *PG-140*, *PG-141*, and *PG-142* equipments are shown respectively in Figs. 18 and 19. The larger complement, shown in Fig. 19, is used on both the *PG-141* and *PG-142* equipments.

Distribution.—As can be seen in Fig. 18, the low-frequency baffle is mounted on its end to permit better low-frequency distribution in the horizontal plane.

New High-Frequency Horn-Mounting Bracket.—As a further aid to readily obtaining equal high-frequency distribution in the theater, a new high-frequency horn-mounting bracket has been designed. This mounting bracket is shown in Fig. 20. It will be noted that this bracket pivots the high-frequency horn about the center layer of cells and is sufficiently close to their mouth that the horn can be angled up or down without seriously changing its phase relationship with the low-frequency baffle. This operation is facilitated by a screw adjustment on the rear support.

Overall Response.—While it has not proved generally practicable to make sound-pressure measurements in theaters, extensive listening tests show that satisfactory overall results are being obtained.

Conclusions.—Consideration of the foregoing will show that the specifications described herein have been met in detail. This is substantiated by the performance this apparatus is giving in service. It is consequently felt that a very definite step has been made in the progress of sound motion picture reproducing equipment. The author wishes to acknowledge the practical contributions received from many members of the motion picture industry and also, the personnel of the sales, service, and engineering divisions of the RCA Manufacturing Co., Inc., which were of material aid in the design of these equipments.

A HIGH-INTENSITY ARC FOR 16-MM PROJECTION*

H. H. STRONG**

Present-day application has lifted 16-mm projection from the strictly portable classification to that of permanent installation in theaters where newsreel service is supplemented with local coverage; in classrooms, since more extensive film service is available and where safety is an important factor; and in large auditoriums where lectures are illustrated by personal film.

However, where large screens are used, it is necessary to employ the high-intensity arc as a light-source to secure a picture brilliancy and color that is at all comparable to theater projection.

To that end has been developed a high-intensity arc which will project approximately 1000 lumens of light with the projector running. This is sufficient light to project a picture up to sixteen feet in width, with the white-light characteristic of the high-intensity arc. This is approximately three times the light secured with a 750-watt commercial Mazda projector.

In designing a high-intensity arc for 16-mm projection, the limiting factors have been film damage due to aperture heat; the burning time without retrimming; the lamp current consumption; optical speed; physical dimensions and weight; simplicity of operation; safety; costs; and Underwriters' requirements for non-theatrical use.

By experimentation, it was determined that a 30-ampere high-intensity arc produced the maximum amount of light that could be projected without buckling the 16-mm film, even though protected by heat-absorbing filter and air-blast.

Since 50 minutes is the running time of a 400-foot 16-mm sound-reel, a carbon burning time of one hour without retrimming was established.

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received March 22, 1939.

** Strong Electric Co., Toledo, Ohio.

To meet the 30-ampere, 60-minute requirements, the National Carbon Company developed a carbon trim which is marketed under the name of *Pearlex*. The positive carbon is 6 mm in diameter and 8 inches long, and the negative is 5.5 mm in diameter and 6 inches long. Both are copper coated.

These carbons, like the *Suprex* used extensively in 35-mm projection, are of the high-intensity type and are very efficient in the production of projection light of desirable quality.

The light-source of a 30-ampere, high-intensity arc is of such an area that it requires a magnification of four diameters to cover effectively the 16-mm film aperture. A reflector $10^1/_4$ inches in diameter, with a geometric focus of 4 inches, is set 16 inches from the film aperture, resulting in an *f* value of 1.6, which matches the *f*/1.6 lens commonly employed on 16-mm projectors.

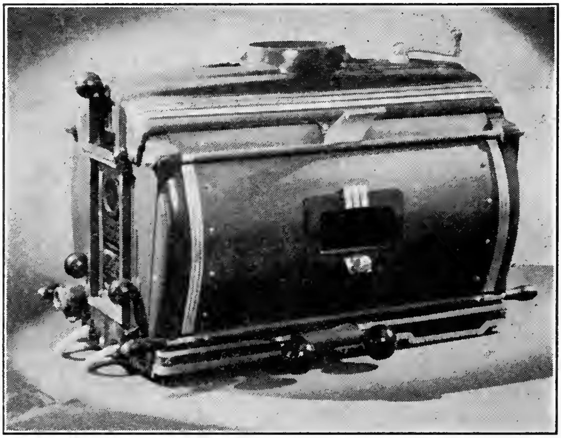

FIG. 1. H.-I. arc for 16-mm projection.

The lamp house follows standard theater practice in design but is built in diminutive proportions. There are horizontal, vertical, and focus adjustments for the reflector; manual controls for the carbon alignment; an adjustable-speed motor for feeding the carbons; an arc imager; an ammeter for reading the current at the arc; and individual supports close to the arc for guiding both the positive and the negative carbons.

The 8-inch positive carbon, which is in horizontal coaxial alignment with the 6-inch negative carbon, the $10^1/_4$-inch diameter of the reflector, as well as the control motor, have all determined the physical dimensions of the lamp, which are 23 inches by 13 inches by 13 inches, with a weight of 50 pounds (Fig. 1).

Since the 16-mm projector is usually operated without the fireproof projection booth and by the lay projectionist, the Underwriters have required a switch that cuts off the line current when the lamp house door is opened.

The direct-current power for the 28-volt, 30-ampere arc is supplied by a single-phase, full-wave rectifier in which are used two 15-ampere Tungar tubes.

The live parts of the lamp are effectively insulated from the grounded line current by the use of a separate primary and secondary winding in the transformer. There is also a smoothing reactor which is connected in the direct-current circuit to the arc; this reduces the a-c component and the resultant light flicker to a commercial acceptance.

Within the rectifier are also housed the necessary switches for manual adjustment of the current to the arc; an a-c line voltmeter; overload circuit-breaker; and the line relay, which is connected to the lamp house door switch.

The a-c load or rectifier input does not exceed the 15-ampere limit provided by any 110-volt convenience outlet.

NEW 16-MM RECORDING EQUIPMENT*

D. CANADY**

New models of Canady recorders and film-phonographs are slightly different in design from the previous ones. While some improvements have been added, the basic reason for re-design was to have a film-driving mechanism that would be equally suitable for both 16-mm and 35-mm recorders and film-phonographs.

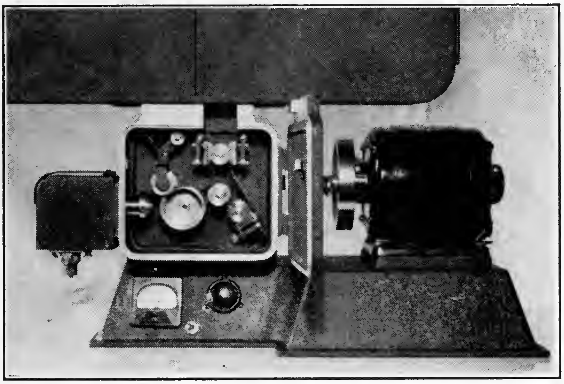

FIG. 1. Film-phonograph unit.

Worm drives of various combinations permit assembly of equipment for any format and for operation on any power supply. The 2-inch scanning drum has been retained for both formats, as scanning drums of too short a radius affect sound quality through light spread at the scanning point.

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 1, 1939.

** Canady Sound Appliance Co., Cleveland, Ohio.

Fig. 1 shows one of the new units completed as a film-phonograph. Film is held against the sprockets by hardened and ground steel shoes which touch the film at the extreme edges. This precludes the sound-tracks being marred by abrasion marks and scratches. A ball-bearing, fabric-covered, steel pad-roller with guiding flanges serves to keep the film in close contact with the scanning drum. A rotary stabilizer insures a constant film-speed at the scanning point. Sixteen-mm recorders are furnished with galvanometers or glow-lamp assemblies which are also optional on the 35-mm units. The glow-lamp assembly retains the well known quartz slit which still remains the most efficient and practicable method of utilizing the actinic light produced by gas-filled lamps.

35-Mm to 16-Mm Optical Reduction Printer.—A film-phonograph forms the basis for the Canady optical reduction sound printer. The door of a film-phonograph is replaced with a special door upon which is mounted the 16-mm section which operates at right angles to the 35-mm unit. This includes a reduction lens assembly, rotary drum with equalizer, 16-mm sprockets, film supporting arms, and take-up.

A prism mounted on the opposite side of the door intercepts the light-beam passing through the 35-mm sound-track and re-directs it at right angles to the reduction lens.

FIG. 2. Miniature glow-lamp and holder.

When the door is closed, the 16-mm section is driven by two pins which engage recesses in the end of the feed sprocket of the film phonograph.

While present design calls for operation in a darkroom, the entire 16-mm section can be readily enclosed in a light-tight cover with provisions for receiving conventional 16-mm film magazines, thus permitting daylight operation.

Miniature Glow-Lamps for 16-Mm Recording.—The miniature glow-lamp and its associated holder shown in Fig. 2 has been developed for use in 16-mm cameras of the "home movie" type. The electrodes are identical to those employed in the 35-mm lamp. While the volume of gas has been reduced, the lamp is capable of recording several thousand feet of film.

When used in conjunction with an amplifier equipped with an automatic volume control or "limiter" circuit, glow-lamps are capable of turning out creditable sound-track in the hands of inexperienced persons, and will no doubt receive serious consideration in future design of sub-standard cameras for photographing sound and picture on the same film.

As small compact amplifiers present no engineering problems, the only item necessary for making talking pictures in the home is a 16-mm camera modified to receive the glow-lamp holder.

NOTES ON FRENCH 16-MM EQUIPMENT*

D. CANADY**

In France, la Société des Télephones Ericsson recently introduced their 16-mm projector equipped with the new mercury arc. The projector originally designed for small audiences is now quite capable of competing with standard 35-mm machines. The complete projector draws approximately 9 amperes at 110 volts, and the screen brilliancy compares very favorably with the output of machines equipped with carbon arcs drawing 45 amperes.

FIG. 1. Ericsson 16-mm projector with mercury arc.

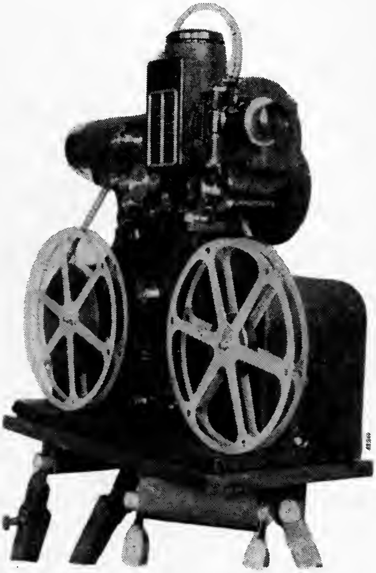

FIG. 2. Mechanism of Ericsson projector.

Some of the advantages claimed are: increased safety-factor as compared to the carbon arc; no smoke or heat, as the lamp is water-cooled; and a minimum amount of space is required for the complete outfit. It can be used without a booth and the equipment is easily portable.

The projector set up ready for operation is shown in Fig. 1. The two cases beneath the machine contain the electric controls and the water-cooling system, respectively. The latter consists of a motor-driven pump and radiator. If,

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 1, 1939.

** Canady Sound Appliance Co., Cleveland, Ohio.

for any reason the water supply is interrupted, an automatic control instantly breaks the circuit going to the mercury arc.

The mercury arc lamp is connected to the water supply by shielded rubber hose. The lamp is composed of a thick-walled quartz tube in which are mounted two tungsten electrodes with a drop of mercury between them under a pressure of 100 atmospheres. An outer shell permits cooling water to flow around the lamp.

The Ericsson 16-mm sound projector mechanism possesses some unusual features. Fig. 2 shows the mechanism while Fig. 3 illustrates the arrangement of the parts: *1* is a synchronous motor connected to the drive shaft by a flexible coupling *2; 4* is a worm drive actuating the film feed sprocket *5; 6* fan for ventilating the lamp; *7* flexible coupling; *8* two-bladed shutter; and *9* the cam for the claw movement.

The entire mechanism is scientifically ventilated. An opening properly placed permits the fan 6 to draw cool air past the aperture.

The amplifier and the preamplifier for the photocell are mounted in the base of the ensemble.

The sub-standard Oehmichen (Paris) projector (Fig. 4) is unique in that it employs no toothed sprockets and provides automatic loop regulation. In Fig. 5, D is a roller having marginal rubber tires the peripheral speed of which is slightly greater than the average speed of the film. The pad roller G_1 is attached to the film-gate and is located at a suitable distance from the roller D.

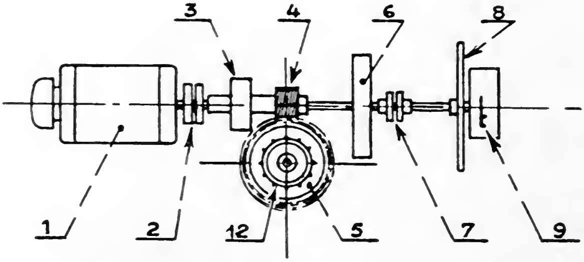

FIG. 3. Diagram of Ericsson mechanism.

When film is pulled down by the intermittent movement and the loop B_1 decreases in radius, the pressure of the film against the roller D increases rapidly. As D is moving at a greater speed than the film, the loop is quickly restored. As the radius of the loop increases, the pressure against D is gradually lessened to the point where there is little or no traction.

After leaving the intermittent movement the film passes under the pad roller G_2 and over the rubber-tired roller E, which has a peripheral speed slightly *less* than that of the film, forming the loop B_2. Pad roller G_2 is located at a point near the roller E so as to "strangle" the loop B_2. When the radius of loop B_2 decreases for any reason, the film pressure against E increases and the loop is quickly restored to its normal size.

In brief, a slight reduction in the radius of the loop brings into play the phenomena which tend to return it to its normal size. This constitutes the principle of automatic regulation. As no sprockets are used, the film passes through the projector without subjection of perforations to strain.

In "threading," careful adjustment of the loop is unnecessary. Once the machine is under way it assumes control, and maintains loops of the proper size regardless of the condition of perforations or film shrinkage.

The projection room of the Musée de l'Homme at the Trocadero (Paris) is equipped with an unusual outlay of apparatus to accommodate the various formats now in use in France. Destined to be used by scientific bodies in presenting films of documentary nature, nothing has been spared to achieve the utmost in fidelity of sound.

In addition to two 35-mm projectors, the installation includes one 16-mm Kodak projector, one 17.5-mm Pathé projector, and one 9.5-mm Pathé projector, each of which is fitted with a specially built sound head. All sub-standard projectors are fitted with carbon arc lamps. Film at each aperture is cooled by a strong air blast.

The amplifying equipment is quite comprehensive and includes several racks which are readily accessible for inspection, testing, *etc.* This unusual installation was handled by Film et Radio (Paris) under the direction of an American engineer. Other than certain projectors, all apparatus is of American manufacture.

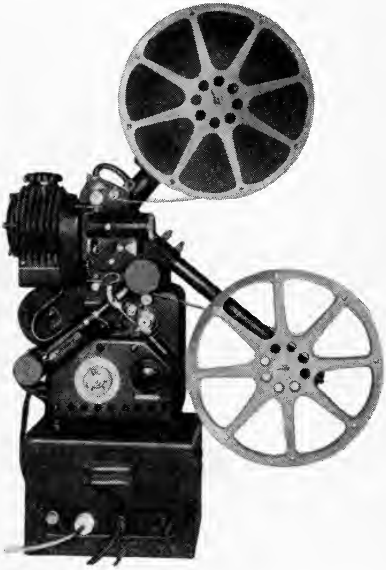

FIG. 4. Sub-standard Oehmichen projector.

ADJUSTABLE ELECTRIC REVERBERATION

Realism in present-day motion pictures is due in no small way to the artistry of cameramen in lighting sets according to the mood or tempo of the scene being filmed. In order to keep pace with photography, sound, too, must be varied from scene to scene to enhance realism.

Sound-stages, in order to reduce troublesome reverberation, must of necessity be deadened by a judicious application of insulating material. After the reverberation period has been reduced to a specified degree, the sound engineer is left with no flexible means of changing the reverberation period to fit the scene being taken.

The reverberation period of the average studio is below that of the theater or concert hall, where a reasonable amount of reverberation is not disagreeable but pleasing to the ear. It is well known that the time of reverberation is not the same at all frequencies, and a curve can be drawn for each studio or auditorium showing the time of reverberation as a function of frequency. It is the shape of such a curve as much as its average value that determines the "timbre" of any given studio.

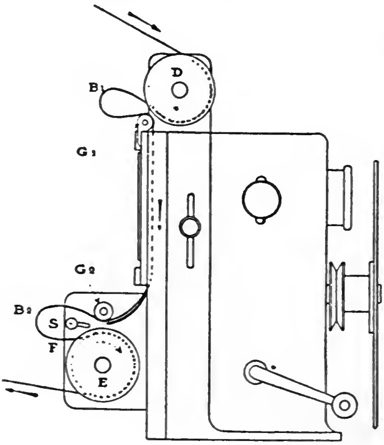

FIG. 5. Automatic loop regulation in Oehmichen projector.

Many have studied and searched to define an ideal curve of a studio in terms of its dimensions and utilization. Unfortunately, their findings are not in agreement. One would suppose that this lack of understanding led the B.B.C. in London to build 32 studios, each having a different reverberation curve.

The ideal solution would be a studio in which the acoustics could be controlled at will and instantaneously, within wide limits. The mechanical solutions conceived thus far are complicated, cumbersome, and sluggish in operation.

In view of this lack of control by mechanical means, it was only natural to seek the solution of the problem through electrical methods. Many years of research work in this field under the direction of M. B. Roux of France, has resulted in a practicable method of reverberation control by electrical means. The inventers have conceived and put into practice a system that not only increases the apparent time of reverberation, but also permits the reverberation characteristics to be changed at will.

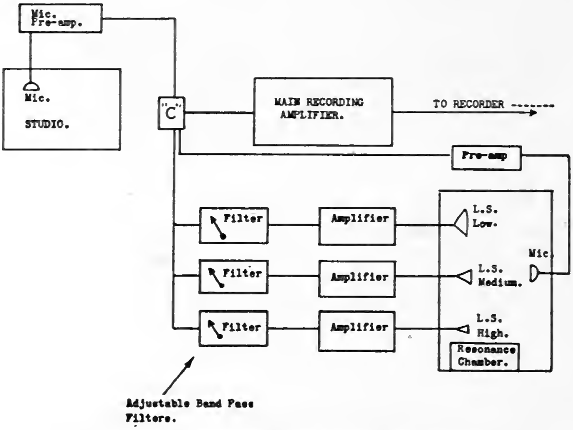

FIG. 6. Adjustable reverberation system.

Sound in the studio is picked up by a microphone and amplified by a preamplifier (Fig. 6). The output of the preamplifier is divided at C, one part going to the main recording amplifier and the other part to the adjustable reverberation equipment. This consists of a series of band-pass filters and amplifiers, the output of each of which being fed to a suitable loud speaker located in a special resonance chamber. A microphone located in the resonance chamber picks up the combined output from the loud speakers and after passing through a preamplifier, this current is fed into C where it is mixed with the output of the studio microphone and then passed on to the main recording amplifier, The principle of using a small resonance chamber is not new. Since the chamber is small, it produces without echo, a long duration of apparent reverberation.

The new principle, as developed under the guidance of M. Roux, is based upon the use of a group of filters which, theoretically, affect each frequency. In actual practice however, the audible band of frequencies is divided into three groups or bands. The intensity of each band is adjustable, which enables the "mixer" or recordist to vary the apparent duration of reverberation. All sorts of reverberant sound can be simulated at will, such as empty auditoriums, theaters, concert halls, churches, railway stations, effects of distance in rooms, and distance in open air. The new system permits the quality of voices to be changed. Special effects can be produced such as ghostly voices, *etc.*

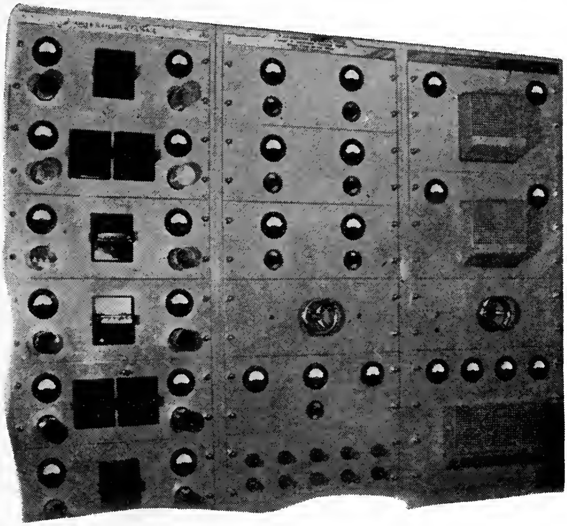

FIG. 7. Adjustable reverberation control installation.

The quality of the sound increases the realism of the scene showing the action. When a character goes from one room to another, the acoustics should change. Dialog in a boudoir has a reverberant quality different from that in a gallery of a museum. This electrical reverberation control, qualitatively and quantitatively adjustable, permits the simulation of acoustics most suitable to the sound or dialog being recorded.

A typical installation is shown in Fig. 7. The rack on the left supports six filter-amplifier units. The filters are of the plug-in type, removable from the front. This permits filters of different band-widths to be quickly changed for certain effects.

The middle rack supports three preamplifiers and a control panel for selecting one of two special control consoles furnished with each installation. Fig. 8 depicts a standard control console which includes everything necessary for remote control of the system.

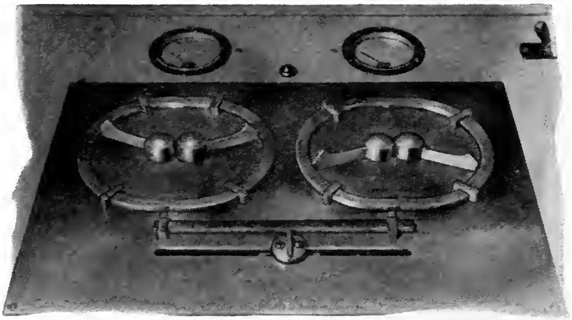

FIG. 8. Remote control console for adjustable reverberation control system.

The rack on the right (Fig. 7) supports three a-c operated power amplifiers which are connected to their respective loud speakers in the resonance chamber. These units have been designed to cover their particular frequency ranges with the utmost fidelity. Generous design precludes the possibility of distortion due to overload, and the hum level is considerably below the accepted level for normal reproduction. The loud speakers also are of special design. Each unit is capable of reproducing its corresponding band of frequencies with a minimum of distortion.

MGM PORTABLE DOLLY CHANNEL*

C. S. PRATT**

The original sound installations in most of the major studios were of the so-called central station type. At the time they were put in there was an entire absence of suitable portable equipment and, moreover, the number of stages to be supplied was generally quite small. Portable apparatus continued to be unavail-

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* Received May 10, 1939.

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

able for quite a period and during this time a large part of the stage expansion took place in the studio. Consequently, the expansion of the central plant became the economical and probably the only practical thing to do.

In the MGM studio the stage expansion took place in a direction on the lot to carry the stages farther and farther from the Sound Department. This meant an expensive and complicated set of comparatively long lines and trunks to provide proper service from the central plant to each of the stages. In addition, the maintenance of the old lines began to be a factor due to the natural deterioration of lead sheaths and other installation. An analysis of the various factors of installation, maintenance, and operation made four or five years ago indicated that more economical and better service could be provided if the sound recording unit were of a mobile nature and complete in itself when established on the stage on which it was to work.

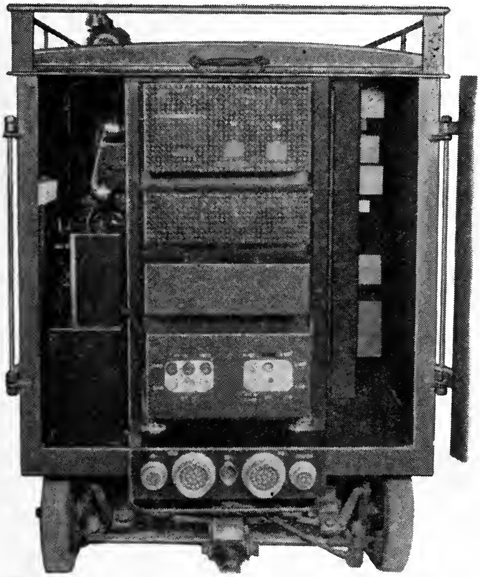

FIG. 1. Front view of portable dolly.

At first thought it might appear that one of the regular portable types of equipment would be desirable for the purpose. However, our conception of portable equipment has been that it should be primarily designed for location work where operation of the complete company unit is generally quite different from that of a unit operating on a stage. For location units some compromises are acceptable in operating facilities in order to secure proper portability just so long as the quality itself is not affected. For stage work within the studio such compromises are not permissible. The effort was made, therefore, to produce a more or less mobile channel which would have in it every element possessed by the central station channel all completely self-contained so that it could be readily transferred from one spot to another. The result is the MGM dolly type of recording channel.

The MGM dolly channel is a sound recording system, operated entirely from alternating current, designed primarily for use on stages not wired to the central plant. However, by standardization of plug outlets it can readily be used on any stage, either singly or as an added channel to the centrally located machines. The carriage is an enclosed body 40 inches wide, 42 inches high, and 60 inches long with steel roof and floor, angle-iron-frame enclosed with metal-covered plywood and hinged doors on all four sides. This is attached to axles by means of cantilever type springs. The rear axle is fixed, while the front is a 37-inch-tread Ford model *T* axle complete with steering knuckles. Twelve-inch wheels are used, equipped with 3-inch solid rubber tires. The steering tie bar is attached to a hollow tubing tow bar.

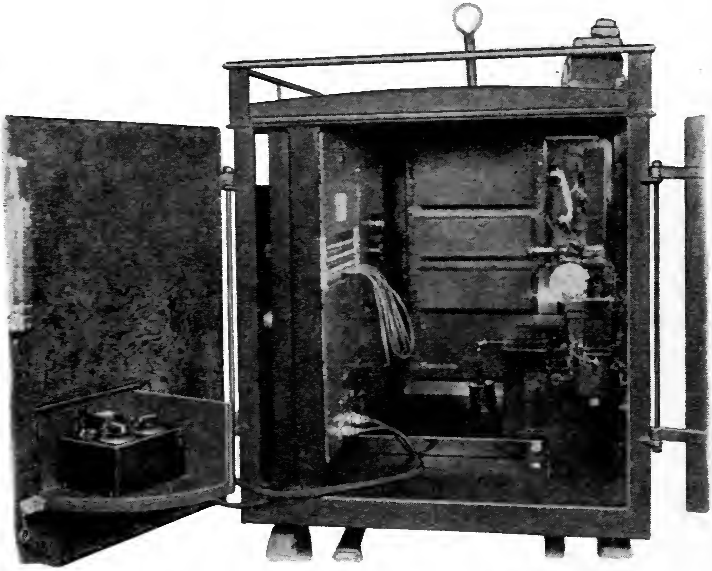

FIG. 2. Rear view of portable dolly.

The channel amplifiers with associated power-supply filters and equalizers are mounted on standard amplifier racks with their backs against the right-side doors looking from the front of the dolly. Opposite these racks on the left side of the dolly is the Western Electric *D-86715* type film-recording machine; its door against the left-side door of the dolly. The a-c power supply, fuse panel, and rectifiers are mounted on a rack across the front of the dolly with their backs against the front door. This arrangement faces all equipment toward the operator and allows maximum accessibility to the rear of the apparatus for repair and maintenance. The recording machine is driven by a 48-cycle synchronous motor and modified to use standard 1000-ft Mitchell magazines. By thus eliminating the use of a lower magazine and take-up, the machine is mounted on a metal can containing valve and lamp controls, the standard Western Electric *Q*-type noise-control unit, intercommunicating telephone, and automatic starting unit. In the rear door of the dolly is mounted a hinged shelf. The two-position mixer with volume-indicator extension and monitoring head-phone jacks is attached to this shelf by wing-nuts and may be used either in this position or extended out to the set. The top of the carriage is covered with rubber and surrounded by a luggage rack that accommodates a full complement of cables and auxiliary equipment.

At the front end, above the tow bar and below the end door, is mounted the panel carrying the plug receptacles which consist of: 120-volt, three-phase, 48-cycle camera and recording machine drive supply; 110-volt, single-phase, 50-cycle rectifier supply; 120-volt, three-phase, 48-cycle supply outlet; and 23 pin-receptacles for signal telephone circuits in and out.

FIG. 3. Operator's side view of dolly.

This allows all cables except the microphone cables to be connected to the dolly at the end away from the mixer, and all doors may be locked without disconnecting.

The amplifier channel consists of mixer, voltage and power amplifiers (totalling 86 decibels gain), low-pass and high-pass filters, volume equalizer and attenuator, volume limiter and volume indicator, noise-reduction unit, and monitoring circuit. The voltage amplifier is Western Electric *81-A* with slight modifications and a gain of 54 decibels. This feeds 500 ohms out into an MGM two-section 7500-

cycle cut-off low-pass which in turn feeds into a 50-cycle MGM high-pass. The output of the high-pass normals into a standard Western Electric *94-A* amplifier with a 500-ohm termination across the jack normals. These normals also carry a *94-A* in multiple jack. The Western Electric *94-A* amplifier is modified to approximately 17 decibels feed back and a gain of 31 decibels. The *94-A* amplifier output feeds into the MGM pre-equalizer. The pre-equalizer induces a loss of approximately 12 decibels at 100 cycles, 6 decibels at 1000 cycles, and zero decibels at 8000 cycles. Across the output of the pre-equalizer is a Western Electric 500–500-ohm film attenuator, the output of which feeds the value repeat coil and a standard *Q*-type Western Electric noise-control unit.

The frequency-response of the amplifier combination is uniform to ±1 decibel from 20 to 10,000 cycles. The noise level of the overall channel measures minus 53 decibels. Across the jack normals between the *94-A* amplifier is a 5000–50-ohm monitor repeat coil, the volume indicator, potentiometer, and standard Western Electric volume limiter. Across the output of the monitor repeat coil is a 50-to-50-ohm attenuator, the output of which is fed to the monitoring phone jack at the mixer. In the same manner, the output of the volume indicator potentiometer feeds to the volume indicator meter at the mixer panel. A test oscillator with a fixed frequency of 3000 cycles per second and variable output is installed in the unit and may be connected to any section of the circuit by use of patch cords. Western Electric type *705* ear-phones are used for monitoring. A full-wave rectifier using two Tungar tubes and operated from 110-volt, single-phase, a-c sources is used to supply 12 volts d-c to all system lamp and signal circuits. A rectifier using one Western Electric *274* type and two *874* type voltage-regulator tubes supplies *B* voltages to the microphones and *81-A* amplifier.

The recording machine and cameras are supplied power through a standard MGM automatic operating system. This consists fundamentally of a motor-driven cam unit equipped with a series of contacts and relays. A 23-conductor cable from dolly to microphone boom supplies the so-called signal-control box with full complement of telephone, signal, and operating controls. By the operation of a single switch in the signal-control box, the director's extension switch is paralleled across this circuit, and the automatic and operating system energizes the following circuits in the order given:

(*1*) "Take" light and warning signal occur at recorder.
(*2*) Take light and warning signal occur at exterior of stage door.
(*3*) Bell telephone is disconnected from incoming line.
(*4*) Recording machine and camera started.
(*5*) Recording machine shutter opens, camera fogging lamp is operated, and a single stroke of warning bell sounds at the set.

Communication is maintained between microphone boom, recording channel, and central sound plant with inter-phone system having individual ring and talk circuits.

SIMPLIFYING AND CONTROLLING FILM TRAVEL THROUGH A DEVELOPING MACHINE*

J. F. VAN LEUVEN**

The developing machine described here is simple in design, thus reducing maintenance costs to a minimum and practically eliminating film breakage and damage hazards from mechanical causes. A very wide range of speed has been accomplished largely through the machine's ability to regulate and maintain an even flow of, and a constant tension on the film throughout its developing and drying process.

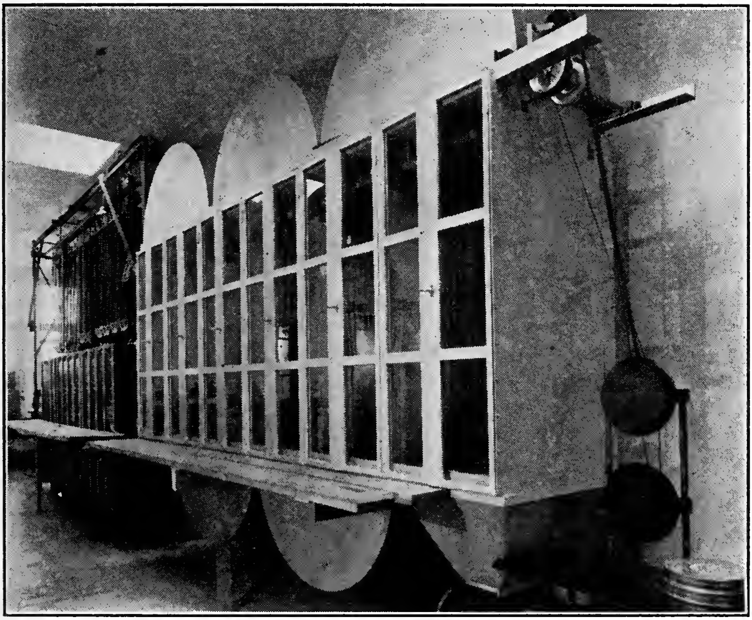

FIG. 1. 35-mm machine: capacity 600 ft per hr.

The entire drive of the film-carrying rollers is frictional, and the power is applied directly to the outer and upper edges of the rollers but only when there is normal tension on the film. This driving action is achieved by creating a light constant drag or tension on the film throughout the machine, and the tension thus set up is relieved in the following manner:

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 14, 1939.

** Fonda Machinery Co., Los Angeles, Calif.

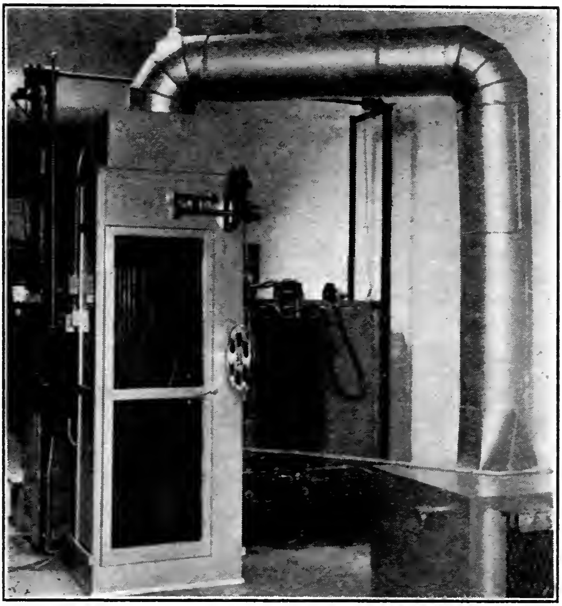

FIG. 2. 16-mm machine: capacity 1000 ft per hr.

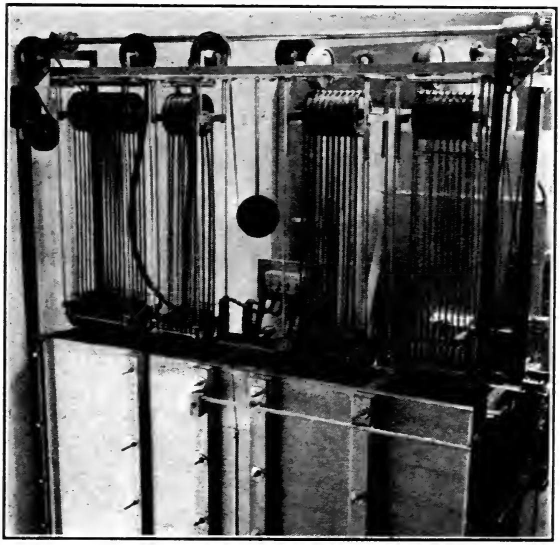

FIG. 3. Wet end of the 1000-ft 16-mm machine.

The film-carrying rollers are mounted on shafting which in turn is mounted yieldably downward on saddles which are carried on springs, and when the film drag or tension exceeds the amount determined by the spring adjustment, these upper film-carrying rollers are drawn downward and away from driving rollers until sufficient slack is fed up to relieve the tension, which then permits the springs to draw the film-carrying rollers again into contact with the driving rollers.

The drawing-downward action takes place almost constantly throughout, but is noticeable only in the dry box where film shrinkage is added to the drag set up in the machine. On the take-off end a driven friction roller keeps the tension constant to the rewind.

At the first entrance of the film into the machine a given speed is established and is maintained throughout the developing and drying process unless changed by the operator.

To meet the high initial and maintenance cost of ball bearings in film-carrying spools, $7^1/_2$-inch film-carrying rollers are used throughout the machine. This also reduces wear and depreciation by at least 50 per cent by slowing the rpm of the whole machine 50 per cent or in some cases even more, and yet maintaining film speed.

The driving rollers are directly over the upper film-carrying rollers. All driving mechanism is out of tanks and solutions. The upper film-carrying rollers are mounted so that they may engage or disengage the driving rollers automatically.

All film-carrying rollers in the wet end are mounted individually free, and in turn are all mounted on free-turning tubing or shafting. All film-carrying rollers in the dry box, in addition to being mounted individually free, are mounted on tubing which in turn is mounted with ball bearings on shafting, the entire unit being free to rotate or to slide laterally on the shaft, thus becoming self-aligning.

There are no ball bearings in the rollers, or bakelite gears to replace.

There are no sprockets to tear or pull film, or elevators to regulate tension.

Breakage from mechanical causes is practically eliminated, and speed and safety coöperate instead of limit each other.

Film enters the machine in a steady constant flow, and tension is regulated by the operator through the spring adjustment which holds the film-carrying roller shaft. When adjusted, the tension of the film remains virtually constant throughout the machine.

Finally, there are no precision parts or need for precision maintenance.

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, N. Y. Micro copies of articles in magazines that are available may be obtained from the Bibliofilm Service, Department of Agriculture, Washington, D. C.

American Cinematographer

20 (Sept., 1939), No. 9

Densitometry and Its Application to Motion Picture Laboratory Practice (pp. 391–394) — E. Huse and G. Chambers

Eclair Camera Makes Hollywood Bow (pp. 418–420, 425) — W. Stull

British Journal of Photography

86 (Aug. 4, 1939), No. 4135

Progress in Colour (pp. 488–489)

86 (Aug. 18, 1939), No. 4137

Progress in Colour (pp. 522–523)

86 (Aug. 25, 1939), No. 4138

Progress in Colour (pp. 536–537)

Communications

19 (Aug., 1939) No 8

Sound Motion Picture Films in Television, Pt. 4 (pp. 17–25, 28–31, 34) — J. A. Maurer

International Photographer

11 (Aug., 1939), No. 7

Problems in Rear Projections (pp. 5–8) — L. Carroll

International Projectionist

14 (Aug., 1939), No. 7

Film Projection by Discharge Lamps (pp. 7–10) — C. Heller

The H-S All-Metal Arc Reflector (pp. 14–15) — C. E. Shultz

Motion Picture Herald (Better Theatres Section)

136 (Aug. 19, 1939), No. 8

What Price Projection Inefficiency? (pp. 35–36) — H. D. Behr

Projection and Sound System for Smaller Theatres (pp. 37–38, 41)

Television Apparatus as Now Available for Theatre Use (p. 39)

Technique Cinematographique

9 (July, 1939), No. 103

La Normalisation en Cinematographie (Standardization in Cinematography) (pp. 1487–1488)	J. Duval
La Bande Sonore sur Film Ozaphane (Sound Strip on Ozaphane Film) (p. 1488)	R. Hardy

Veröffentlichungen des Wissenschaftlichen Zentral-Laboratoriums der Photographischen Abteilung, Agfa. I. G. Farbenindustrie Aktiengesellschaft

6, 1939

Veröffentlichungen des Wissenschaftlichen Zentral-Laboratoriums der Photographischen Abteilung, Agfa. I. G. Farbenindustrie Aktiengesellschaft 6, 1939.

Zurspektralen Empfindlichkeit photographischer Schichten, I and II (On the Spectral Sensitivity of Photographic Emulsions, I and II) (pp. 23–45)	J. Eggert and M. Biltz
Das Agfa-Pantachromverfahren (Agfa Pantachrome Method) (pp. 46–64)	J. Eggert and G. Heymer
Fortschritte auf dem Gebiete der Kinefilm-Emulsionen für Aufnahmezwecke (Progress in the Field of Negative Motion Picture Film Emulsions (pp. 65–75)	A. Schilling
Ein Neues Material für Tonaufzeichnung in Zackenschrift (New Film for Variable Width Sound Recording) (pp. 76–85)	A. Küster
Tonaufzeichnung in Doppelzackenschrift auf 16-mm-Filme (Double-edge Variable Width Sound Recording on 16-Mm Film) (pp. 86–98)	A. Küster
Tonaufzeichnung auf Ozaphanfilm (Sound Recording on Ozaphane Film) (pp. 99–107)	H. Hörmann
Die "Agfa-Farbentafel für Farbenphotographie" (Agfa Color Chart for Color Photography) (pp. 225–229)	H. Arens and G. Heymer
Hilfsgeräte zür sensitometrischen Uberwachung der Filmverarbeitung (Apparatus for Sensitometric Control in Film Manufacture) (pp. 248–258)	H. Brandes, K. V. Briessen, and E. Fess
Über eine einfache Bestimmungsmethode des Silbers in gebrauchten Fixierbädern (A Simple Method of Determination of Silver in Used Fixing Baths) (pp. 270–272)	H. Arens

HIGHLIGHTS OF THE FALL CONVENTION

HOTEL PENNSYLVANIA, NEW YORK, N. Y., OCTOBER 16-19, 1939

One of the outstanding features of the Conventions of the Society is the great variety of subjects covered in the papers sessions. This is especially so with regard to the 1939 Fall Convention just ended, at the Hotel Pennsylvania, New York, N. Y., October 16th to 19th, inclusive. The Convention was unusually well attended, the number of paid registrations being greater than at any convention held heretofore either on the East Coast or the West Coast. The attendance at the individual sessions was also unusually good, there being at no time fewer than 100 persons at any session, and, in several cases, the attendance reached 250 or 300 persons.

Mr. J. I. Crabtree opened the Monday morning session. Then, following reports of several convention committees, the delegates were formally welcomed to the Convention by President Williford, who occupied the chair for the remainder of the session.

During the business part of the program, several amendments of the By-Laws were proposed and acted upon, and announcement was made of the results of the election of officers for 1940. These results were as follows:

***Engineering Vice-President*	D. E. HYNDMAN
***Financial Vice-President*	A. S. DICKINSON
**Secretary*	J. FRANK, JR.
**Treasurer*	R. O. STROCK
***Governors*	A. N. GOLDSMITH H. GRIFFIN A. C. HARDY

* Term expires December 31, 1940.
** Term expires December 31, 1941.

After an interesting discussion of "The Problem of Distortion in the Human Ear," by S. S. Stevens of Harvard University, a very interesting demonstration of "High-Speed Motion Pictures of the Human Vocal Cords" was presented by J. Crabtree and D. W. Farnsworth of the Bell Telephone Laboratories. A 16-mm motion picture of the vocal cords in action was projected upon the screen, illustrating the movement of the cords during the emission of various kinds of sounds.

The Informal Get-Together Luncheon was held at noon of this day (Monday, October 16th). Seated at the speakers' table with President Williford were the Honorable Fiorello H. LaGuardia, Mayor of the City of New York; the Honorable Bruce Barton, Congressman from New York; Mr. W. G. Van Schmus, Managing Director of Radio City Music Hall; Mr. E. P. Curtis of the Eastman Kodak Company; Messrs. F. Speidell and W. Brooks of Audio Productions, Inc.; Dr. A. N. Goldsmith; Mr. S. K. Wolf; and Mr. D. E. Hyndman.

After introducing the officers-elect, listed above, President Williford introduced Mayor LaGuardia, who discussed at some length his hope and wish that the motion picture industry would some day move from Hollywood to New York. Brief addresses were then delivered by Messrs. Barton and Van Schmus. About 250 persons attended the luncheon.

The succeeding afternoon included a group of five papers on widely varying subjects. The interesting paper by H. Roger described the vast territory covered by the motion picture as an aid in scientific research. Emphasis was placed on the application of the motion picture to biological research, and some remarkable motion pictures were shown of the cellular activities of living tissues, magnified some 200 times on the film. A valuable paper on the subject of "Photographic Duping of Variable-Area Sound" was presented by F. W. Roberts and E. Taenzer of the Ace Film Laboratories, in which a method of duping was evolved that would satisfy a number of criteria for making duplicate sound negatives to be used in replacement of damaged original negative sections. The paper included a cross-modulation treatment of the subject and a film demonstration.

Mr. S. L. Reiches of the Case School of Applied Science, Cleveland, discussed the subject of "Volume Distortion" from the point of view that despite the fact that linear recording and reproducing systems may be used in sound recording, experience shows that the sound reproduced by the system does not exactly represent the original recorded sound. Mr. Reiches' discussion revolved about the thesis that the discrepancy was due to the ear sensitivity to frequency as a function of loudness.

The afternoon closed with a brief description by W. A. MacNair of the Bell Telephone Laboratories of the sound equipment to be seen by the delegates at the Bell Telephone Exhibit at the New York World's Fair.

About 400 delegates and guests of the Society convened in the auditorium of the Chrysler Exhibit at the Fair at 8 o'clock, at which time Mr. J. A. Norling presented a discussion of the principles involved in producing three-dimensional motion pictures, following which was projected a film in which stereoscopic effects were produced by using polaroid filters on the cameras and viewing spectacles for separating the stereoscopic pairs successively for each eye of the viewer.

The delegates then paid a visit to the RCA Exhibit where a demonstration of television was in progress, and then the group proceeded to the Kodak Exhibit, where Mr. F. Tuttle presented a paper describing the automatic slide projectors installed in the building. The hall where the exhibit was held was semicircular in shape, or approximately so, and arranged on the concave surface of the wall were eleven large screens upon which were projected in rather quick succession groups of Kodachrome still pictures by eleven specially built projectors. The eleven screens on the concave surface were contiguous, thus allowing the simultaneous projection of eleven pictures in a beautiful panorama effect.

After the projection of the pictures, the delegates were permitted to inspect the projection room and the equipment therein.

The last event of the evening was a visit to the American Telephone and Telegraph Exhibit where a demonstration was given of two-channel recording and reproduction with steel tape, in which demonstration a number of the delegates participated, by having recorded on the steel tape their conversations held on the stage set up for the purpose. At the end of the conversations, the participants were replaced by dummy figures, and the steel tape played back. The stereophonic set-up resulted in a very satisfying facsimile of the voices.

The delegates were also permitted to have tests made of their aural acuity by means of special tone-producing machines.

A demonstration was also given of the Voder, which is a machine for synthesizing speech by combining in their proper sequence varying levels of selected tone and noise frequencies by means of manual and foot controls.

The morning of Tuesday, October 16th, included a report of the Laboratory Practice Committee by D. E. Hyndman, Chairman, which discussed in detail the possible design of motion picture processing laboratories of several footage capacities. Although the report was not presented in full, it will, when published in the JOURNAL, represent the most comprehensive treatise on the subject available up to the present time.

The morning concluded with a discussion by L. L. Ryder of Paramount Studios, Hollywood, on the subject of coöperation between story construction and sound, and a paper by R. Kingslake of Eastman Kodak Company on the subject of 16-mm and 8-mm lenses for motion picture equipment.

The evening of Tuesday was devoted to a joint meeting with the New York Electrical Society in the auditorium of the Engineering Societies Building, the speaker being Mr. Homer Dudley of the Bell Telephone Laboratories. In these Laboratories, Mr. Dudley and his associates have developed electric circuits for the artificial production of speech. One form of the device is itself voice-controlled, thus differing fundamentally from the Voder of the World's Fair which is controlled by keys and pedals. It has been christened the "Vocoder" or "voice coder."

The speaker demonstrated many of the startling effects which result when the code is varied. In this way the Vocoder created sounds quite other than those used by the person speaking. Cadences became monotones, rising inflections were turned into falling inflections, a vigorous voice became a quaver, and a single voice accompanied itself at any desired musical interval—thus converting a solo into a duet. Also non-speech sounds were coded into intelligible speech and instrumental music into vocal music.

There were present at the meeting about 250 SMPE delegates, in addition to the representation from the New York Electrical Society.

On the morning of Wednesday, October 18th, a symposium was held on projection, with Dr. Alfred N. Goldsmith acting as Chairman. The symposium included eight papers on various phases of projection. One of the most interesting of the group was a paper by B. Schlanger on the subject of "Motion Picture Auditorium Lighting." The report of the Projection Practice Committee traced the influence upon the industry of the Committee's projection room plans, first evolved in 1930, and subsequently revised several times. Announcement was made to the effect that these plans were proving of considerable importance to a number of States in drafting their regulations for constructing and operating motion picture projection rooms, and were also being used as a basis for insurance ratings by an insurance rating bureau in New England. They also provided the basis for the recent revision of the regulations of the National Fire Protection Association, adopted at Chicago last May.

Wednesday afternoon contained an assortment of papers on motion picture carbons, television control equipment, the transmission of animated line images, sound recording, and the production of synthetic reverberation. The paper by A. M. Skellett describing a narrow-band transmission system for animated line images demonstrated a method of converting line drawings into photographic sound records, in the form of variable-area sound-track, and the reconversion of these records into line images on the fluorescent screen of a cathode-ray tube. G. L. Dimmick described in considerable detail methods of controlling wave-shape and amplitude characteristics in variable-density recording by the use of the so-called "penumbra system" of varying the intensity of the recording light-beam and the control of this intensity by means of variously shaped masks on the penumbra vane or mirror.

Messrs. P. C. Goldmark and P. S. Hendricks of the Columbia Broadcasting System demonstrated a method of introducing reverberation into "dead" records by means of a rotating disk, the periphery of which is coated with a fluorescent material. Part of the sound current coming from the original source, either disk, film, or microphone, is caused to vary the intensity of a light-beam incident upon the fluorescent edge of the disk. Around the periphery of the disk are located a number of sound pick-up devices so located as to provide various time-intervals between the point at which the fluorescent material is activated and the points where the sound is picked up again. The sound or sounds thus picked up are then mixed with the original sound signal in the required proportions, and reproduced in the usual manner.

Mr. C. R. Daily of the Paramount Studio, Hollywood, presented a paper on the "Improvement in Sound and Picture Release through the Use of Fine-Grain Film," presenting data on some of the problems encountered in the use of such film for original sound negative, dubbing prints, release negative, and release prints. The sound quality is improved due to the reduction in noise and modulated noise effects which partially mask the signal when emulsions of the coarser grained positive type are used. The picture image on such fine-grain films was warm-toned as distinct from the usual blue-black image, and a vote of the members present indicated an approximately 50–50 preference for the two tones.

On the evening of Wednesday, October 18th, was held the semi-annual banquet and dance of the Society, in the Grand Ballroom of the Hotel Pennsylvania. The banquet was attended by approximately 250 persons. President Williford introduced the officers-elect for 1940. Seated at the speakers' table were President and Mrs. Williford; Mr. and Mrs. Frank Meyer of Paramount Pictures, Inc.; Mr. and Mrs. Hyndman; Dr. L. A. Jones, recipient of the 1939 Progress Medal; Dr. A. N. Goldsmith, citationist for Dr. Jones; Dr. H. T. Kalmus, recipient of the 1938 Journal Award; Mr. E. P. Curtis, citationist for Dr. Kalmus; Mr. G. F. Lewis, Technicolor, Inc.; Mr. E. G. Hines, General Theatre Equipment Corporation; and Mr. J. I. Crabtree, Editorial Vice-President.

After a few words of welcome by the President and the introduction of the officers-elect for 1940, the citations of the work of Dr. Jones and Dr. Kalmus were read by Dr. Goldsmith and Mr. Curtis, respectively. (These citations will be published in the next issue of the JOURNAL.) The awards were made by President Williford and appropriate responses delivered by the recipients.

The banquet concluded with dancing and entertainment.

The morning of Thursday, October 19th, included an assortment of papers on 16-mm applications, the report of the Non-Theatrical Equipment Committee, a time-lapse outfit adapted to the 16-mm Cinekodak, a sound-track center line measuring device, and the development and application of the triple-head background projector in the Warner Brothers First National Studios at Burbank, California.

Messrs. F. Ehrenhaft and F. G. Back presented a paper discussing the optical requirements of non-intermittent motion picture projectors, and gave a demonstration of a 16-mm non-intermittent projector designed in accordance with the principles discussed in the paper. The sound-track center-line measuring device described by F. W. Roberts and H. R. Cook, Jr., of the Ace Film Laboratories, Brooklyn, permits the measurement of the position of a sound-track center-line within a ten-thousandth of an inch. Direct readings may be taken with the instrument in ten seconds.

Thursday afternoon (October 19th) was devoted to a sound session. Mr. E. S. Seeley of the Altec Service Corporation, New York, discussed in considerable detail the characteristics of warbled frequency films, pointing out that the warbled signal is a frequency-modulated signal and may be represented by a carrier frequency and a series of side-frequencies, all of which are steady and discrete. The frequency structure of a warbled film in current use is calculated and shown graphically.

Dr. J. G. Frayne of Electrical Research Products, Inc., Hollywood, presented a report of progress on the adaptation of fine-grain films to variable-density sound technics. This is a report of a committee of representatives of twelve organizations on the West Coast, set up for the study of the problem, with Dr. Frayne as Chairman.

Messrs. R. O. Drew and E. W. Kellogg of RCA Manufacturing Company, Camden, discussed by means of a series of oscillograms, the wave-shapes of spoken sounds, showing in particular the build-up of the sound-wave from the instant the sound is started. Messrs. D. J. Bloomberg and C. L. Lootens of Republic Productions, Inc., Hollywood, discussed the progression of the industry from standard variable-area types of recording to Class *A* push-pull and finally to Class *B* push-pull, indicating that this transition was primarily motivated by an appreciation of the inherent advantages of the push-pull types of recordings and an ability to perfect processing and recording controls necessary to realize the finer qualities of the Class *B* push-pull method.

A tape splicer for film developing machines was described and illustrated by Messrs. J. G. Capstaff and J. S. Beggs of the Eastman Kodak Company, and Mr. A. L. Holcomb of Electrical Research Products, Inc., Hollywood, analyzed a new motor-drive system for motion picture studios, which will operate on either alternating or direct current and provide either running interlock or interlock from start. The multiduty motors described are basically d-c motors with the commutators tapped for three-phase interlock as used in previous d-c interlock systems.

ACKNOWLEDGMENTS

The Society wishes to acknowledge its gratitude to the large number of persons and companies who collaborated in providing the various facilities of the Convention and, in fact, making the Convention possible.

The general facilities of the Convention were arranged by Mr. W. C. Kunzmann, *Convention Vice-President:* Mr. J. I. Crabtree, *Editorial Vice-President:* Mr. D. E. Hyndman, Chairman of the Atlantic Coast Section and Chairman of the Local Arrangements Committee; Mr. Julius Haber, Chairman of the Publicity Committee; Dr. A. N. Goldsmith, Chairman of the Banquet Committee; Mr. S. Harris, Chairman of the Papers Committee; and Mr. L. A. Aicholtz, Chairman of the West Coast Branch of the Papers Committee.

Messrs. H. Griffin and G. Friedl, Jr., are to be thanked for their efforts and labor in providing the projection and sound-reproducing equipment used at the meetings. The Society extends its thanks also to Mrs. O. F. Neu, Chairman of the Ladies Committee, for her efforts in arranging an interesting program for the ladies attending the Convention.

Among the companies who contributed in equipment and service to the Convention are the following: National Carbon Company, Bausch & Lomb Optical Company, National Theater Supply Company, International Projector Corporation, Raven Screen Corporation, Bell & Howell Company, Local 306, IATSE; the Management of the Hotel Pennsylvania; and the New York Convention Bureau.

The Society is indebted also to the Chrysler Motor Corporation, the RCA Manufacturing Company, the Eastman Kodak Company, and the American Telephone and Telegraph Company for making their exhibits at the World's Fair available to the Society on Monday evening of the Convention; also to the Capitol Theater, Paramount Theater, Radio City Music Hall, Roxy Theater, and Warner's Strand Theater for the passes issued to the delegates to the Convention during the week of the meeting; to Mr. W. G. Van Schmus and the Radio City Music Hall for the entertainment at the banquet.

PROGRAM*

MONDAY, OCTOBER 16TH

Banquet Room; General and Business Session; J. I. Crabtree, *Chairman.*

Report of the Convention Arrangements Committee; W. C. Kunzmann, *Convention Vice-President.*

Report of the Membership and Admissions Committee; E. R. Geib, *Chairman.*

Welcome by the President; E. A. Williford.

Society Business:

Election of Officers for 1940.

Proposed Amendments of the By-Laws.

"The Problem of Distortion in the Human Ear;" S. S. Stevens, Department of Psychology, Harvard University, Cambridge, Mass.

"High-Speed Motion Pictures of the Human Vocal Cords;" J. Crabtree and D. W. Farnsworth, Bell Telephone Laboratories, New York, N. Y. (*Demonstration.*)

Grand Ballroom; Informal Get-Together Luncheon; E. A. Williford, *Chairman.*

Address of Welcome by the Honorable Fiorello H. LaGuardia, Mayor of the City of New York.

Guests: Hon. Bruce Barton, Mr. W. G. Van Schmus.

Banquet Room; General Session; *Chairman.*

"Science and the Motion Picture;" H. Roger, Rolab Photo-Science Laboratories, Sandy Hook, Conn. (*Demonstration.*)

"Backward Perspective—A Review in Retrospect of the Work of the Museum of Modern Art Film Library since 1936;" D. L. Baxter, Museum of Modern Art Film Library, New York, N. Y. (*Demonstration.*)

"Photographic Duping of Variable-Area Sound;" F. W. Roberts and E. Taenzer, Ace Film Laboratories, Brooklyn, N. Y. (*Demonstration.*)

"Volume Distortion;" S. L. Reiches, Case School of Applied Science, Cleveland, Ohio. (*Demonstration.*)

"Sound Equipment at the Bell Telephone Exhibit at the New York World's Fair;" W. A. MacNair, Bell Telephone Laboratories, New York, N. Y.

Chrysler Auditorium, New York World's Fair.

"Three Dimensional Motion Pictures;" J. A. Norling, Loucks & Norling, New York, N. Y. (*Demonstration.*)

RCA Building, New York World's Fair.

Demonstration of television by engineers of the RCA.

Kodak Building, New York World's Fair.

"Automatic Slide Projectors for the New York World's Fair;" F. Tuttle, Eastman Kodak Co., Rochester, N. Y.

After presentation of the paper there was a demonstration of projected Kodachromes, after which the delegates were conducted through the projection rooms.

American Telephone and Telegraph Building, New York World's Fair.

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* As actually followed at the sessions.

Demonstration of Two-Channel Recording and Reproduction with Steel Tape, with participation by the visiting delegates, followed by a demonstration of the "Voder." Aural acuity tests were also made by means of special tone-hearing test machines.

TUESDAY, OCTOBER 17TH

Banquet Room; Laboratory and General Session; D. E. Hyndman, ***Chairman.***

Report of the Laboratory Practice Committee; D. E. Hyndman, *Chairman.*

"The Importance of Coöperation between Story Construction and Sound to Achieve a New Personality in Motion Pictures;" L. L. Ryder, Paramount Studios, Hollywood, Calif.

"Lenses for Amateur Motion Picture Equipment (16-Mm and 8-Mm);" R. Kingslake, Eastman Kodak Co., Rochester, N. Y.

Joint meeting with the New York Electrical Society; in the auditorium of the Engineering Societies Building, 29 West 39th Street, New York, N. Y.

Speaker: Homer Dudley, Bell Telephone Laboratories, New York, N. Y. Demonstration of the "Vocoder."

WEDNESDAY, OCTOBER 18TH

Banquet Room; Projection Session; A. N. Goldsmith, ***Chairman.***

"Future Development in the Field of the Projectionist;" A. N. Goldsmith, New York, N. Y.

"Motion Picture Auditorium Lighting;" B. Schlanger, New York, N. Y.

"Simplex 4-Star Double-Film Attachment;" W. Borberg and B. Pirner, International Projector Corp., New York, N. Y.

"The Projectionist's Part in Maintenance and Servicing;" J. R. Prater, Congress Theater, Palouse, Wash.

"Suggestions for Encouraging Study by Projectionists;" F. H. Richardson, Quigley Publishing Co., New York, N. Y.

"Delivering Laboratory Results to Theater Patrons;" J. R. Prater, Congress Theater, Palouse, Wash.

Report of the Projection Practice Committee; H. Rubin, *Chairman.*

"Projection Room Planning for Safety;" E. R. Morin, State of Connecticut, Department of State Police, Hartford, Conn.

Banquet Room; General Session; H. Griffin, ***Chairman.***

"Large-Size Non-Rotating High-Intensity Carbons and Their Application to Motion Picture Projection;" D. B. Joy, W. W. Lozier, and R. Simon, National Carbon Co., Fostoria, Ohio.

"Television Control Equipment for Film Transmission;" R. L. Campbell, Allen B. DuMont Laboratories, Passaic, N. J.

"A Narrow-Band Transmission System for Animated Line Images;" A. M. Skellett, Bell Telephone Laboratories, New York, N. Y. (*Demonstration.*)

"Optical Control of Wave-Shape and Amplitude Characteristics in Variable-Density Recording;" G. L. Dimmick, RCA Manufacturing Co., Camden, N. J. (*Demonstration.*)

"Improvement in Sound and Picture Release through the Use of Fine-Grain Film;" C. R. Daily, Paramount Studios, Hollywood, Calif. (*Demonstration.*)

"Synthetic Reverberation for Motion Picture Studios;" P. C. Goldmark and P. S. Hendricks, Columbia Broadcasting Co., New York, N. Y. (*Demonstration.*)

Grand Ballroom; Semi-Annual Banquet and Dance.

Introduction of Officers-Elect for 1940.

Presentation of the SMPE Progress Medal.

Presentation of the SMPE Journal Award.

Entertainment and Dancing.

THURSDAY, OCTOBER 19TH

Banquet Room; Sixteen-Mm and General Session; R. C. Holslag, *Chairman.*

Report of the Non-Theatrical Equipment Committee; R. C. Holslag, *Chairman.*

"Some Industrial Applications of Current 16-Mm Sound Motion Picture Equipment;" W. H. Offenhauser, Jr., and F. H. Hargrove, Berndt-Maurer Corp., New York, N. Y.

"A New Non-Intermittent Motion Picture Projector;" F. Ehrenhaft and F. G. Back, New York, N. Y. (*Demonstration.*)

"A Flexible Time-Lapse Outfit;" A. B. Fuller and W. W. Eaton, Eastman Kodak Co., Rochester, N. Y.

"A Sound-Track Center-Line Measuring Device;" F. W. Roberts and H. R. Cook, Jr., Ace Film Laboratories, Brooklyn, N. Y.

"Development and Application of the Triple-Head Background Projector;" B. Haskins, Warner Bros. First National Studios, Burbank, Calif.

Banquet Room; Sound Session; K. F. Morgan, *Chairman.*

"Considerations Relating to Warbled Frequency Film;" E. S. Seeley, Altec Service Corp., New York, N. Y.

Report of the Standards Committee, E. K. Carver, *Chairman.*

"Report on the Adaptation of Fine-Grain Films to Variable-Density Sound Technics;" J. G. Frayne, Hollywood, Calif.

"New High-Quality Sound System;" G. Friedl, Jr., H. Barnett and E. J. Shortt, International Projector Corp., New York, N. Y.

"Starting Characteristics of Speech Sound;" R. O. Drew and E. W. Kellogg, RCA Manufacturing Co., Camden, N. J.

"Tape Splicers for Film Developing Machines;" J. G. Capstaff and J. S. Beggs Eastman Kodak Co., Rochester, N. Y.

Report of the Studio Lighting Committee; C. W. Handley, *Chairman.*

"Class *B* Push-Pull for Original Recording;" D. J. Bloomberg and C. L. Lootens, Republic Productions, Inc., Hollywood, Calif.

"A Multiduty Motor System;" A. L. Holcomb, Electrical Research Products, Inc., Hollywood, Calif.

ABSTRACTS OF PAPERS AT THE FALL CONVENTION

The following are abstracts of papers for the Fall Convention received too late for inclusion in the preceding issue of the Journal.

Starting Characteristics of Speech Sounds; R. O. Drew and E. W. Kellogg, *RCA Mfg. Co., Inc.*, Camden, N. J.

In view of its bearing on the design of ground-noise-reduction systems, a study was undertaken to determine how sudden or how rapid are the increases in amplitude of the speech sounds that must be recorded in dialog. A large number of oscillograms were taken, a number of which are reproduced.

The most important observation is that the human voice can start several of the vowel sounds in such a way that the first wave is from 40 to 80 per cent of the final amplitude or, in other words, with a suddenness comparable to that of keying in an oscillator. This is rare, and is, for all practical purposes, confined to a few of the more open vowel sounds, when not preceded by any consonant, and is true only of certain individuals, depending on the manner of releasing the breath. Progressive build-up at rates which would carry the modulation from zero to 100 per cent in 0.05 second are frequent, while the great majority of syllables start more gradually than this.

Improvement in Sound and Picture Release through the Use of Fine-Grain Film; C. R. Daily, *Paramount Pictures, Inc.*, Hollywood, Calif.

Many types of picture scenes are improved in quality when some of the new fine-grain films are used as a printing stock. More detail on the screen and less image "boiling" is observed due to the greater resolution of the fine-grain films. When such films are used for variable density sound recording, a material increase in volume range is obtained which permits greater latitude in the original and dubbing recording operations. The sound quality is improved due to the reduction in noise and modulated noise effects which partially mask the signal when the coarser-grained positive type of emulsions are used. Data are presented on some of the problems encountered in the use of fine-grain films for original sound negative, dubbing prints, release negative, and release prints.

Optical Control of Wave-Shape and Amplitude Characteristics in Variable-Density Recording; G. L. Dimmick, *RCA Mfg. Co., Inc.*, Camden, N. J.

The use of the optical penumbra to obtain linear variable-intensity light-modulation has already been described. The present paper shows how to obtain non-linear penumbras having predetermined intensity-amplitude characteristics. By this means it is possible to compensate optically for non-linear relation between negative exposure and print transmission known to exist in the variable-density system.

Variable-density noise-reduction has been obtained by moving the penumbra vane at right-angles to the optical axis in accordance with the volume of the original sound. If a fixed penumbra vane is placed close to the movable vane, it forms an optical end-stop which limits the deflection of the penumbra after it has reached a predetermined position. The optical characteristics of penumbras formed by two displaced vanes are also shown.

For a given amplitude of galvanometer-mirror vibration, the extent of the light-modulation is determined by the penumbra height at the recording slit. The penumbra height may be varied by moving the penumbra vane along the optical axis. Either compression or expansion of the sound volume obtained from a film record may be affected by causing the penumbra vane to move along the axis in accordance with the volume of the original sound. Such a system is described in detail.

A combined system is also described which permits both noise-reduction and compression to be obtained by the use of a single shutter and noise-reduction amplifier.

Large-Size Non-Rotating High-Intensity Carbons and Their Application to Motion Picture Projection; D. B. Joy, W. W. Lozier, and R. W. Simon, *National Carbon Co.*, Fostoria, Ohio.

The high-intensity, direct-current arc between small, copper-coated carbons operated in coaxial alignment without rotation with a reflector optical system has achieved a widespread and growing popularity over the past few years for theatrical projection of motion pictures. This type of light-source has now been extended to include larger carbons and higher currents. These larger carbons of this type with the proper optical system will give substantially higher light on the motion picture screen.

Fundamental facts about the arc behavior and the conditions necessary to obtain stable and steady operation with these larger carbons are described. The correlation of the luminous characteristics of the arc with the optical system is reviewed. The performance of a new arc with a suitable optical system is given from the standpoint of offering possibilities for projection. Carbon consumption rates, arc current and voltage, and light on the screen are discussed.

High-Speed Motion Pictures of the Human Vocal Cords; J. Crabtree and D. W. Farnsworth, *Bell Telephone Laboratories*, New York, N. Y.

Pictures taken at the rate of 4000 per second, by means of a special high-speed camera and lighting arrangement, show the vocal cord movements during phonation in ultra-slow motion. The experiments throw new light on the old question of the role of the cords in speech production.

The Importance of Coöperation between Story Construction and Sound to Achieve a New Personality in Pictures; Loren L. Ryder, *Paramount Studios*, Hollywood, Calif.

The information presented in this paper has been taken from a paper which the writer prepared at the request of the Paramount administration for presentation to the producers, directors, and writers of the company. The thought is that too large a gap exists between the creative and technical groups, and that much can be done to better production through a better understanding by our creative group of the technical possibilities and limitations of our various equipments.

The paper discusses our sound personnel as competent technical and analytical thinkers working in a business largely guided by the creative mind. Further, it points out that many improvements have been made toward technical perfection of our equipments, but that only small concern has been given toward taking full advantage of our technical knowledge in obtaining dramatic effectiveness in pictures.

Our objective in picture making is largely one of creating an illusion to the audience. The audience is either listening in on the intimate lives of our characters or are a part of the dramatic scene which is being portrayed before them. Our problem is one of making this illusion more effective even though we are limited by obstacles such as distance, reverberation, volume range, theater noise, and even the playing levels of our pictures.

The paper discusses the problem of determining wherein we miss our objectives as well as the problem of evaluating our successes. It gives a coverage of the music problem pointing out that there are 78 different systems of scoring music for pictures, now in use in the industry. It discusses audience reactions as observed at previews and the psychological effect of sounds on the audience. In this regard new sounds, backward sounds, and sounds which the audience have never heard before are pointed out as creating reactions which otherwise could not be obtained. Toward the end of the paper there is a discussion of the future possibilities of sound as a means of obtaining greater dramatic expression in our picture work.

The Development and Practical Application of the Triple-Head Background Projector; Byron Haskin, *Warner Bros. First National Studios*, Burbank, Calif.

Up to a recent date, background process work had been limited to the size of picture that could be successfully illuminated through a single projecting machine.

The origination of a combination of projectors superimposing identical prints of the same background on the screen simultaneously compounded the light delivery of a single machine and therefore greatly expanded the scope of background process photography for natural color and black-and-white.

Class B Push-Pull Recording for Original Negatives; D. J. Bloomberg and C. L. Lootens, *Republic Productions, Inc.*, Hollywood, Calif.

Progression from standard variable-area types of recording to Class *A* push-pull and finally from Class *A* to Class *B* push-pull was primarily motivated by an appreciation of the inherent advantages of the push-pull types of recording, and an ability to perfect processing and recording controls necessary to realize the finer qualities of the Class *B* push-pull recording. The adoption of Class *B* push-pull variable-area for original recording has eliminated distortion introduced by noise-reduction systems, and has reduced background noise by at least 6 db.

SOCIETY ANNOUNCEMENTS

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:

BEDFORD, J. H. C.
2505 W. Lanvale St.,
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BIELUSICI, A.
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S. M. P. E. 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 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. 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.

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An optical reduction of the 35-mm. visual test-film, identical as to contents and approximately 225 feet long.

Price $25.00 each.

SOCIETY OF MOTION PICTURE ENGINEERS
HOTEL PENNSYLVANIA
NEW YORK, N. Y.

JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

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* Term expires December 31, 1939.
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WELCOME BY THE PRESIDENT*

TO THE

1939 FALL CONVENTION AT NEW YORK

(OCTOBER 16–19, 1939)

Unlike political subdivisions of this earth, the moving picture world has two capitals. Last April we were entertained in the production capital at Hollywood, California, and from all reports, our meeting was considered about the most successful we have ever had. This fall, the financial, exhibition, and distribution capital is our host, and those of us who live here, welcome you to our city and to the halls of our convention.

The advent of war in Europe, with all its attendant emotional, economic, and cultural dislocations has had a serious effect upon our industry. Only by calm resistance to emotional propaganda and an enlightened self-interest for the welfare of our country, its institutions, and its people—especially our young men—can we avoid a fate which will be common to all belligerents, whether they ultimately are designated as "victors" or "vanquished."

The formulation of a program for our conventions is an exceedingly difficult task. Our Editorial Vice-President, Mr. Crabtree, and the Chairman of the Papers Committee, Mr. Harris, have worked diligently to secure worthy papers and demonstrations for our program. As so often happens, we receive more than we can handle effectively in the time allotted, and, as a result, may find it necessary to carry on our program into Thursday evening.

Our evening programs for Monday and Tuesday did not work out quite as we had planned, but Mr. Crabtree felt that you would rather include the programs of both evenings as arranged than to forego one of them in the interest of better time arrangements. We hope you will enjoy the full program and feel benefited thereby.

It was my pleasure to represent the Society at a Projectionists' Day celebration at the New York World's Fair on September 7th. My remarks, if anyone cares to read them, are printed in the Septem-

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* Presented at the 1939 Fall Meeting at New York, N. Y.

ber issue of the *International Projectionist.* The program was one of recognition for the part played by the motion picture projectionist in the advancement of the art and science of motion pictures, and in addition to our Society, many prominent individuals, including our own Past-President, Dr. Goldsmith, paid tribute to the work of the projectionist.

Since our last convention, progress has continued in the development of new materials and in the technic of applying the tools of our industry to the production and projection of motion pictures.

Our Pacific Coast, Chicago, and New York sections have been active in bringing interesting programs to their local members. Our Committees have been carrying on their work of standardization studies and other functional responsibilities. Our Society continues to grow in numbers and in influence.

On Wednesday evening at our banquet, we not only expect to relax from the labors of technical sessions, but we shall honor two of our members who have made distinctive contributions to the world of motion pictures. I welcome you to all the sessions of our convention, and hope particularly that you will be present on Wednesday night to do honor to these two men.

E. A. WILLIFORD
President

PROCEEDINGS OF THE SEMI-ANNUAL BANQUET

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

HOTEL PENNSYLVANIA
NEW YORK, N. Y.

OCTOBER 18, 1939

Nearly 250 members and guests of the Society assembled at the Fall, 1939, Semi-Annual Banquet held at the Hotel Pennsylvania, New York, N. Y., on October 18th. Guests at the speakers' table were: President and Mrs. Williford; Mr. and Mrs. Frank Meyer of Paramount Pictures, Inc.; Mr. and Mrs. D. E. Hyndman; Dr. L. A. Jones, recipient of the 1939 Progress Medal; Dr. Alfred N. Goldsmith, citationist for Dr. Jones; Dr. H. T. Kalmus, recipient of the 1938 Journal Award; Mr. E. P. Curtis, citationist for Dr. Kalmus; Mr. G. F. Lewis, Technicolor Motion Picture Corporation; Mr. E. G. Hines, International Projector Corporation; and Mr. J. I. Crabtree, Editorial Vice-President. After introducing those seated at the speakers' table, President Williford announced the results of the annual election of officers for 1940 which were as follows:

**Engineering Vice-President	D. E. Hyndman
** Financial Vice-President	A. S. Dickinson
* Secretary	J. Frank, Jr.
* Treasurer	R. O. Strock
**Governors	A. N. Goldsmith H. Griffin A. C. Hardy

Following this announcement, President Williford next introduced Dr. Alfred N. Goldsmith, who presented the following citation on the work of Dr. Loyd Ancile Jones, the recipient of the SMPE Progress Medal for 1939:

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* Term expires December 31, 1940.

** Term expires December 31, 1941.

CITATION ON LOYD ANCILE JONES

It is a relatively frequent occurrence for a scientist or engineer to make a single contribution of substantial value in his chosen field by rigid scientific reasoning and painstaking experimentation (or even by sheer accident and relatively limited analysis and test). Even after one such achievement, his standing is correspondingly raised.

It is far rarer to find a man who is able to accomplish noteworthy and valuable advances in his art not once but repeatedly, and particularly in those fields that require the utmost exercise of thorough scientific reasoning and elaborately planned experimentation. One such field is that of photographic research, beset as it is by unusual complexities and subtle pitfalls, and requiring as it does truly outstanding ability and determination for its mastery. Accordingly, our respect and admiration must properly go to the master workers in that domain.

The Progress Medal.

Outstanding among these is Dr. Loyd A. Jones, to whom has been awarded the Progress Medal of the Society of Motion Picture Engineers for 1939.

Dr. Jones was born at York, Nebraska, in 1884; was graduated from High School in 1903; received his Bachelor of Science degree in Electrical Engineering at the University of Nebraska in 1908; his Master's degree in 1910; and the honorary degree of Doctor of Science from the University of Rochester in 1933.

From 1908 to 1910 he was assistant in the Physics Department of the University of Nebraska, and from 1910 to 1912, physicist at the

Bureau of Standards. In 1912 he took the position of assistant physicist at the Kodak Research Laboratories, and has been chief physicist there since 1916.

During the World War in 1917–1918, he was commissioned a Lieutenant in the U. S. Naval Reserve Force, in charge of camouflage investigation.

LOYD ANCILE JONES

Dr. Jones has been constructively active for many years in the Society of Motion Picture Engineers, having served as its president from 1923 to 1926, and as its engineering vice-president from 1933 to the present time. The Optical Society of America honored him by electing him its president in 1931, and he is an active member of at least six other scientific societies.

In 1935, Dr. Jones, as co-author with Dr. Julian Hale Webb, was awarded the Journal Award of the Society of Motion Picture Engineers for the paper entitled "Reciprocity Law Failure in Photographic Exposure," published by the Society in September, 1934.

In 1925 he received an award from the Association of Scientific Apparatus Makers of the United States of America for the best instrument paper offered for publication in the "Journal of the Optical Society of America and Review of Scientific Instruments." His contribution on this occasion was "A New Method of Photographic Spectrophotometry."

In 1935 the Kinematography Section of the Royal Photographic Society of Great Britain awarded a medal to Dr. Jones for his motion photomicrographs in Kodachrome of growing crystals.

During his long term of service to the industry, Dr. Jones has conducted and published many extensive investigations in the field of photometry, physical optics, illumination, colorimetry, physics of photography, visual sensitometry, and motion picture engineering.

The following citation illustrates briefly what the Progress Award Committee, for which I speak, had in mind when referring to a remarkable repetition of noteworthy accomplishments. Guided by these facts, we have accordingly nominated Dr. Jones for the Progress Medal for 1939 of the Society of Motion Picture Engineers with the following citation:

To Dr. Loyd A. Jones: In recognition of the outstanding character of his scientific researches in the field of photography, with particular reference to his investigations of sensitometric procedures; his studies of photographic processes; his contributions to precision in photographic terminology; and his determinations of the criteria of pictorial excellence achieved by photographic processes.

Mr. President, it is with pleasure and friendly esteem that the Progress Award Committee names Dr. Loyd Ancile Jones for the 1939 Progress Medal of the Society.

Following the citation by Dr. Goldsmith, President Williford presented the Progress Medal to Dr. Jones, who then thanked the officers, Board of Governors, and members of the Society for the honor thus bestowed upon him, and concluded by expressing his gratitude and thanks to all his co-workers who had collaborated with him during so many years, in so many of the activities on which the award of the medal was based.

President Williford next called upon Mr. E. P. Curtis to deliver the citation on Dr. Herbert Thomas Kalmus, recipient of the SMPE Journal Award for 1938. Mr. Curtis spoke as follows:

CITATION ON HERBERT THOMAS KALMUS

Mr. President and Members of the Society of Motion Picture Engineers—

In citing the achievements of those whom this Society honors with its awards, I understand it is generally customary to go into some detail about the ancestry, education, and previous condition of servitude of the recipient. Tonight, however, I am going to skip rather lightly over this phase of the subject because it has been pretty adequately covered already.

HERBERT THOMAS KALMUS

Last year in Detroit, Dr. Herbert T. Kalmus, President of the Technicolor Company, received the Society's Progress Award. It is now my pleasure and privilege to announce that he has also this year received as well the Journal Award for his fascinating paper "Technicolor Adventures in Cinemaland." On last year's occasion, Mr. Gerald Rackett, in an admirable citation, covered the history of Dr. Kalmus' career far beyond my poor power to add or detract. I shall confine myself therefore to pointing out tonight a few of the varied interests and achievements of this versatile gentleman.

In the first place this paper is not, strictly speaking, an engineering paper at all and I suspect that in selecting it the Award Committee was influenced by the interest inherent in the subject it covered and by the literary excellence it displayed. If this is true Dr. Kalmus is not only a scientist but obviously an author as well.

With his career as head of a major motion picture enterprise most of you here tonight are pretty familiar. It is indeed fair to say that the difficulties which have been overcome and the problems which have been solved in bringing the present magnificent Technicolor pictures to the screens of the world can be fully appreciated only by the motion picture engineer. The story of the struggles and development of the Technicolor Company as covered in this paper are no less amazing than the history of the motion picture industry itself.

There are other sides of Dr. Kalmus' life with which you are undoubtedly less familiar. As a student—in his early years here and afterward abroad in the University of Berlin and at Zurich—he showed the kind of ability and promise which might easily have led him into the life of a scholar. He did remain in the field of education for some time, first as the headmaster and owner of a boys' school in San Francisco. Here he early showed signs of his subsequent business shrewdness by selling the school outright a few weeks before it was destroyed by the San Francisco Fire. Later he was an instructor at Massachusetts Institute of Technology, a Professor at Queens University, Canada, and a consultant to the Canadian Government in the field of metallurgy. For many years in later life, in the midst of his business pursuits, he was a keen student of psychology under the late Dr. Seldes and for a considerable period of time was an interested if somewhat skeptical, investigator in the field of psychic research. In more recent years other demands have prevented his devoting the necessary time to studies in fields like these but his intellectual interests are none the less keen and active.

No summary of his career, however brief, would be complete without some reference to his extraordinary capacity for friendship. His hosts of friends both here and abroad, of whom I have the honor to consider myself one, bear testimony to the fact that his human relationships have developed as extensively and successfully as his scientific and business achievements.

Mr. President, on behalf of the Journal Award Committee, it is my privilege to present to you Dr. Herbert T. Kalmus.

At the conclusion of Mr. Curtis' citation, President Williford awarded the Certificate to Dr. Kalmus, who responded with appropriate words of thanks to the Society.

In addition to nominating the recipient of the Journal Award, the Journal Award Committee of the Society named the following five papers published during 1938 for honorary mention:

"The Theory of Three-Color Photography," by A. C. Hardy (Oct., p. 331).

"Recent Developments in Gaseous Discharge Lamps," by S. Dushman (Jan., p. 58).

"Modulated High Frequency Recording as a Means of Determining Conditions for Optimal Processing," by J. O. Baker and D. H. Robinson (Jan., p. 3).

"The Transmission of Motion Pictures over a Coaxial Cable," by H. E. Ives (Sept., p. 256).

"Distortion in Sound Reproduction from Phonograph Records," by J. A. Pierce and F. V. Hunt (Aug., p. 157).

The banquet concluded with dancing and entertainment

THREE-DIMENSIONAL MOTION PICTURES*

J. A. NORLING**

***Summary.**—Some problems involved in the production of satisfactory three-dimensional motion pictures have not received much mention in the literature dealing with stereoscopy. Their practical solution has contributed marked improvements to the three-dimensional picture of today.*

The fundamental problem in projecting three-dimensional pictures is that of providing a "right-eye" picture that will reach only the right eye and be prevented from reaching the left eye, and to do the same for the "left-eye" picture. To attain this result two methods have been employed with success, namely: the "anaglyph" in which substantially complementary colors are employed in the viewing devices, and polarized light.

The screen surface upon which three-dimensional pictures are projected by polarization methods is of extreme importance. The selection of the proper type of screen raises real problems but these also have been overcome in a practical way.

I

In the winter of 1935 a new type of entertainment film was released by Metro-Goldwyn-Mayer. These films, which carried the name of *Audioscopiks*, were the first three-dimensional movies with sound. They were produced by J. F. Leventhal and the author. Pete Smith's unique narrative touches added the humorous qualities that contributed to their remarkable success.

The *Audioscopiks* were a direct descendant of Mr. Leventhal's *Plastigrams* released eleven years earlier.

While it was gratifying to the producers that *Audioscopiks* was one of the most successful shorts ever made, it is more important to our industry that their success is a sure indication of public acceptance.

No doubt most of you have seen one or more of these films and know that in order to view them one must look through spectacles containing red and green filters.

With the exception of *Audioscopiks*, and the earlier *Plastigrams*, there have never been any stereoscopic films widely distributed. The reason for such limited use of three-dimensional films has been ascribed to the fact that individual viewing spectacles have been re-

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[*] Presented at the 1939 Fall Meeting at New York, N. Y.; received September 15, 1939.

[**] Loucks & Norling Studios, New York, N. Y.

quired. No doubt there would be an objection to frequent releases which required *red-and-green* (or any other color combination) viewing devices, and probably such films will always remain merely interesting and entertaining novelties.

There are good reasons why attempts should have been made to devise some way of bringing three-dimensional movies to the public without the supposed handicaps of individual viewing accessories. A lot of methods have been suggested, none of which have ever worked. Perhaps some day someone will come along with a practical solution for mass viewing of three-dimensional films without spectacles of some sort. But, at present, nothing of the sort looms over any horizon.

The fundamental problem is that of providing a "right-eye" picture that will reach the right eye only and not be allowed to reach the left eye and to do the same for the other member of the stereoscopic pair. The disparate pictures of the stereoscopic pair must be distributed to the eyes of the audience in a selective manner. To quote Dr. H. E. Ives:[1]

"There are only two places where the distribution of images to eyes can be done; these are at the screen and at the eyes. The number of images at the screen can be reduced to two, if the number of viewing instruments is equal to the number of spectators. The number of viewing instruments can be reduced to zero if the number of images at the screen is made infinite. Any gain in simplification at one point is offset by increase in the complexity or expense at the other."

To increase the number of images at the screen is fraught with so many problems that it does not promise any practical application. Line screens, lenticulated and so forth, have been tried but no *satisfactory* results have been attained by projecting on such screens or by projection through them from any motion picture film. It is not the purpose of this paper to review the schemes which have been suggested and tried in the effort to attain the distribution of images at the screen, nor is it the purpose of this paper to devote much space to a discussion of the whole subject of stereoscopy. I shall therefore confine myself to a brief summary of, *first*, fundamental principles; *second*, their application in actual production; *third*, some of the problems which arose in the production of the film you are about to see;* and *fourth*, the projection of the three-dimensional picture.

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* A stereoscopic picture, to be described later, employing the polaroid principle and produced for the Chrysler Motor Corp., was projected at the conclusion of the paper.

II

An ordinary two-dimensional picture does not depict the scene as both eyes see it, but only as one eye does. When looking at a subject each eye sees a different view of the subject. Each of these views is a *two-dimensional* record of the scene and gives no real indication of the spacing apart of objects within the scene. However, when these two dissimilar views, one received by the right eye and one by the left, are brought together in the brain of the observer they fuse into a view that has depth, and objects will appear to be distributed throughout the scene in accordance with their actual spacing.

The distance of an object determines whether or not it can be seen stereoscopically. The closer it is the more definite is the observer's sense of its depth, its real dimensions, and its distance away. The farther away an object is from the observer the less the observer's sensation of its real dimensions. There is a distance at which stereoscopic seeing no longer exists for human eyes. At this distance an object will not show relief.

Aided by optical instruments, which have a long base, the observer can see stereoscopically at great distances. To see naturally, the images seen in the instrument should be magnified in proportion to the increase in the base-line over the normal interocular distance. If the magnification is increased the base has to be increased likewise. The ratio of increase in interocular separation and the ratio of magnification should be the same. The effect of not increasing the base in the same ratio as the magnification is apparent in a binocular field glass. Here the magnification may be 6 times and the base only $1^1/_2$ times. This accounts for the compression of depth one sees when looking through such glasses, and hence the inability accurately to judge distances between objects within the field of view. The angle subtended by the base formed by the interocular distance is termed the *convergence*, or *parallax*.

There is a lower limit of parallax, fixed by the ability to see distantly. This lower limit varies among individuals but is probably greater than one might suppose by reference to existing literature. For instance, Judge[2] has stated that the limiting distance of stereoscopic perception is about 670 meters, or approximately $^2/_5$ mile. I doubt very much whether the unaided eyes can see stereoscopically at this distance. At any rate we need not be concerned about it because most stereograms are made with objects near to the camera that provide a definite feeling of space between them and the distant portions of the scene.

There is also an upper limit of parallax which depends upon the ability to converge the eyes and also to focus upon a near object. Some persons are far-sighted and can not focus upon an object as close as 10 inches. Others, able to focus, can not easily converge their eyes that much. The angle of convergence at this distance would be 15 to 16 degrees.

The difference in parallax between the nearest point of an object and its farthest point is called the *differential parallax.* Judge has given a formula to establish the parallactic limit and the greatest depth of a distant object which can be perceived stereoscopically.

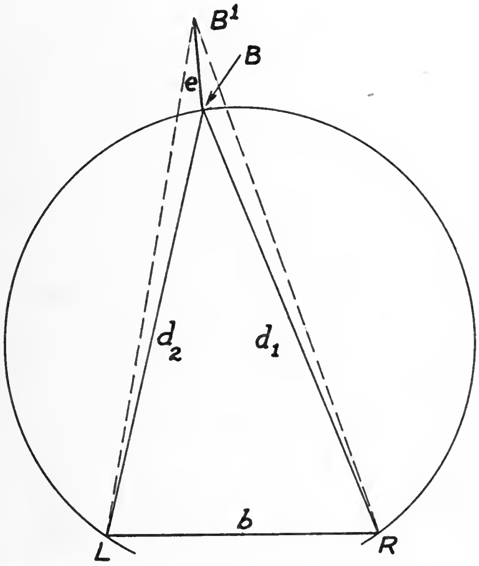

FIG. 1. Illustrating parallax and the differential parallax.

Referring to Fig. 1, R and L are the right and left eyes, b the interocular distance; d_1 and d_2 the distances of the object B from R and L. The angle RBL is the parallax. A circle through the points LBR is called the *horopter.*

Considering a point B^1 outside the horopter, the distance between B and $B^1 = e$, and calling the angles LBR and LB^1R, θ and θ_1, respectively, and $\theta - \theta_1 = -\Delta\theta$, and considering that $d_1 = d_2 = d$ (since b is usually small compared with the object distance) we have for e:

$$e = -\Delta\theta \cdot \frac{d^2}{b}$$

The quantity $\Delta\theta$ represents the change in convergence between the front and rear of an object, or the distance betweeen two objects, and is called the *differential parallax.* The smallest limit of the differential parallax corresponds to the smallest separation apart of two points which can be seen stereoscopically. The minimum value of $\Delta\theta$ for normal interocular spacing may be accepted as 20 seconds of arc.

III

One-eyed persons, or those with certain abnormalities in vision that produce marked differences in the apparent size or shape of objects as seen by each eye, are not able to see the scene in three dimensions. Neither is the ordinary single-lens camera capable of recording any but a two-dimensional view.

In three-dimensional photography, the single lens of the ordinary camera is replaced by two exactly similar lenses mounted some distance apart. This two-lensed camera produces two slightly dissimilar views of the scene. The lens on the right shows slightly more of the right-hand side of an object and less of its left-hand side. The lens on the left performs in a similar fashion in the other direction. In order for the two disparate pictures of the stereoscopic pair to combine into a three-dimensional picture it remains to devise some convenient means of viewing them.

The old-fashioned stereoscope was a convenient way of viewing stereograms in still form. Obviously any such instrument applied to moving pictures would be impracticable since the pictures would be seen by only one spectator at a time. For mass viewing of projected stereoscopic pictures, whether in still or motion, some more practicable means must be employed. Two methods have been used in recent years: (*1*) projecting each picture of the pair, one in one color, the other in a complementary color, and viewing through spectacles containing colored lenses; and (*2*) by using polarized light, the axis of polarization for one picture being at right angles to the axis for the other, and viewing through spectacles fitted with polaroid filters properly oriented.

The disadvantages of the complementary color method or anaglyph system are, first, that the projection of color is impossible and, second, the difficulty of obtaining commercial dye-toned or dye-imbibed prints of suitable colors.

It has been claimed that the anaglyph system, because one eye sees one color and the other its complementary, causes serious retinal rivalry in a short time. Personally I have never noticed anything of the sort, and I have looked at anaglyphs for hours on end. Any defense of the system based on purely personal experience may be waived, but it has been my observation that no one suffers any discomfort in viewing a reel or two.

It has also been stated that with the anaglyph the sensation of depth is as if given by a series of thin cardboard models placed in different planes; that while anaglyphs show depth they lack roundness. The author feels that that is ridiculous and that no one who has viewed good anaglyphs can honestly make such a criticism.

The polarized-light method has many advantages because the filters do not change the quality of the light to any great extent and color pictures can be projected without loss of color balance. It also affords more complete elimination of the unwanted image, or more complete "cutting" between images, thus making certain that one eye shall not perceive a noticeable trace of the image that is supposed to reach only the other eye.

Mention should be made of the *eclipse* method of stereo projection. This system is one in which no filters of any kind are used but in which each spectator has to use a shutter viewing device. The blades of the viewing shutter move so as to pass light from the screen to each eye in turn and are synchronized with the projector. In this way the spectator views his right-eye and left-eye pictures alternately. While it is possible to employ such methods, they are, undoubtedly, productive of serious eye-strain and, in most cases, objectionable flicker. This is because there is a complete period of darkness for one eye while the other is seeing its picture.

Increasing the picture frequency to 48 frames per second has been thought adequate to eliminate flicker. A brief study of the problem reveals why this is no solution. Fig. 2 represents graphically the light and dark areas for each eye at a picture frequency of 48 frames per second.

It will be seen that the periods of darkness for each eye consist of two for each picture cycle, one of them the normal interruption of the flicker shutter, which has an effective duration of about $^1/_{192}$ second; and another interruption by the other shutter blade which consumes another $^1/_{192}$ second, and by the viewing shutter which has a duration of about $^1/_{48}$ of a second.

The diagram shows the percentages of the light and dark periods for each eye. Referring to the "left-eye" portion, it will be seen that the first light period has a value of 12.5 per cent of the complete picture cycle. The flicker blade on the projector shutter (considering a 2-bladed shutter) gives a period lasting 12.5 per cent; then there is a light period of 12.5 per cent; then a long dark period lasting 62.5 per cent. This is divided as 12.5 per cent for the pull-down period and 50 per cent for the eclipse at the viewing device. Thus each eye is darkened during at least 75 per cent of each picture cycle. It is obvious that such an unbalanced arrangement would require a much higher picture frequency than would be practicable. Regardless of any frequency increase within workable limits, the fact that there is a complete period of darkness for one eye while the light reaches the other will still account for probable retinal fatigue.

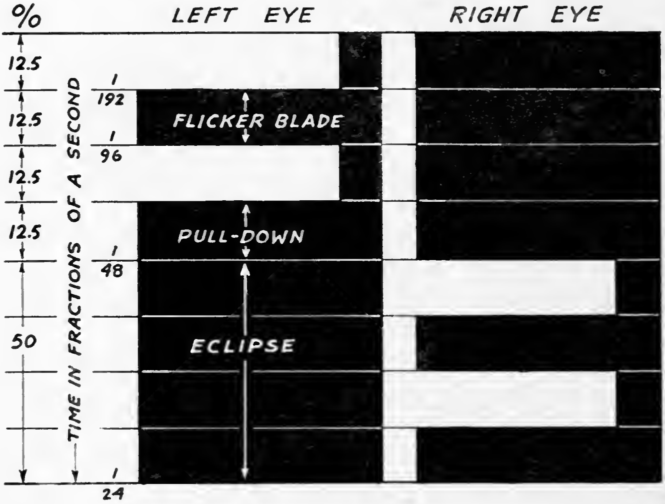

FIG. 2. Illustrating the light and dark periods in "*eclipse*" stereoscopic projection.

The motion pictures you will see tonight will be projected by the light-polarization method. Each of you has been supplied with a polaroid viewer so that you will be able properly to see these three-dimensional pictures.

IV

In stereoscopic photography it is not necessary to employ any special photographic technics not used in ordinary photography. Lighting methods are the same; any improvement that helps a two-dimensional picture is equally advantageous in stereoscopy.

There are special mechanical features on the stereo camera, some of which have no counterpart on the ordinary camera. The special functions that make it necessary to provide additional adjustments and other things will be discussed later. The chief difference between the ordinary camera and one designed for three-dimensional photography is that in the latter there is a double optical system and provision for moving two films simultaneously, or for other ways of recording two disparate views of the same scene.

As has been pointed out, the view taken by the double-lens camera differs from that taken by one lens. The distance of the object and the spacing apart of the two lenses control the three-dimensional effect. For normal subjects the most natural effect is achieved by spacing the lenses apart a distance equivalent to the interocular spacing of the eyes of the average normal human being. The interocular range is from $2^1/_2$ to $2^3/_4$ inches, an average of approximately $2^5/_8$ inches.

For special purposes it may be advantageous to change the lens spacing. For small objects very close, such as in microscopic and macroscopic stereoscopy, the spacing may be very small indeed. On the other hand, it may add an apparently increased sense of depth and thus enhance a picture's effectiveness to increase the lens spacing when photographing views of large objects located far away. Obviously no "three-dimensional" sensation can be experienced in viewing a stereogram of the moon if a $2^1/_2$-inch lens separation is employed since the object is so far away. Many stereograms of the moon have been made using lens separations equivalent to several thousand miles. (The exposures for each picture of all stereograms of the moon had to be made at different times.)

In order that the projected three-dimensional pictures may reproduce in correct perspective, that is, so that the objects will appear in their natural space relationships, it is essential that the angles subtended at the eyes by the projected views of these objects be the same as the angles subtended at the eyes by these objects if the objects are viewed in reality. It has been stated that the projected views shall subtend the same angles for the eyes as for the camera lenses used in taking the pictures. This requirement means, in theory, that there is but one ideal position from which to view the projected picture and that this position should be on the mean optical axis of the projected beams at a distance from the screen that will give the spectator the same angle of view as the camera lenses. Extending this theory still further it is presupposed that the optical axis of each projection beam coincide with and be parallel to that of the eyes.

In practice this ideal arrangement would be difficult to achieve and would have no practical value since it would mean that only one person could view the picture. Actually these requirements should not be too strongly emphasized since every human being is capable of psychological adjustments to his environment; in particular, to a picture on the screen. The observer is no scientific instrument that functions in one way and one way only. Thus mass seeing of three-dimensional pictures, while requiring special conditions, is just as practicable as mass seeing of ordinary pictures. In fact, viewing distances and spectator placement are theoretically almost as important for two-dimensional as for three-dimensional pictures. View distortions occur in many parts of any theater. These distortions are

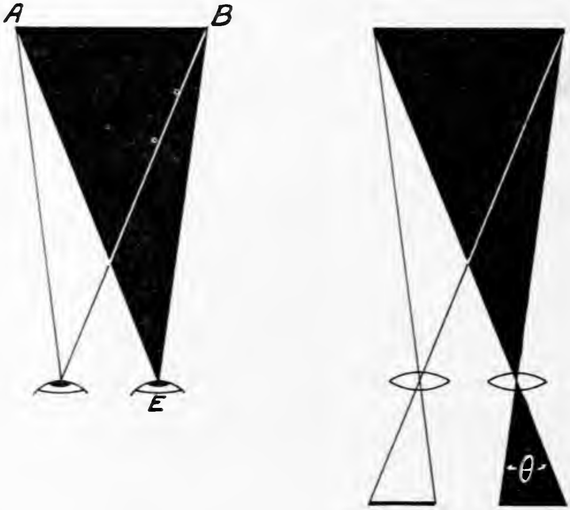

FIG. 3. Illustrating the principle of lens angle and viewing angle.

worse from side seats near the screen, and less serious elsewhere, being practically absent in the center of the house.

There is, however, more consciousness of these distortions when viewing a three-dimensional picture at an unfavorable angle. More care will have to be exercised in planning the distribution of seats in the theater of the future than has been the practice in the past.

The spectator's distance from the screen is important, because this controls his viewing angle. If the viewing angle is less than the camera angle the depth of the scene will appear exaggerated. On the other hand, if the viewing angle is greater than the camera angle the scene will appear to shrink in depth; objects will appear to become flatter.

While there is, theoretically, but one correct viewing distance, in practice one finds a reasonable leeway, since even the trained observer can tolerate a reasonable depth distortion, and the average person a considerable amount.

The angle subtended at the camera lens by each picture of the three-dimensional pair is given by the relation

$$\tan\frac{\theta}{2} = \frac{d}{2f}$$

where d is the horizontal dimension of the picture and f the focal length of the lens.

It is necessary that the angle subtended by the projected image shall be the same as θ. Reference is made to Fig. 3. In Fig. 3 the angle AEB must be the same as angle θ.

V

The spacing between lenses is as important as their focal lengths and the field angles. *Hyperstereoscopy* is the term applied to the method of making stereograms employing a lens separation different from that of the normal interocular. It is advantageously employed in some cases, in order to obtain the most natural relief; in others to exaggerate the relief or to create the illusion of less relief. Varying the lens spacing is also employed to increase or decrease the *apparent* size of objects.

If the lens separation is twice that of the eyes, the stereoscopic effect will be that of an object half the size seen at half the distance.

Thus if we were to make a stereogram of the Empire State Building, which would require a field of approximately 2000 feet in width, taking the picture from a distance of 5000 feet, and using a lens spacing of 2500 inches, 1000 times that of the normal, the building would appear to be 5 feet away and to be $^1/_{1000}$ as big. Theoretically one should experience, in viewing such a stereogram, what one would experience in viewing a model of the building constructed on a scale of 1000 to 1.

Applying the principle in the other direction, if the lens spacing is reduced to $^1/_{10}$ that of normal, or $^1/_4$ inch, and the object, say, a small animal, is 4 inches away, the *apparent* size of the animal would increase 10 times, but it would also appear to be 10 times as far away.

The capacity to see objects in absolutely true *relative* scale is probably lacking in most individuals. Thus, even though we know that, theoretically, the observer should see the Empire State Building at $^1/_{1000}$ of its real size he would probably still *think* of it as big and his probable reaction would be that he would think he were seeing it without a shrinkage in size unless some reference object, such as a yardstick, were artificially introduced into the scene.

VI

It is interesting that objects of dissimilar form can be combined stereoscopically if the objects include the same average angles of view. A circle can be merged with a polygon but not if they are of different sizes.

It is also interesting that when an object is photographed in such a way as to produce an image in one picture that is very light and one for the other picture that is very dark, keeping the tonal values in the balance of the picture normal, the object will appear to glow—it will appear to be iridescent. This iridescent effect can be very startling and might be employed to produce eerie effects in a three-dimensional photoplay.

The effect of irridescence probably accounts for the fact that texture is so faithfully reproduced by stereoscopic photography. I have attempted to illustrate why, in Fig. 4, *A* represents a surface, such as leather, L_1 and L_2 represent beams of light striking the material, and R_1 and R_2 the reflected beams. Notice that reflections reach the observer's eyes from different localities. The lines depicting the reflections, of course, represent that portion of the total reflected light that photographer's call a "catch-light." The surface of an orange, for instance, has thousands of such catch-lights and each eye sees each of them somewhat differently.

Everyone who has had an opportunity to view a great number of stereograms in which texture is a prominent feature has been impressed by the feeling of seeing the real thing, whether it is steel, or wool, or wax. These qualities are almost entirely missing in even the best and most expertly made ordinary picture. Adding color to three-dimensional pictures further enhances the feeling that one is looking at the real thing.

As Professor Kennedy[3] has pointed out, "even when we succeed in obtaining films that will truthfully reproduce the colors of nature, they will not *seem* true until we add binocular vision." Truly, one of the most engaging prospects in stereoscopy is its contribution to color photography.

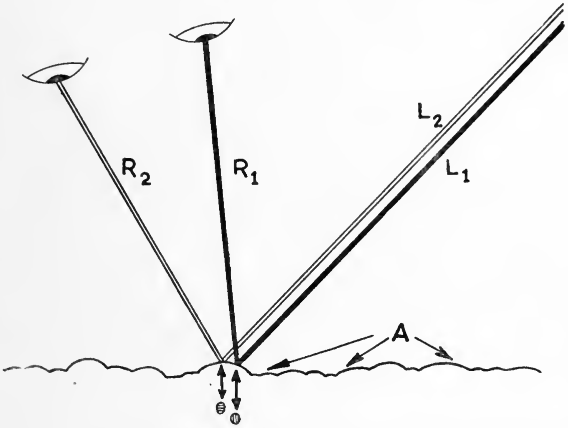

FIG. 4. Illustrating how each eye sees a different reflection from a rough surface.

VII

In the production of a three-dimensional motion picture it is necessary to take both pictures simultaneously. The placing of the exposure period in the picture cycle must be exactly the same for each, otherwise fast-moving objects will not occupy *relatively* the same place within the area of the two frames. For wide separation work two cameras are used with a mechanical interlock for a nominal lens separation and with electrical interlock for extreme separation.

A problem that continually arises in stereoscopic filming relates to vertical displacement between the disparate pictures. This vertical displacement may be due to two chief causes: the camera may be off level or the pull-down mechanisms and apertures (when using a two-camera set-up) may be out of alignment. Vertical displacement is very annoying as it forces the spectator to twist his eyeballs. Most persons are unable to do this and the effect of the effort to do it causes a great strain. If, when two cameras are used, one camera is off level the spectator, viewing scenes made under those conditions, will have a very unpleasant experience.

It is necessary to employ matched lenses, since a very slight variation in focal length between the two will result in images of different sizes. Most authorities agree that the eyes can tolerate almost no disparity in size between the two pictures and if a spectator looks at such a picture he is certain to suffer great eye-strain.

The solution of most of these problems is relatively simple, but ingenuity must often be employed in overcoming some of them quickly and in a practicable manner. For instance, aligning cameras spaced at a distance can become a difficult and long-drawn job, unless advance provision is made for simple adjustment. In addition to accurate horizontal alignment to eliminate vertical displacement and off-level set-up, the optical axes of the two lenses must be aligned. The axes can not be allowed to form a diverging angle, nor should they, except for special cases, be allowed to converge to a point very close to the lenses. If the film planes are not parallel one to the other, slight distortions will result that may be very annoying to the spectator.

The area to be covered by each lens must be given consideration before the scene is photographed. If the field areas match at infinity, that is, if the optical axes of the lenses are parallel, an entirely different effect is produced for the spectator from that produced when the axes converge at some point in the foreground. If the nature of the picture is such that the screen margins cut off important foreground objects differently in each picture, the spectator, viewing the scene, may be annoyed by seeing more or less at the left and right of the screen with one eye and less or more with the other. The effect will be as if the picture area had no definite margins at the sides.

The ordinary stereo camera, with the lenses placed so that the optical axes are parallel, as in Fig. 5, does not produce stereograms in which the side margins for each picture include exactly the same field area except at infinity. Thus, all nearby objects at one side margin of one picture will be cut off partially by the side margin of the other, as demonstrated in Fig. 7 which represents the appearance of the two pictures taken as in Fig. 5, when they are superimposed in projection. Pictures that have been made so that their principal field margins are in coincidence at some point in front of the nearest objects, as in Fig. 6, will give a better "frame" to the picture than if the coincidence of field margins should be farther away. When the coincidence of field margins is in front of the nearest objects the scene will appear as if viewed through a window, with all elements comprising the scene appearing to be beyond the window.

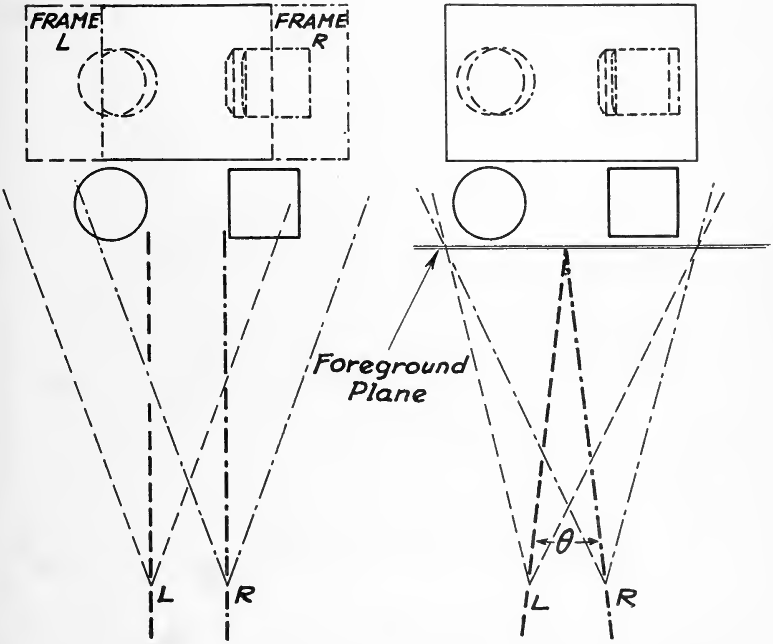

FIG. 5. (*Left*) The effect on side margins when lens axes are parallel.
FIG. 6. (*Right*) The effect on side margins when lens axes converge to a foreground point.

There are cases in which, for dramatic reasons, it may be desirable to have the action apparently take place in front of the screen plane. In such case it becomes necessary partially to sacrifice the marginal areas. Since such action is usually at the center of the screen, thus tending to keep the spectator's attention away from the sides, the viewer will not be conscious of a marginal disturbance.

But in a long scene, and one in which the spectator's eyes tend to wander about the total field area, the scenes should be photographed so as to afford the spectator the greatest visual comfort. This happy result is unquestionably achieved when a definite foreground frame exists.

It is obvious that stereoscopic cameras should be provided with means for changing the point of coincidence of the camera field, in other words, the effective convergence, in accordance with the requirements of any given scene.

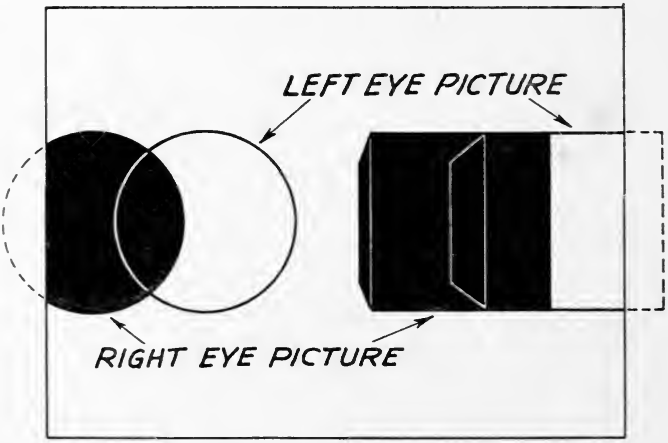

Fig. 7. Illustrating how nearby objects are cut off when lens axes are parallel or converge on distant objects.

The amount of distortion resulting from toeing-in of the optical axes may, in some cases, be considerable. The result of toe-in is illustrated in Fig. 8. The horizontal lines in each picture should remain parallel for the reason that the eyes of the spectator may wander off to the corners. In case distortion exists, as shown in the illustration, an object in a corner will be smaller (or larger) in one image than in the other. As pointed out, an observer may feel an unpleasant strain in trying to merge images of different sizes.

These are the reasons why the planes at which the images are formed in the camera should be parallel and the camera design be such as to maintain this parallel relationship, except for special cases. As has been pointed out, it is desirable to photograph the scene so that the fields of the two pictures coincide at some selected point, usually in front of the action. To do this it is necessary to toe-in the picture axes without converging the whole system, and this may be done by shifting the lenses along a line parallel to the picture plane, as illustrated in Fig. 9.

The above rule applies to projection, as well as to "shooting," where the projection is from two machines. If, as in the case of the Chrysler installation, which is a special one employing two projectors, the projectors themselves are toed-in to superimpose the pictures. The angle of toe-in must be considered when shooting the scenes. In a case like this, the angle of convergence should be the same in the camera as in the projectors, and the lenses and films must be swung in to the required angle. For the Chrysler installation the projection distance is 90 feet and the spacing of the projector lenses 5 feet.

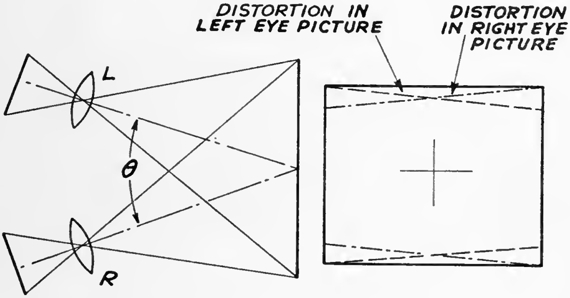

FIG. 8. Illustrating the distortion resulting from the "toe-in" of stereoscopic camera lenses.

Knowing in advance that this would be the final convergence in projection it was easy to calculate the angle of convergence for the camera set-up. Our lens spacing, or base-line b, averaged slightly more than the normal interocular distance, so a value of 3 inches was established for b. This produced a calculated value for θ of 6° 18′ and for d of 54 inches, obviously too close for practical work.

Anticipating also the probability that the films would be projected under other conditions, we established arbitrary values for θ and d which became respectively 2° 18′ and 12 feet. This angle was the average, and was decreased considerably on many of the shots and increased somewhat on others. Some of the extremely close views called for much less than a normal value of b and hence it became necessary in some of these to reduce the value of θ considerably.

These divergences from the exact requirements produce very slight disturbances and can not readily be perceived as they are of rather insignificant extent. They are mentioned merely to emphasize a few of the things to be considered in planning a satisfactory exhibition of three-dimensional pictures.

VIII

The three-dimensional motion picture in the Chrysler Motors Exhibit at the New York World's Fair has offered the only opportunity to date to see the first full-size polaroid three-dimensional picture ever to be made. This picture may be a forerunner of the type of films the movie-going public of the future will be shown.

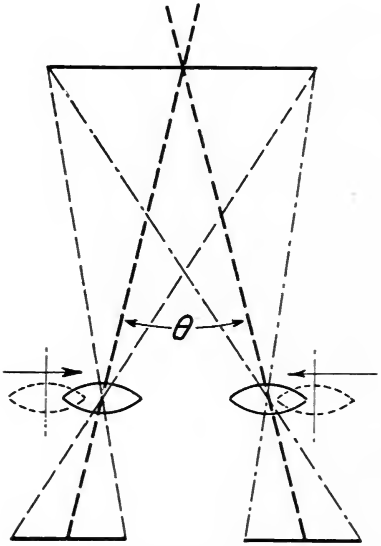

Fig. 9. Illustrating the method of convergence to overcome distortion.

The doors of this theater were opened on May 4, 1939, for the first public showing of really satisfying three-dimensional motion pictures. Since that day the theater has been in operation from 10 in the morning until 10 at night. As many as 17,000 persons daily have viewed this film and up to the hour at which you entered the auditorium on the evening of this day (October 16, 1939) 1,343,930 persons have seen it.

All visitors viewing the films have been given polaroid viewers as they entered. Through these they see actual operations in the half-mile long Plymouth plant at Detroit, and a trick-assembly picture that shows the Plymouth car magically coming into being without the apparent aid of human hands. The various parts of the car, numbering many thousand, come waltzing in together or separately, each to take its proper place in engine, chassis, or body—all in carefully synchronized step to the beat of the music.

Thirty-six days were required to shoot the 12-minute film; and more than 13,000 frames were photographed in "stop motion."

Each part had to be moved a predetermined distance, and photographed one frame at a time.

For taking the "auto-assembly" pictures three stages were erected at the Plymouth plant in Detroit. On these stages each part had its every different movement photographed. Parts that moved along the floor involved little difficulty except for accurate timing and spacing, but to make a heavy motor or an entire body sail in through the air raised real technical problems. Overhead tracks were built from which to suspend these parts on steel wires attached to a movable trolley. To make these wires invisible they were camouflaged by painting and, in addition, were plucked like banjo strings at the moment of photographing, the rapid vibration serving to prevent their registering on the film.

FIG. 10. A page from the music manuscript for the Chrysler three-dimensional picture.

The order of the scenes in the film follows the actual routine in the plant. The producers realized that the Plymouth engineers had devised the order of assembly of the various parts on the assembly line in such a way that the whole car could be brought together with a minimum expenditure of effort. Thus, we followed this standardized routine religiously. Every foot of film was "assigned" in advance of shooting; the editing was done during shooting and not in the cutting room later. The music was composed, its score adjusted to the assigned footages, recorded, and a print of the sound-track scaled off frame by frame on a special listening machine on which beats and notes could be marked for cue points. These cue points then were given frame numbers.

Fig. 10 shows a page from the original score. You will notice the frame numbers as well as numbers that indicate the number of frames between beats (or notes, in some cases). On the score were notations regarding the action.

All this preliminary work was necessary so that it would be possible to chart each scene and time each movement. The result is that

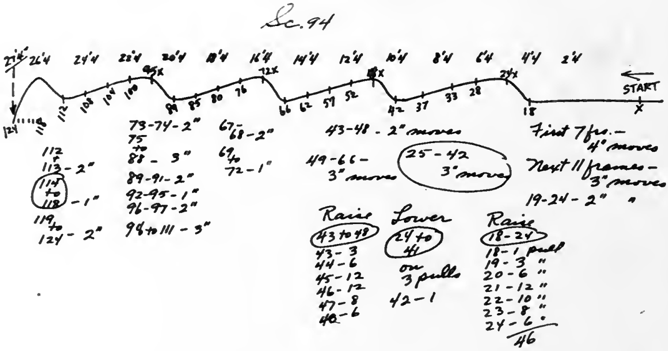

FIG. 11. An exposure sheet and "move" diagram used for the Chrysler three-dimensional picture.

the parts move in exact time with the music—a part dances, or marches in as the case may be, so that its downward movement is accented by occurring on the beat.

Charts were prepared for each scene as well as exposure sheets. Fig. 11 is a typical chart in which are shown the line depicting the movement of the object through space and the frame numbers assigned to each stopping point, as well as data relating to the elevation above the stage, *etc.*

Fig. 12 shows a part suspended from the overhead trolley and one operator moving the carriage forward while the other raises or lowers the object the required distance. Each movement had to be effected manually, and often adjusted in several directions, such as forward, upward, and sidewise. Then the operators had to step off the stage, into an area from which they would cast no shadows, and wait there until the single-frame exposure has been made, after which they would again come out on the stage and carry on as before. The overhead track was marked off in inches, each foot being numbered. The trolley carriage was equipped with a ratchet device that controlled the upward or downward moves of the suspended parts.

FIG. 12. Showing one of the stages; operators moving the suspended object.

Fig. 13 shows the special camera set-up that was used for most of the trick scenes. The director, referring to the charts and exposure sheets, instructed the operators in their work. After the parts had been set and the stage was all clear, he pressed a button which actuated a remote-control mechanism to make the exposure.

These operations may seem tedious to you but to us it was all in the day's work. Each day provided new problems to solve, and this added novelty and interesting variety to a very exacting job. One of our problems was how to turn the chassis over, since the assembly of the underparts of the frame had to be done with the frame upside down. To receive the parts on top, the frame had to be turned over, and this had to be done without the use of visible means of support. In the film you will see this action rapidly taking place. To photograph the sixteen frames assigned to this movement took over four hours. Overhead wires and side guy-wires had to be rigged anew for each frame, and rigged without shifting the chassis in relation to its center or turning point.

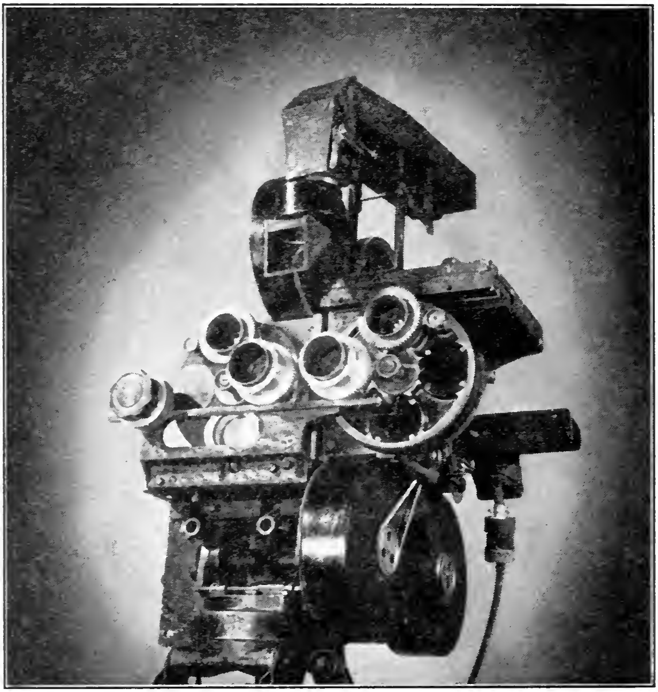

FIG. 13. A camera designed for stop-motion and regular stereoscopy, and having a variable "interocular."

In the picture you will see springs dancing in and may wonder how it is possible to compress these heavy springs without visible clamps or other devices. Rather than try anything like that we had the foundry make up a set of springs with varying degrees of compression. A set of twelve springs was made up—two each of different heights.

Then these were placed in the scene two at a time; an exposure made; the two removed and replaced by two that were shorter or longer as might be required.

Approximately half the picture was photographed backward, *i. e.*, parts were removed instead of brought in. Running the cameras in reverse causes this action in the projected picture to appear as if the parts moved in.

Two negatives were produced; one carries the right-eye picture, the other the left. Each negative was carefully assembled so that matched pairs of pictures would exist throughout its length.

The prints are projected by polarized light using polaroid filters.

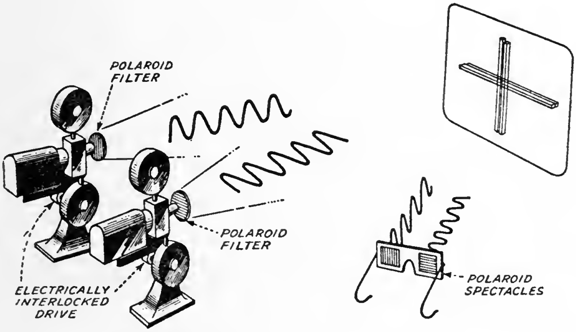

FIG. 14. Diagram of a double projector installation using polaroid. (*Courtesy Photo-Technique*)

These filters are placed directly in front of the projection lenses. Fig. 14 is a diagram of the projection and viewing system. Two projectors are used, interlocked electrically through Selsyn motor drives. Although a mechanical coupling between projectors could have been employed it seemed advisable to employ electrical interlock. Each projector is equipped with 120-ampere high-intensity arcs.

The prints are threaded through the projectors so that they will start in motion together from the same cue marks. The electrical interlock keeps the matched pairs of pictures in exact synchronism. The shutters work together in perfect step.

Two projectors were used for this installation because time did not permit the construction of special equipment. Several designs utilizing single projectors have been made and such equipment would become available if and when the market widens.

The type of screen material is very important when using polarized light. The surface must be such that it will not disturb the polarization. Ordinary fabric screens or those coated with glass beads, or rubberized surface screens, are not satisfactory; in fact, they are absolutely unusable. The best screen surface that we have been able to find is a sprayed aluminum coating. The aluminum lacquer should not contain any admixture of pigment paints. The screen in the Chrysler theater is the best that we could find among the commercial screens. Unfortunately, it is not a wide-angle screen, but the falling off in illumination for the side seats is not too bad.

We have a rather large screen considering the size of the auditorium. A screen as wide as this—a little over 17 feet—would be big enough for a much larger theater if used for standard motion pictures. However, we always have felt that a big picture is much more effective for three-dimensional pictures than a small one.

The standard aperture proportions are perhaps not the best for three-dimensional pictures but I do not consider that point very important for the present. The advantages of adhering to the existing standard far outweigh the advantages to be gained by adopting some new ones more suited to this particular medium.

Fig. 14 shows also the axes of polarization for each projected beam. The polaroid filter on the left-hand projector polarizes its light vertically and the filter on the right-hand projector polarizes its light horizontally. The filters in the polaroid viewers allow only the vertically polarized light to reach the left eye and the horizontally polarized light to reach the right eye.

Thus far I have purposely avoided any mention of a number of schemes that have been proposed in attempts to achieve three-dimensional effects, such as movement of the camera during taking, trick lenses, or any of the other devices such as extremely wide pictures for which a stereoscopic effect has been claimed. Not one of these suggestions has ever resulted in the production of *real* three-dimensional movies and probably never will.

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SYNTHETIC REVERBERATION*

AN ELECTROÖPTICAL SYSTEM FOR CONTROLLING THE REVERBERATION OF SOUND SIGNALS

PETER C. GOLDMARK AND PAUL S. HENDRICKS**

Summary.—*An electroöptical method of producing reverberation synthetically is described. The method employed consists in recording the original program on the rim of a phosphor-coated disk by means of a modulated light-source and then picking up the continuously decaying sound images after a predetermined time interval by means of photocells.*

The exponential decay curve of the phosphorescent substance produces an infinite number of secondary sound impulses to which any desired decay characteristic can be applied. This reverberation signal is then mixed with the original program in the proportion required.

This new reverberation device has been employed in radio broadcasting and can be used in phonograph as well as in motion picture sound recording, where the scenic effect or script requires a type of sound which, due to the deadness of the sound stage, might not readily be available.

This device would replace the use of so-called echo chambers, at the same time introducing an appreciable amount of flexibility without degrading the quality of the original sound.

A consideration of the requirements for a sound channel to be used with television studio productions brought forth the problem of how to maintain suitable acoustic conditions when frequent and rapid changes must be made in the settings. With all the problems involved in maintaining a good television camera pick-up, anything that would simplify the sound pick-up problem is highly desirable. With this in mind it was thought that if a practicable device for producing artificial reverberation were available, it would be feasible to build all sets with subnormal reverberation and then permit the sound channel operator under the direction of the production personnel to add reverberation to provide the desired effect. Such an artificial reverberation device would also be desirable for use in sound motion picture production as well as in sound broadcasting and recording. With this in mind, a search was made for a new

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* Presented at the 1939 Fall Meeting at New York, N. Y.; received October 3, 1939.

** Columbia Broadcasting System, New York, N. Y.

method that would be more practicable than the means used occasionally heretofore in adding reverberation, mostly for dramatic effects.

The device to be described produces artificial reverberation by taking advantage of the fact that the decay characteristic of phosphorescent substances excited by light or electronic bombardment is approximately logarithmic, similar to the decay of reverberant sound. This phenomenon is made use of by having the desired signal modulate a light-source which is recorded through a suitable optical system on the rim of a phosphor-coated rotating disk. This fugitive signal is then picked up a great number of times on successive revolu-

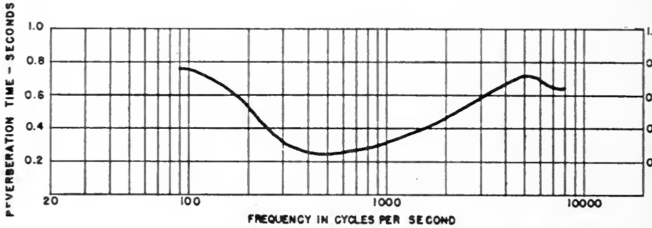

FIG. 1. (*a*) Typical studio frequency-reverberation characteristic.

Length 34′	Volume, 9325 cu. ft.
Width 21′	Surface area, 2918 cu. ft.
Height 12′	Treated area, 1000 cu. ft.

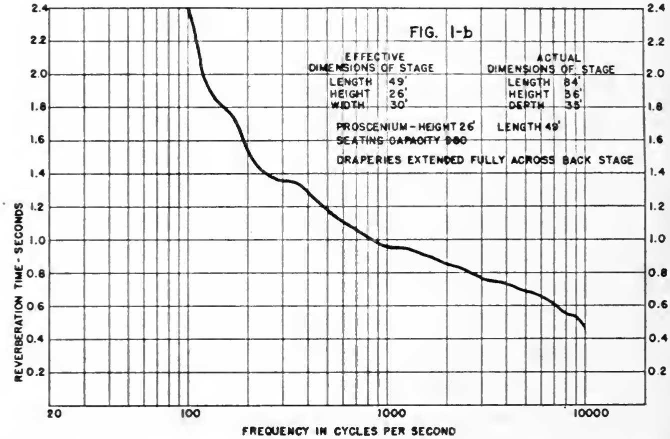

FIG. 1. (*b*) Reverberation characteristic of a typical auditorium.

tions with logarithmically decreasing amplitude by means of one or more phototubes. By a proper choice of the size of the disk and its speed, the number of pick-up tubes, and their location, together with a phosphor having an appropriate decay characteristic, it is possible to produce a large number of reverberation effects.

Nature of Reverberation.—Before going further it might be well to look briefly into the nature of reverberation, which may be defined briefly as the persistence of sound due to repeated reflections.

The phenomenon of reverberation is so common in every-day life that when familiar sounds are produced without it they may sound unnatural. Audiences have long been accustomed to hearing symphony concerts and soloists in auditoriums having considerable reverberation. If, therefore, a symphony orchestra should perform in a studio that was just large enough to accommodate the players with their instruments but relatively small compared to a concert hall, the result would be quite unnatural because of the dissimilarity of the reverberation characteristics.

A single echo is seldom heard except when reflected from a large surface such as a cliff or mountain at a distance. Reverberation indoors has a very complex sound structure because of the multiple reflections from many surfaces having different absorption coefficients and being at different distances.

Experience has shown the approximate reverberation times which are desirable for typical studios and auditoriums. Fig. 1 shows a reverberation curve (reverberation time plotted against frequency) of a typical studio and Fig. 1(*b*) the reverberation characteristic of a typical auditorium.

Equipment has been developed with which it is possible to measure rapidly and accurately the reverberation time of a studio or auditorium.[1] Measurements made with such equipment in many studios and auditoriums serve to show what reverberation time is most suitable for a given purpose. Reverberation time is defined as the time for a given sound to decay to an intensity of one millionth (or 60 db) of the original signal.

The device to be described, of which two different designs have been built and operated, provides a maximum reverberation time of over 2.5 seconds, which is probably more than would be desired at any time in actual use. The artificial reverberation, once produced, is then mixed electrically with the original signal in the proper proportion to produce the desired effect.

It might be pointed out here for those not familiar with the nature of reverberation that any scheme which simply introduces a small time delay will not produce reverberation but only a single echo. In order to simulate reverberation it is necessary to have the echo repeated many times, at least 40 or more, with logarithmically decreasing amplitude. The successive echoes must be frequent enough so that the individual impulses will not be noticeable.

Methods Employed.—Fig. 2 is a simple schematic diagram of the electroöptical system to be described and the manner in which it is used. Because of the low luminous efficiency of phosphors, it was evident from the beginning that a powerful light-source would be required. This eliminated the ordinary low-pressure ionized gas lamp such as the neon and similar types. A search for something more powerful led to the newly developed mercury high-pressure capillary type lamp. First attempts at modulating the lamp were made by operating it with sound-modulated radio frequency. This scheme worked quite well but it was soon found that the lamp could be modulated better by operating it on direct current and modulating the latter.

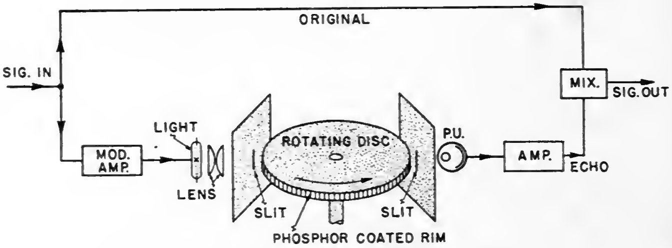

FIG. 2. Basic schematic diagram.

With such a powerful modulated light-source focused through a slit onto a phosphor-coated disk, attempts were made to obtain a delayed signal from the disk. To this end the sound image was picked up from the disk through a slit similar to that at the modulating source and focused onto a sensitive gas-type phototube. The dimensions of the slits and spacings of the lamp, photocell, and disk were arranged so as to take maximum advantage of the light available, as shown in Fig. 3.

Phosphorescent Material.—An important consideration was that of finding the most suitable phosphorescent substance, taking into account the fact that a considerable portion of the light from the mercury vapor high-pressure lamp is in the blue and ultraviolet region and that the maximum sensitivity of the most sensitive type of photoelectric cell is in the red end of the spectrum. Fortunately phosphorescent materials generally reradiate energy at a longer wavelength than that of the exciting source. The best compromise between decay time and light output was obtained with a material having a rather slow decay time (several seconds) and giving a color in the yellow-orange region. Later, as the light output was better utilized the choice of a phosphor for a specific decay time was possible.

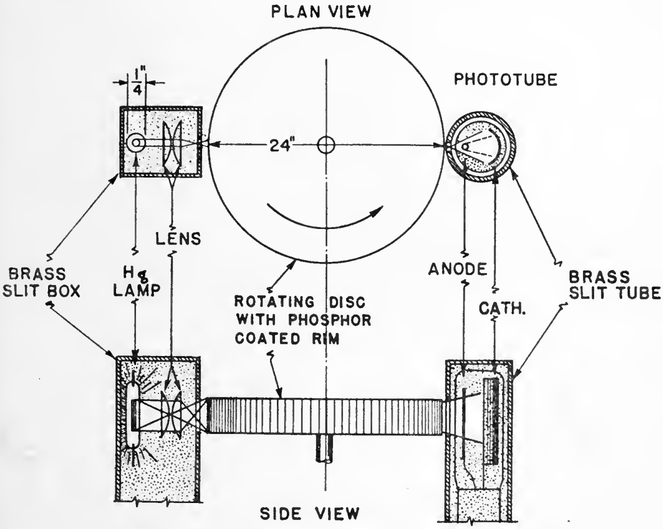

FIG. 3. Lamp, disk, and phototube optical system.

Lamp Operation and Modulation.—The mercury vapor high-pressure lamp selected is one of a type rated at 85 watts and forms an arc about $^3/_4$ inch long and $^1/_{16}$ inch in diameter, within a quartz tube about $^1/_4$ inch in diameter. It was originally designed to operate from ordinary a-c lighting circuits with a reactive transformer. This has a no-load potential of about 450 volts (as required to start the lamp) which drops to about 20 volts after the lamp has ignited. The potential across the lamp gradually increases as it heats up; the pressure within the lamp increases to 20 to 30 atmospheres and the potential rises to about 250 volts after a few minutes. If the lamp is extinguished after it has become heated, it can not be started again until it has cooled.

When modulation was applied to the lamp while operating it near the rated input, using either radio frequency or d-c, it was likely to go out on any overmodulation peak, especially at low frequencies.

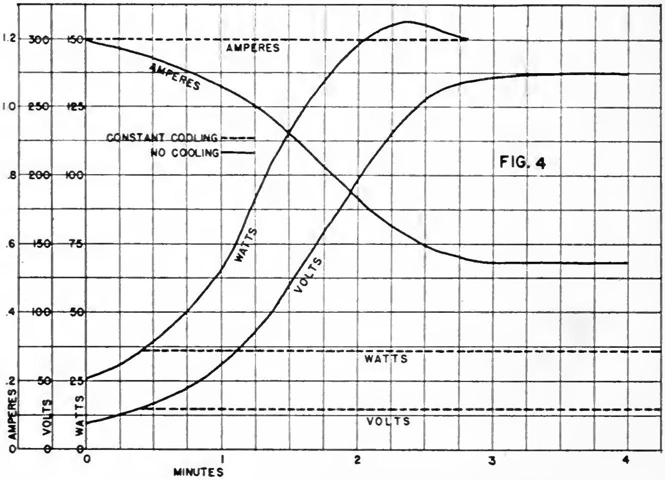

FIG. 4. Characteristics of the lamp with and without cooling.

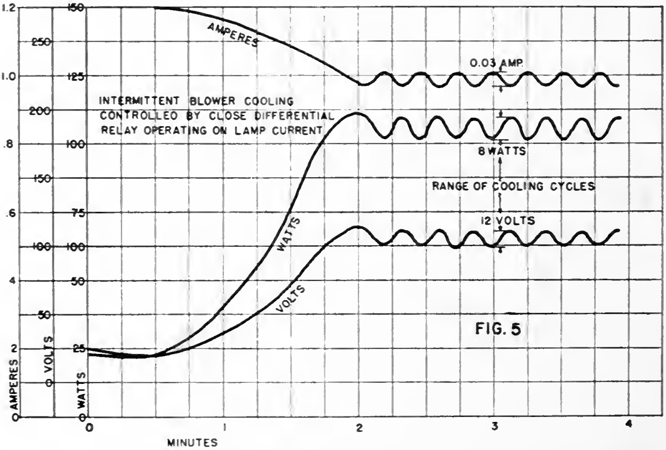

FIG. 5. Characteristics of the lamp with controlled cooling.

This had to be remedied and several schemes were tried before a satisfactory operating condition was established.

Attempts were made to reduce the input power somewhat, but it was evident that the operating voltage and current of the lamp were still rather critical. If the input were too low, the arc would not maintain itself properly and the intensity would drop to a value that provided insufficient light.

A scheme that proved to be fairly successful and at the same time improved the signal-to-noise ratio was the utilization of a triode valve in series with the lamp d-c supply. The supply voltage was about twice the normal required and the resistance of the triode valve, consisting of a bank of low-plate-impedance triodes in parallel, was controlled by its bias. This bias was automatically adjusted to the average signal level by rectifying a part of the audio voltage and applying it to the valve grids through a suitable d-c amplifier and resistance-capacitance network.

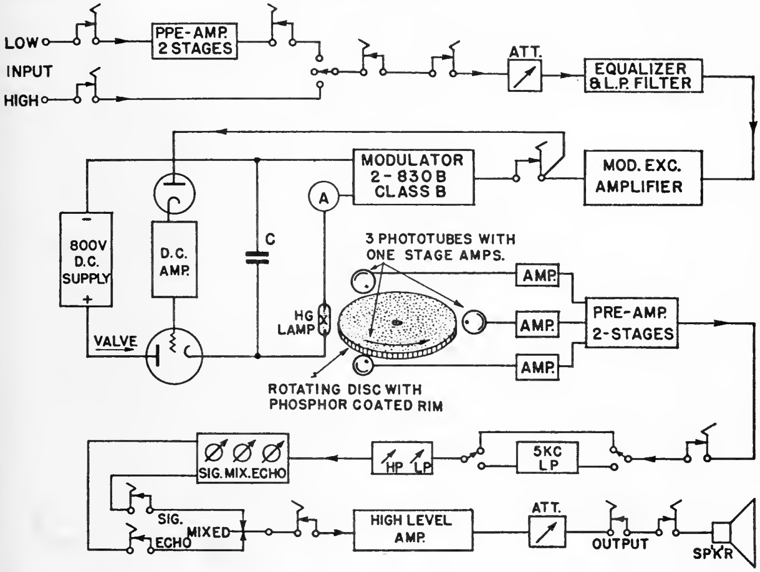

FIG. 6. Arrangement of first complete model d-c control amplifier and tube valve.

The difficulty with this scheme was that it was hard to find a combination of circuit constants that could be relied on over a period of time. The lamp input would gradually drift to a lower or higher value, making reliable operation difficult.

The most satisfactory solution of the problem was relatively simple. The operation of the lamp, while being modulated, was investigated for a considerable time with various input voltages and currents. It was found that the most satisfactory condition exists when the lamp is operated in the unstable region of its resistance characteristic. This condition exists when the lamp current is about one ampere and the potential across it approximately 100 volts.

It was discovered that the operation of the lamp could be controlled successfully by controlling the temperature with a small stream of air. With a given supply voltage the current through the lamp varied according to the combined action of the room or equipment temperature and the modulating power. In order to maintain the lamp operating current at some fixed value such as the 1.0 ampere condition indicated above, it was only necessary to have a cooling device that operated according to the lamp current or voltage. This was accomplished with a small blower which was turned on and off by a differential relay operating on the lamp current. This relay is of a type which drops out at 95 per cent of the pull in current, thus providing a rather fine cooling control.

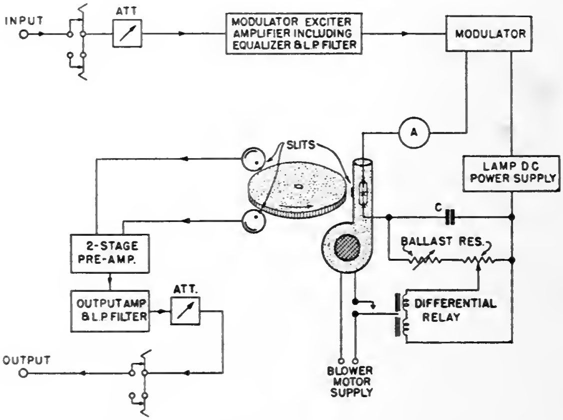

Fig. 7 Arrangement of present model.

Fig. 4 shows the current and voltage characteristics of the lamp with and without cooling, while Fig. 5 gives similar diagrams with controlled cooling.

Phosphor Surface and Signal-to-Noise Ratio.—The optimal signal-to-noise ratio is determined either by the thermal noise of the photocell coupling resistor or by the shot noise originated in the photocell by the unmodulated light-source. Noise is introduced also by low-frequency "bumps" due to any unevenness of the phosphor coating or smudges on its surface. Considerable protection against touching the disk accidently was provided in the latest model of the apparatus

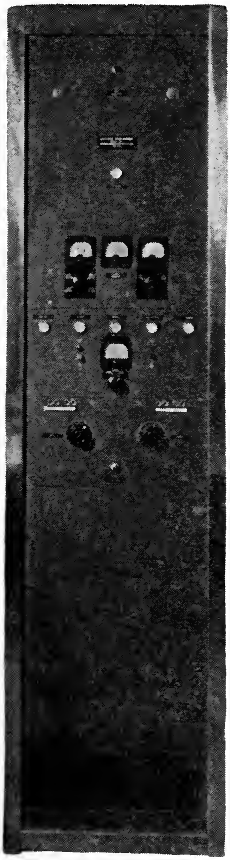

FIG. 8. Latest model in standard cabinet rack.

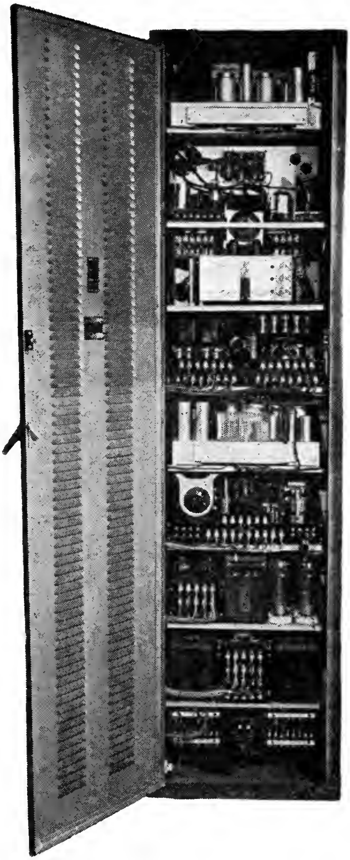

FIG. 9. Rear of the rack, with door open.

by leaving small shoulders about $^1/_{16}$ inch wide and 0.01 inch high (very slightly greater than the thickness of the phosphor coating) at the edges of the disk.

The maximum variation in the distance between the rim of the disk and the slit tubes is less than 0.005 inch. Such disks, with a variation in radius of not more than a few thousandths of an inch, can be machined without difficulty.

The phosphor binding material and method of applying the coating to the disk presented a difficult problem. Various kinds of binders were tried but considerable difficulty was experienced in getting a coating that was sufficiently uniform and at the same time adhered permanently.

A quite satisfactory and durable coating was finally achieved by thoroughly cleaning the metal disk rim with acetone and lacquer thinner and then spraying on many coats of a mixture of the phosphor and a certain diluted lacquer.

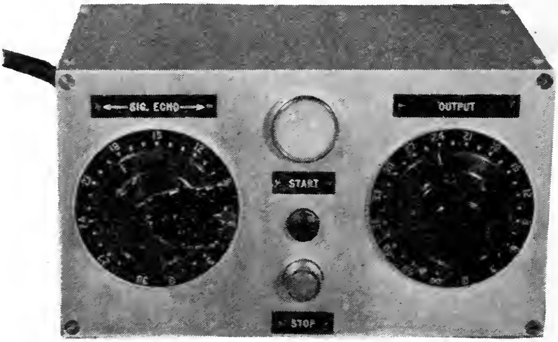

FIG. 10. Remote start-stop and mixer-attenuator box.

Mechanical Construction.—After the first experiments promised success, a rather elaborate model, consisting of three units was built. Fig. 6 is a schematic diagram of this equipment. Fig. 7 is a diagram of the final apparatus. Note that it has been considerably simplified by combining a number of the amplifiers, equalizers, and filters into single units and by substituting a ballast resistor for the d-c amplifier and the tube valve controlling the lamp.

The resistance of the mercury vapor lamp is regulated by means of a blower controlled by a differential relay operating on the lamp current. A large capacitor C across the ballast resistor R by-passes the audio modulating power and together with the ballast resistor serves to prevent the lamp from being extinguished by severe overmodulation peaks.

The final model is mounted in a standard cabinet rack, Fig. 8.

The input and output jacks and attenuators are on the fourth panel from the top. Above it is the power control panel with the start-stop buttons on the left and a high-voltage switch on the right. The meter in the center reads the modulator filament voltage and serves also to indicate the line voltage. Above these, on the left, is a d-c volt meter with a swtich to read lamp supply voltage, lamp voltage, modulator supply voltage, or the photocell d-c potential. The d-c ammeter in the center is permanently connected in the lamp circuit. The milliammeter on the right reads the class *B* modulator plate current normally and serves also as a modulation level indictor.

Fig. 9 shows the rear of the rack with the door open. At the top is the output amplifier and directly below it the disk chassis. The disk is on the front panel side of a vertical partition. At the center of this chassis is the disk shaft bearing with a centrifugal interlock switch to prevent damage to the disk coating if an attempt is made to operate the lamp without the disk running. The shelf at the shaft level supports the d-c supply for the photocells. The lower shelf supports the two-stage preamplifier which connects to the pick-up phototubes through special low-capacity shielded cable. Two phototube pick-ups are normally used in this set-up, either of which may be used alone if desired. The rear of one of the phototube housings, which shield the tube thoroughly and into which the optical slot is cut, is at the lower right of the chassis and the other is diagonally opposite and immediately below the mercury lamp housing.

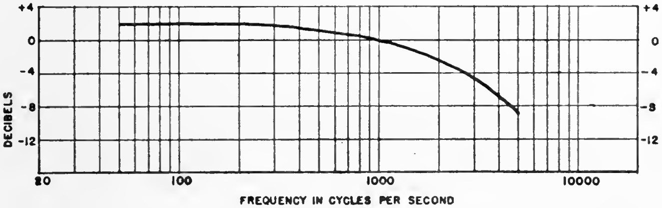

FIG. 11. Audio-frequency response of modulated mercury pressure lamp without equalization; input, 100 watts (1 a. at 100 v).

The next chassis contains the power control circuits and relays, including a time-delay relay to protect the mercury vapor power-rectifier tubes. It contains also the lamp-cooling blower and the disk drive motor. The blower connects to the lamp mounting through a piece of flexible hose. An induction type motor drives the disk with a small *V* belt running in grooved pulleys. Because of the fact that both the recording and the pick-up occur on the same disk, it is unnecessary to maintain a very constant speed. The next lower chassis supports the modulator input exciter amplifier. On the front panel of this unit are mounted the input and output jacks and attenuators.

The class *B* modulator, including input and output transformers, is immediately below its exciter amplifier. The lamp series resistor and its by-pass capacitor are also on this modulator chassis along with the differential relay which may be seen to the right of the center.

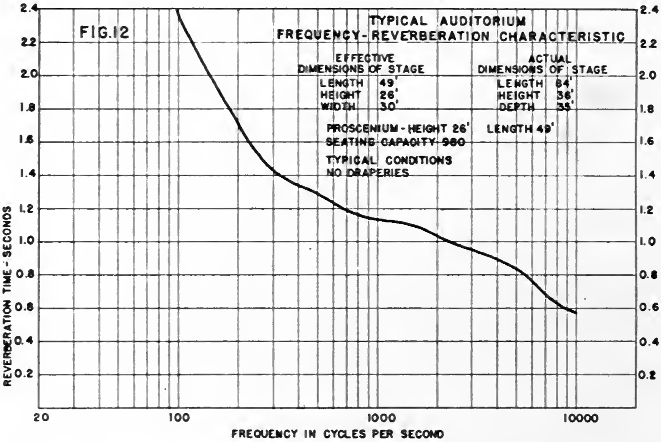

FIG. 12. Reverberation characteristic of typical broadcasting auditorium.

The modulator is protected against no-load operation by the small underload relay at the left of the differential relay which also operates on the lamp current.

The next two chassis contain the separate power supplies for the lamp and the modulator. The upper one contains the power transformers and rectifiers and the lower one the filter chokes, capacitors, and bleeders. All input and output connections for both signal and power circuits appear on the panel at the bottom of the rack. This panel contains also an overload circuit-breaker which is in the main a-c power line.

Both the disk chassis panel and rear cabinet door have interlock safety switches for the high-voltage circuits. Terminals are provided for remote start, stop, and interlock connections.

Fig. 10 shows a remote start-stop and mixer-attenuator box which controls the operation of the reverberation apparatus. The attenuator on the right controls the output level. The unit at the left is a dual *T* type attenuator in which one section carries the original signal and the other the reverberation signal. It is arranged so that when it is turned all the way counterclockwise only the original signal is passed, while when turned all the way clockwise only the reverberation signal passes. At any intermediate point the ratio of original signal to reverberation is proportional to the amount of rotation. The unit is so designed that when the outputs are fed to a common load having the proper terminating resistance, the overall signal level remains constant. Thus with one control knob it is possible to add any desired amount of reverberation without disturbing the overall level of the program.

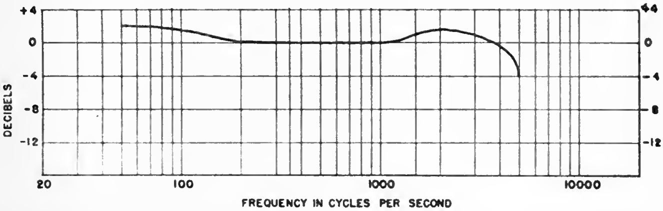

FIG. 13. Overall frequency response of Model *C* reverberation equipment.

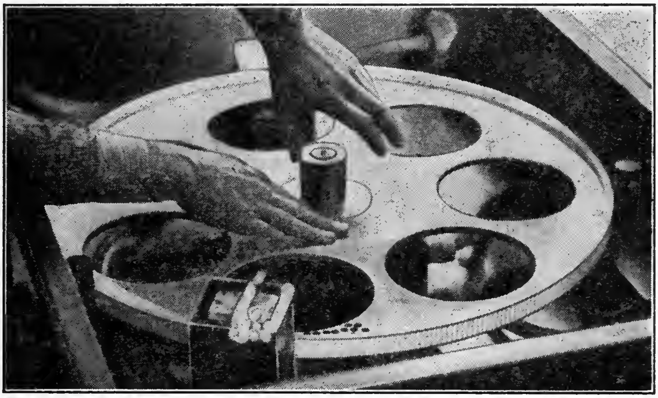

FIG. 14. Photograph of disk while the sound modulation is still visible.

Performance.—The frequency response of the mercury vapor lamp drops off toward the high-frequency end where at the same time the apparent impedance of the lamp increases. Equalization therefore becomes necessary and can easily be carried out if it is kept in mind that the power contained in sound programs is confined to the lower frequencies. Fig. 11 shows the lamp output *vs.* frequency characteristic before equalization. From a practical operating viewpoint these facts mean that the modulation level at the higher frequencies can be increased, improving the overall signal-to-noise ratio.

A frequency response for reverberation above 5000 cycles is hardly needed as proved by subsequent tests. As shown in Fig. 12, which represents the reverberation characteristic of a typical broadcast auditorium, the reverberation time above 5000 cycles is negligible compared with that at lower frequencies. The overall frequency characteristic of the synthetic reverberation device is shown in Fig. 13. Measurements showed that the total distortion is of the order of 2 to 5 per cent overall at full modulation. The signal-to-noise ratio of the reverberation signal only, picked up from the disk, is about 45 db at full modulation. However, since only a fraction of that signal is added to the original sound, the overall signal-to-noise ratio is appreciably better. A compression-type amplifier which reduces the volume range of modulation logarithmically is used in this model further to improve the signal-to-noise ratio at low modulation levels. Fig. 14 shows a photograph of the disk while the sound modulation is still visible.

The authors wish to express their appreciation to their associates at Columbia Broadcasting System, especially to Messrs. Murphy, Dyer, and Wilner, for their advice and active assistance in this development.

REFERENCE

[1] CHINN, H. A., AND JAMES, V. N.: "Apparatus for Acoustic and Audio Measurements," *J. Acoust. Soc. Amer.* (Jan., 1939), p. 239.

DISCUSSION

MR. BENDHEIM: You said that forty impulses were required to get natural sound reverberation. Your instrument has only two pick-ups.

DR. GOLDMARK: Each revolution of the disk supplies two impulses, and the sound decays completely as the disk revolves five or six times. There are between forty and fifty impulses, the envelope of which represents a smooth logarithmic curve. The new sound is superimposed upon the decaying sound. The speed of the disk is 300 rpm.

Mr. Palmer: What size of slit is used between the mercury lamp and the disk?

Dr. Goldmark: Half a millimeter wide.

Mr. Crabtree: Perhaps you can tell us how you apply this in the CBS.

Dr. Goldmark: At present the apparatus is located in the laboratories at 485 Madison Avenue. It is used over a program in one of the playhouses on 45th Street. The program is piped through the master control at 485 Madison Ave., and then to the laboratories; then back to the control room and out to the transmitter. Of course, this is only experimental; in actual work each studio might have a rack like this.

Mr. Crabtree: The effect you give here is of a person singing in an empty hall. We do not like to hear that on the radio. In what particular instances have you used it?

Dr. Goldmark: The effects we have used it for can not be demonstrated here, because the room is too large, for one thing. It consists mainly in adding a certain amount of brilliance or liveliness to the program. Most of our broadcasts come from a dead studio, or a fairly deadened playhouse, where some of the instruments sound unnatural. Also, sometimes the singing sounds insufficiently "live." We add a very small amount of reverberation, which our conductors claim livens the sound and renders it more agreeable in the home.

Mr. Crabtree: In other words, when the studios were built it was thought that all studios should be dead.

Dr. Goldmark: Yes, but we need dead studios, also, for many programs, and the number of studios is limited. We can not make a live studio dead, but with this we can make a dead studio live.

Mr. Frank: There are other methods of introducing artificial reverberation, including the steel tape. Has this system particular advantages over the others?

Dr. Goldmark: The main advantage is that we have this one. Several years ago, when we conceived this idea, we looked into the other systems but our curiosity was not satisfied, so we went ahead with this because a device was needed. We have had no opportunity to make side-by-side comparisons.

Mr. Bradbury: Would a conductor be content to have his music picked up in a dead studio and livened up by means of this device, instead of being picked directly up by a transmitter?

Dr. Goldmark: We would not go to extremes. A studio large enough to house a large orchestra would not be dead.

Mr. Walker: What is the useful life of the phosphorescent material?

Dr. Goldmark: So far as we know, it is indefinite. We coated this disk a year ago. The fingers must be kept off the material. An interlocking switch in this device prevents turning on the light while the disk is stationery; a spot might otherwise be burned into it.

Mr. Kellogg: What difference do you notice between the effect of this instrument and an echo chamber?

Dr. Goldmark: The echo chamber introduces appreciable distortion, as much as 5 or 6 per cent, as indicated by an echo chamber we have at CBS. The chamber is not flexible, either. The reverberation time is not very flexible and does not provide the brilliance that this device does. Also, it is more expensive.

OPTICAL CONTROL OF WAVE-SHAPE AND AMPLITUDE CHARACTERISTICS IN VARIABLE-DENSITY RECORDING*

G. L. DIMMICK**

Summary.—*The use of the optical penumbra to obtain linear variable-intensity light-modulation has already been described. The present paper shows how to obtain non-linear penumbras having predetermined intensity-amplitude characteristics. By this means it is possible to compensate optically for non-linear relation between negative exposure and print transmission known to exist in the variable-density system.*

Variable-density noise-reduction has been obtained by moving the penumbra vane at right angles to the optical axis in accordance with the volume of the original sound. If a fixed penumbra vane is placed close to the movable vane, it forms an optical end-stop which limits the deflection of the penumbra after it has reached a predetermined position. The optical characteristics of penumbras formed by two displaced vanes are also shown.

For a given amplitude of galvanometer-mirror vibration, the extent of the light-modulation is determined by the penumbra height at the recording slit. The penumbra height may be varied by moving the penumbra vane along the optical axis. Either compression or expansion of the sound volume obtained from a film record may be effected by causing the penumbra vane to move along the axis in accordance with the volume of the original sound. Such a system is described in detail.

A combined system is also described which permits both noise-reduction and compression to be obtained by the use of a single shutter and noise-reduction amplifier.

The first commercial variable-density sound records were made by modulating the intensity of a glow-lamp and allowing the light from this lamp to pass through a fixed slit to the film. This arrangement was very good from a theoretical standpoint, but its practical use was seriously limited by the operating characteristics of the glow-lamp. As a result of these limitations, the light-valve, or variable-slit-width modulator, was developed and almost completely replaced the glow-lamp. This type of modulator was quite linear and, when used in connection with an incandescent lamp, gave the relatively high intensities required for straight-line recording on positive film.

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* Presented at the 1939 Fall Meeting at New York, N. Y.; received October 18, 1939.

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

Because of the "ribbon-velocity effect"[1] and the "variable-slit-width effect"[2] the light-valve was responsible for the introduction of considerable distortion not present in the variable-intensity system.

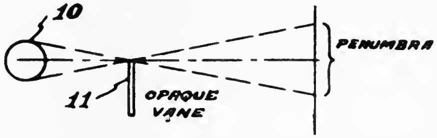


FIG. 1. Formation of a simple penumbra.

In 1934 a variable-density recording system was developed, which combined the advantages of linear variable-intensity modulation, high light-intensity, and extreme ruggedness. This was the penumbra recording system described previously in the JOURNAL.[3,4] The purpose of the present paper is to discuss certain interesting properties of this system and to show how they are made use of to control wave-shape and amplitude characteristics.

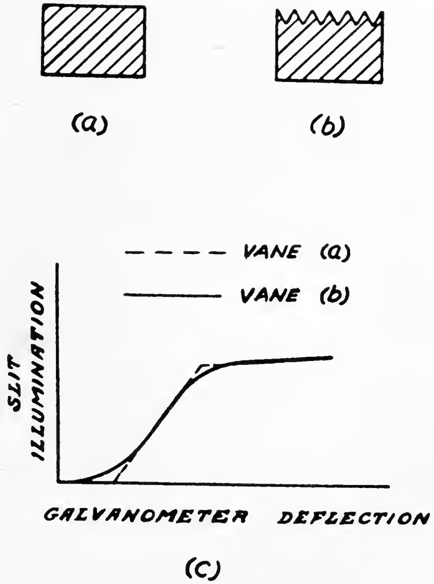


FIG. 2. Comparison of a plane and a serrated penumbra vane.

THE FORMATION OF A PENUMBRA

Fig. 1 shows how a simple penumbra is formed by placing an opaque vane *11* at a distance from a light-source *10*. The height of the penumbra at any point along the axis is directly proportional to distance of the point from the vane. The variation of intensity within the penumbra depends upon the shape of the source, the shape of the vane, and the alignment of the vane with the source. For the case of a rectangular light-source of uniform intensity and a plane smooth vane parallel to the source, the penumbra intensity varies linearly with height. If a horizontal slit were placed at the penumbra and the light vibrated in a vertical plane by a galvanometer, we should have the essential elements of a variable-intensity light-modulator. Fig. 2 shows the relation between slit illumination and galvanometer deflection for a vane having a plane edge, and for a vane having a serrated edge. The serrations result in a letter *S* curve, the exact shape of which is determined by the shape of the serrations and the ratio of their depth to the height of the penumbra.

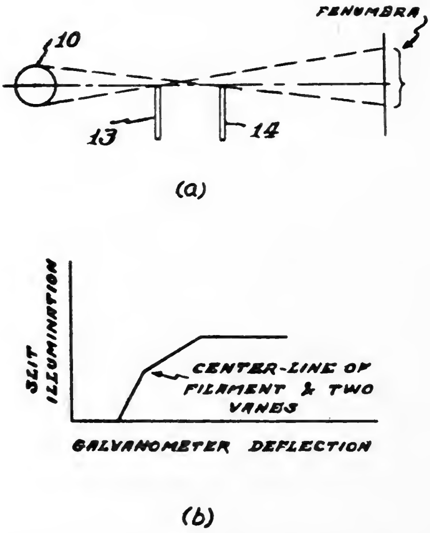


Fig. 3. Intensity characteristic of a penumbra formed by two separate vanes.

For a given light-source height, the slope of the illumination *vs.* deflection curve is a function of the distance from the source to the vane. Fig. 3*b* shows how a curve having two slopes may be produced by placing two vanes at different positions along the optical axis (Fig. 3*a*). It will be observed that the intersection of the two slopes occurs at the centerline of the filament and the two vanes.

The slope of the illumination *vs.* deflection curve may be made to vary continuously, between limits, by replacing the thin penumbra vane with a curved plate which has considerable depth as shown in Fig. 4. It is apparent that at each point in the penumbra the limiting ray strikes the vane at a different point along the optical axis.

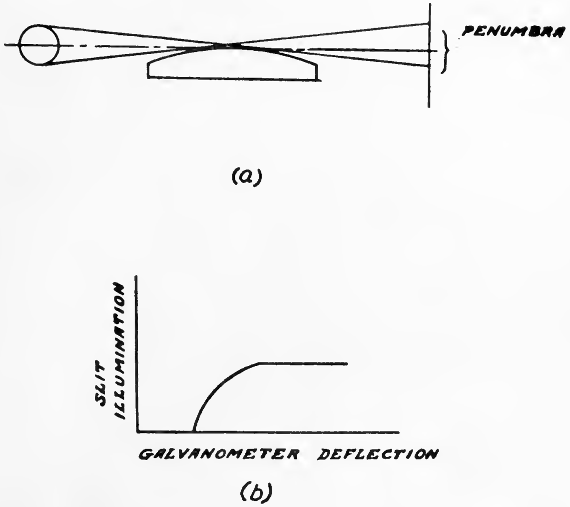


FIG. 4. Effect of a curved plate upon the penumbra intensity characteristic.

WAVE-SHAPE CONTROL

The penumbra system of variable-density recording described in previous papers was so arranged as to produce a linear relation between galvanometer deflection and intensity of the recording light-beam. This is, however, only a special case and the same general system may be so modified as to produce a predetermined non-linear relation between deflection and intensity. The non-linearity may be obtained by making the filament of a special shape or by placing a specially shaped mask either in front of the filament, at the image of the filament on the galvanometer, or at the image of the filament and mirror near the back lens of the objective.

The Recording Optical System.—Fig. 5 shows an optical layout of a recording optical system with the special mask *21* placed near the objective lens *22*. As the penumbra *24* is moved across the slit *19*, the variations in intensity at the slit are converted, by the slit condenser into corresponding variations in area at the objective plane *22*. If the image of the filament is larger than the mirror then the height of the penumbra is determined by the mirror height and the relative intensities at different points within the penumbra are determined by the shape of the mirror. Fig. 6 shows three positions of the penumbra relative to the slit, and the appearance of the mirror image near the objective plane for each position. It is clear that if no limiting mask were placed over the filament or its images, the rectangular shape of the mirror would result in a linear relation between slit illumination and penumbra deflection. The effect of any other shape of mirror or mask may be easily determined by applying two simple rules. The maximum intensity at the light edge of the penumbra is proportional to the total effective area of the mirror. The slope of the intensity-deflection curve at a particular height on the penumbra is proportional to the width of the mask or mirror at

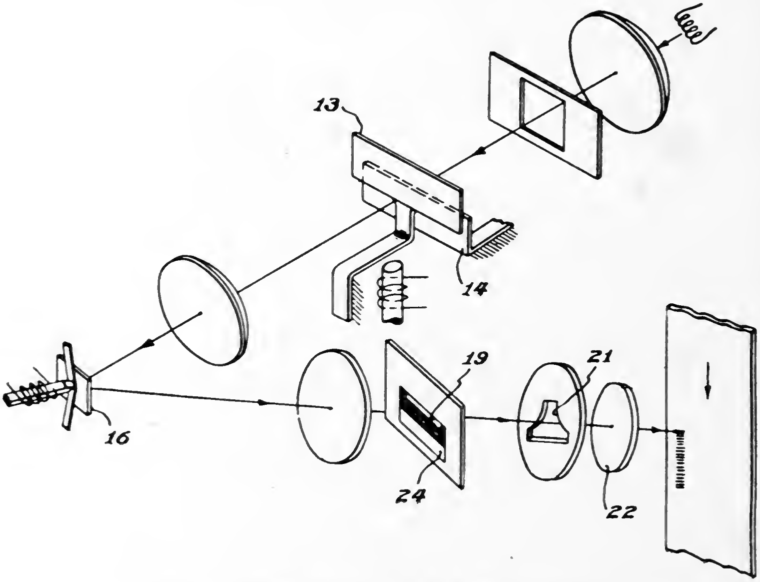


FIG. 5. Layout of the recording optical system.

the corresponding height. Applying these rules to the triangular mask shown in Fig. 7*b* we find that the intensity-deflection curve takes the form of a parabola until it reaches a maximum intensity of one-half that produced by the rectangular mirror of Fig. 7*a*.

Curvature of the Photographic Characteristic.—Fig. 8*a* shows a typical H&D characteristic of the positive film normally used for release prints. The slope of the straight-line portion of the curve is about 2.1, but for densities below 0.6, the slope decreases until it reaches zero. In order to obtain sufficient volume from variable-density records, it is customary to make use of a portion of the print toe even though it causes a departure from linearity in the overall result. Fig. 8*b* shows how the print transmission varies with negative exposure for the so-called straight-line recording method in general use at the present time. The curve is quite linear between the limits of 2 per cent and 25 per cent transmission, but departs from linearity above and below these values. The curvature below 2 per cent is caused by the negative toe and does very little harm if the biased transmission is kept well above this point. The curvature above 25 per cent transmission is caused mostly by the print toe and results in considerable distortion.

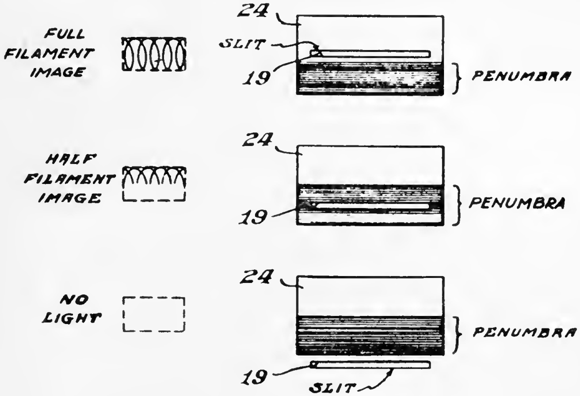
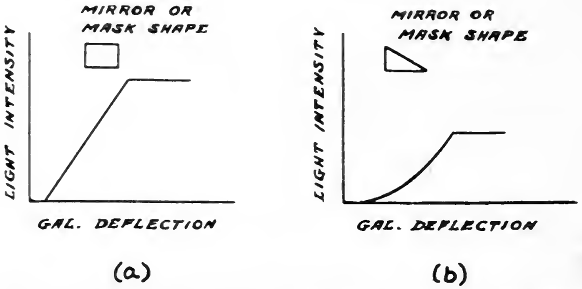


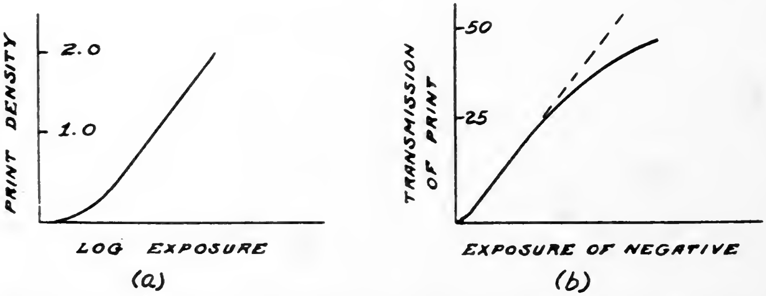
FIG. 6. Appearance of the light at the objective plane and the slit plane for three positions of the penumbra.

Design of a Compensating Mask.—After having determined the average overall negative exposure *vs.* print transmission characteristic, it is quite easy to design a mask of such shape as to make the recording optical system compensate for the non-linearity. Although the overall film characteristic may be arrived at by making static measurements from negative and print sensitometer strips, the dynamic method has been found to be more satisfactory. A constant frequency is applied to the recording galvanometer at a level of 30 db below full penumbra deflection. With the aid of the monitoring card, the galvanometer is rotated successively to positions representing relative slit illuminations of 5, 15, 25 per cent, *etc.*, to 95 per cent. For each of these positions a few feet of the low-level constant frequency is recorded. The complete record is processed and printed in the normal way. The print is reproduced through a band-pass filter to minimize surface noise, and output measurements are made. The measured outputs are proportional to the slopes at the various points on the overall transmission curve. The slopes of the compensation curve should be proportional to the reciprocal of the measured outputs.



(a) (b)

FIG. 7. Effect of mirror or mask shape upon the penumbra intensity characteristic.



(a) (b)

FIG. 8. (*a*) H&D characteristic for ordinary positive film. (*b*) Overall characteristic for present "straight-line" variable-density recording method.

It has already been pointed out that the effective width of the mirror at a particular height should be proportional to the slope of the desired intensity-deflection curve at the corresponding height on the penumbra. Thus if it is found that the output at the position of 65 per cent slit illumination is one-half the maximum output, then the width of the mirror at the corresponding height should be twice its minimum width. Fig. 9*a* shows an output curve made as described above and Fig. 10 shows the shape of the mask placed in front of the mirror to produce an overall curve which was practically linear from 2 to 45 per cent print transmission. Fig. 9*b* shows an output curve made after the correcting mask was in place.

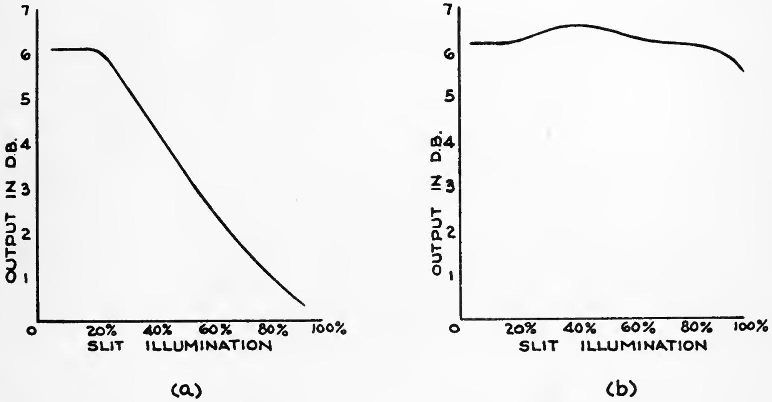


FIG. 9. Output curve (*a*) before compensation was applied; (*b*) after compensation was applied.

Application to Direct Positive and Toe Recording.—In order to make full use of this method of optical control, it is desirable to increase the negative gamma. By processing the negative to a gamma of 0.75, it has been found possible to make variable-density records having a linear output to 85 per cent of the maximum track transmission. The method could be beneficially applied to toe recording and to direct positive variable-density recording. Modulating devices such as the galvanometer and the light-valve may be considered as having a gamma of practically 1.0. A correcting mask could be so designed as to produce a logarithmic relation between intensity and deflection. The modulating device would then have a fixed gamma either greater or less than unity depending upon the shape of the mask. A recording optical system having a gamma of 2.5 used in combination with a film processed to a photographic gamma of 0.4 would produce a linear overall result without the necessity of making a print.

Compensation for Average Characteristic.—At present it is not practicable to duplicate a photographic characteristic exactly from day to day. The many variables in the developing process result in uncontrollable differences in the gamma, the density, and the shape of the toe. The changing of output levels by varying the print density is also an important factor. Even in view of these variables it is believed that the average quality of variable-density records may be improved by introducing an amount of compensation sufficient to make the average photographic characteristic linear.

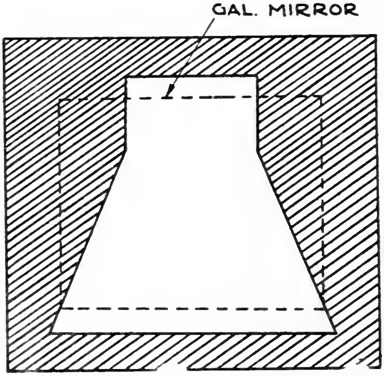


FIG. 10. Shape of a correcting mask used for low-gamma variable-density recording.

AMPLITUDE CONTROL

Noise-Reduction.—The recording optical system shown in Fig. 5 makes use of a movable penumbra vane to obtain noise-reduction. The vane *13* is connected to a shutter motor and moves at right angles to the optical axis. The fixed penumbra vane *14* serves as an optical end stop and prevents any further motion of the penumbra after the movable vane passes behind it. In this system the height of the penumbra at the slit remains fixed and depends upon the height of the mirror and the location of vanes along the optical axis.

Volume Compression or Expansion.—The linearity of the penumbra is not altered by moving the vane along the axis, but the slope of the exposure *vs.* deflection curve is different for each position. Fig. 11*a* shows how penumbras of different heights are formed by vanes placed at different distances from a light-source. Fig. 11*b* shows the relation between slit illumination and galvanometer deflection for these two conditions. By moving a single vane back and forth along the optical axis in accordance with the envelope of the sound-waves, it is possible to obtain volume compression or expansion of the sound. If increased sound volume causes the vane to move in such direction as to increase the height of the penumbra, compression of the volume range is obtained. If increased sound volume causes the vane to move in such direction as to decrease the height of the penumbra, expansion

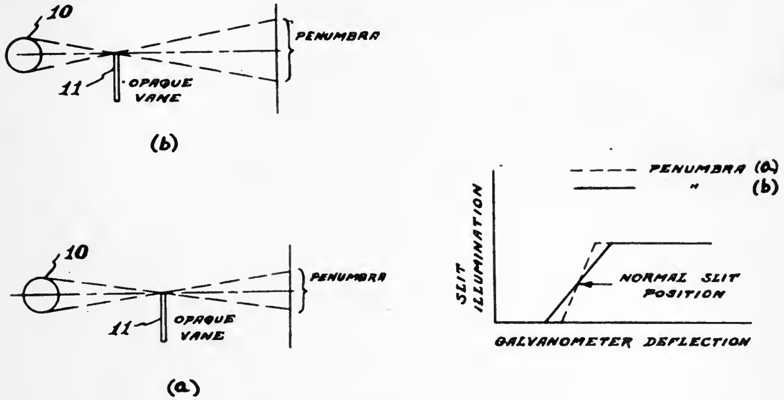


FIG. 11. Effect of vane position upon the intensity characteristic of a penumbra.

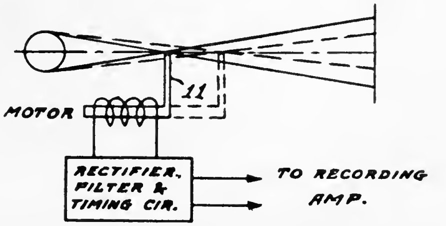


FIG. 12. A motor for controlling the pneumbra height.

of volume range results. Fig. 12 shows a system in which a vane is moved along the axis by a motor which receives its power from an amplifier similar to the present noise-reduction amplifier. The timing and filtering requirements for a compressor are much the same as for noise-reduction. In fact, the same amplifier may be used for both purposes. Fig. 13 shows how a vane can be pivoted in such a way that a single motor produces components of motion both along the axis and at right angles to it. As a result, noise-reduction and compression may be had simultaneously. The fixed vane forms an optical end stop for both components of motion. Since the vane moves in a circular arc, the ratio of the two components of motion varies with displacement. By making the radius long as compared with the displacement, the variation in ratio can be made small.

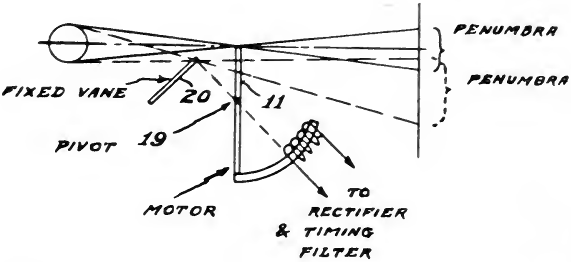


Fig. 13. A motor for simultaneously varying the position and height of the penumbra.

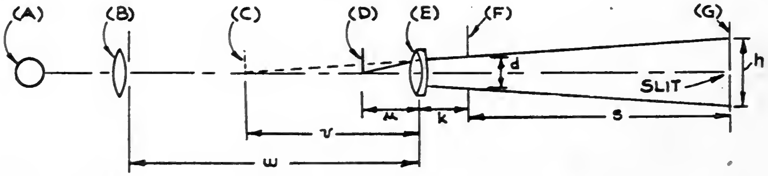


Fig. 14. A "straight-line" layout of the recording optics from the lamp to the slit.

Relation between Penumbra Height and Vane Location.—Fig. 14 shows a layout of the recording optics from the lamp to the slit. The system is laid out along a straight line, with the galvanometer mirror replaced by an aperture of the same height. From an optical standpoint it makes no difference whether the penumbra is formed by a vane placed between the lamp *A* and the condenser *B*, or between the condenser *B* and the intermediate lens *E*. From a practical standpoint it is much better to place the vane within the closed condenser barrel, where it is kept clean and is not subject to the intense heat of the lamp. When the vane is placed in this position, the penumbra height at the slit is determined not only by the mirror height *d* and the galvanometer throw *s*, but also by the focal length *f* of the intermediate lens *E*. When the distance *u* between the vane and the lens is less than *f*, a virtual image of the vane is formed at *C*. If a straight line is drawn from the edge of the virtual penumbra vane past the upper edge of the mirror, it will strike the slit plate at the upper edge of the penumbra.

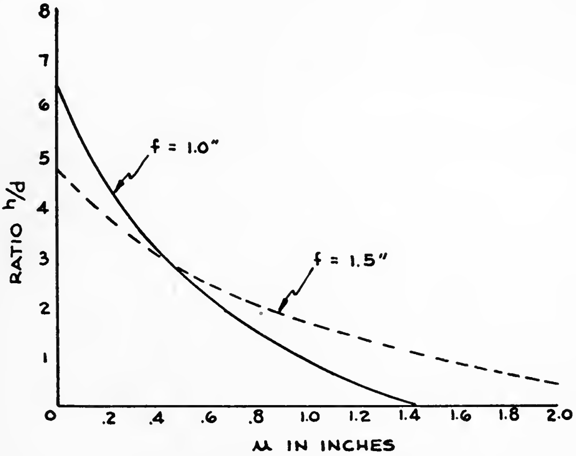


FIG. 15. Curves relating penumbra height to penumbra position.

For values of *u* from *o* to *f* the following relation holds:

$$\frac{1}{u} - \frac{1}{v} = \frac{1}{f} \text{ or } v = \frac{f}{\frac{f}{u} - 1}$$

From the geometry of Fig. 14 it is also apparent that:

$$\frac{h}{d} = \frac{s + k + v}{k + v} = \frac{s}{k + v} + 1$$

Combining these equations gives:

$$\frac{h}{d} = \frac{s}{k + \dfrac{f}{\dfrac{f}{u} - 1}} + 1 \qquad (1)$$

In the same way it is found that for values of u from f to w the ratio of mirror height to penumbra height is:

$$\frac{h}{d} = 1 - \frac{s}{\dfrac{f}{1 - \dfrac{f}{u}} - k} \qquad (2)$$

Fig. 15 shows curves relating h/d to u for two values of f. The present values of $S = 2.63$ and $k = 0.71$ were used. These were plotted with the aid of equations *1* and *2*. Since the height of the present galvanometer mirror is 0.1 inch and the focal length of the intermediate lens is 1.5 inches, the ordinates of this curve give the penumbra heights in tenths of an inch. The maximum height of the penumbra is limited by the permissible deflection of the galvanometer, which for the present design is 0.150 inch at the slit. From the curves it can be determined that, for $f = 1.5$ inches, it would be necessary to move the penumbra vane through a distance of 0.38 inch in order to obtain 8 db of compression in volume range. If f were reduced to 1.0 inch, it would require only 0.18 inch of vane deflection to produce the same amount of compression. It will be observed that over the required range, the variation of penumbra height with vane deflection is quite linear.

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DISCUSSION

MR. KELLOGG: There are various ways of applying compression and a great many of them employ vacuum tubes. These involve a sudden change in plate current whenever there is a rapid change in gain, and this change in current is likely to make a noise. The axial movement of the penumbra mask does not involve a change in average light transmitted. It is the ground-noise-reduction feature that is responsible for whatever change in transmission occurs, and there is no ground-noise-reduction system that does not at some time bring in the possibility of a thump when there is a sudden increase in modulation, except that this disturbance may be cancelled out with a push-pull reproducing system.

MR. MAURER: The difference in behavior that is ordinarily noticed between variable-density and variable-area in the recording of speech has been discussed here before. Some of us have attributed this difference to the fact that in variable-area recording we have a linear characteristic that is terminated abruptly at both ends, whereas in ordinary variable-density recording we have a linear characteristic over the middle of the range with a curved characteristic at each end. The result of this has been expressed by someone in this way, that "variable-density overloads more gracefully than variable-area."

Some studios using variable-area have used volume-limiting amplifiers in order to simulate this characteristic of variable-density, and have claimed that a definite improvement in speech recording was obtained by this practice.

Now here Mr. Dimmick has presented a method of variable-density recording that approximates the variable-area characteristic of linearity over a wide range with an abrupt stop at each end. Has anything been observed as to the effect of this change on the reproduction of speech by the system?

MR. DIMMICK: There is, of course, less compression in a density record if you make it linear. But it would seem that if we need compression in speech it would be best first to make the characteristic linear, and then compress it by non-distorting means. For instance, we could use the aperture plate to make the system linear as shown, and also use the movable vane along the axis to gain compression without distortion.

MR. BRADBURY: Mr. Maurer's question creates the impression that most variable-area recording these days has a linear form. Almost any RCA system today using variable-area uses a degree of compression for speech work. As an example, *The March of Time*, dedicated to the Museum of Modern Art, has a compression of about 10 db. So far as I know, anyone in Hollywood who uses our variable-area equipment uses the compression system with it. I assume that Mr. Dimmick's new system is not limited to linear variable-density, but can be used as a compression system operating with a minimum of distortion.

MR. DIMMICK: That is correct.

MR. KELLOGG: Our interest in the density system has been a good deal stimulated by the conviction on the part of a good many producers that variable-density recording has an important advantage in being less easily damaged in quality by imperfections in a reproducing optical system; and, in deference to their preferences, we tried to develop density systems. It seems to me that a density system of the kind just described by Mr. Dimmick preserves the most important advantage of the density system, with the substantial linearity and lower distortion of an area system.

CLASS B PUSH-PULL RECORDING FOR ORIGINAL NEGATIVES*

D. J. BLOOMBERG AND C. L. LOOTENS**

Summary.—*Progression from standard variable-area types of recording to class A push-pull and finally from class A to class B push-pull was primarily motivated by an appreciation of the inherent advantages of the push-pull types of recordings, and an ability to perfect processing and recording controls necessary to realize the finer qualities of the class B push-pull recording. The adoption of class B push-pull variable-area for original recording has eliminated distortion introduced by noise-reduction systems, and has reduced background noise by at least 6 db.*

Interest in variable-area class *B* push-pull recording has been dormant due to the exacting requirements of laboratory processing, recording, and reproducing adjustments, and the apparent lack of proper control methods.[1,2] With the advent of modulated high-frequency test recordings, laboratory processing control has become well established.[3] In addition, special tools have also been developed for accurately aligning recorders and reproducers both electrically and optically.

The Republic Sound Department initially used the standard RCA variable-area type of recording for both original and release negatives. Later when the advantages of variable-area class *A* push-pull recordings were appreciated, this type of track was adopted to record all original sound negatives.[4] However, even with the marked improvements gained by class *A* push-pull recording, there remained two objectionable factors:

(*1*) Distortion introduced by noise-reduction systems.

(*2*) Difficulty in procuring master sound-tracks with uniformly low background noise.

With these facts in mind, it was decided to investigate the practical operation problems of class *B* push-pull recording for originals.

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* Presented at the 1939 Fall Meeting at New York, N. Y.; received October 11, 1939.

** Republic Productions Inc., North Hollywood, Calif.

Class *B* variable-area push-pull recording of a pure tone contains the positive and negative half-wave on opposite sides of the track. This requires that the proper phase relation between these two half-tracks be maintained on the prints used for reproduction. This phase relation is affected by exposure and subsequent development and printing. The proper phase relationship can be obtained by rotating the aperture in the recorder optical system to meet the processing conditions. As will be shown later, once these adjustments are made the density tolerances are quite broad.

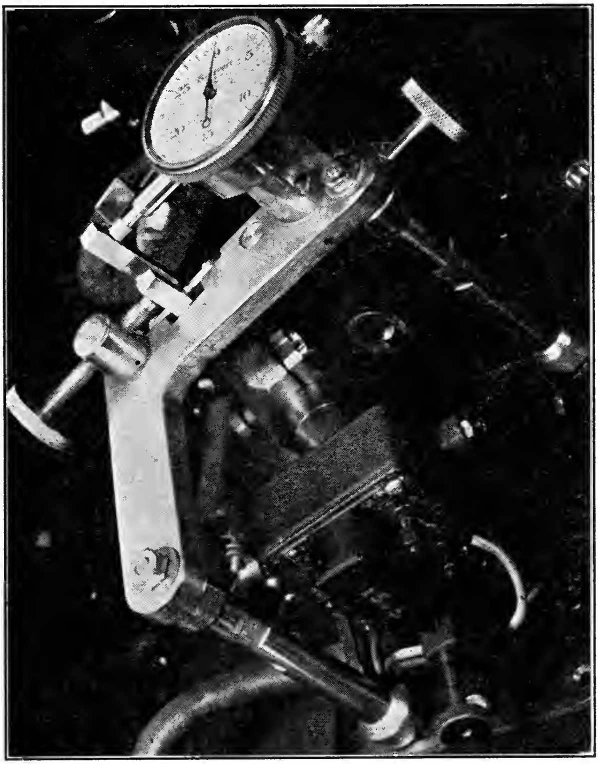

FIG. 1. Micrometer mounted for azimuth adjustment.

An accurately aligned bilateral recorder was selected as a standard for all subsequent slit azimuth adjustments. A film phonograph was then carefully aligned with this recorder and retained as a substandard for all azimuth measurements. The recorder to be modified for class *B* push-pull operation was first equipped with a standard aperture to facilitate the slit azimuth and focus adjustment. This adjustment was accurately made by measurement of film tests on the substandard film phonograph. The advantage of using a standard aperture was to utilize the cancellation method of measurement which is considered the most critical means known. The standard aperture was replaced with a class *B* push-pull aperture, and a preliminary azimuth adjustment made by viewing the track images with a periscope in the rotating drum.

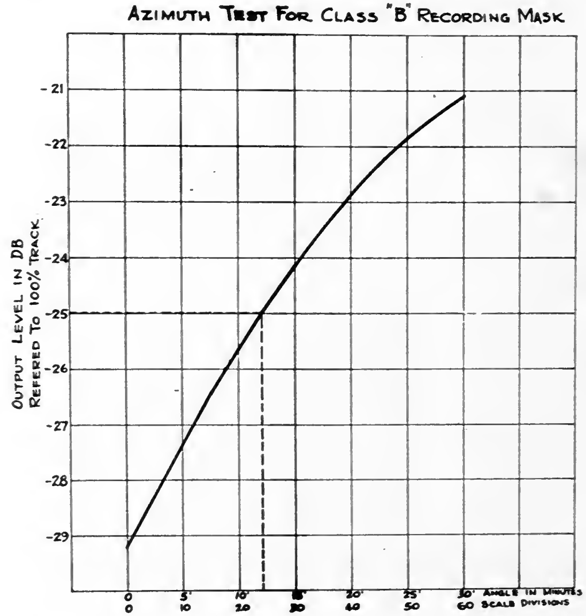

FIG. 2. Azimuth test for class *B* recording mask.

To obtain accurate azimuth adjustments a special tool (Fig. 1) was mounted on the optical system and attached to the intermediate lens barrel. A standard micrometer was used to indicate the rotational adjustment. Each division on this micrometer is equal to 30 seconds of angular rotation. A series of 1000-cycle recordings at −25 db from 100 per cent galvanometer deflection was made on each side of the preliminary adjustment. The galvanometer was then tilted so that all the modulation appeared on first one and then the other side of the track. This in effect records a standard bilateral track on either side. A standard track-modulated high-frequency test was then recorded on the end of this film to insure maintenance of processing standards. The prints of these recordings was then measured on the substandard push-pull film phonograph. The rotational adjustment was selected at which the output level of the push-pull track equalled the level of the standard tracks. A typical curve of this test is shown in Fig. 2. The aperture was then set at the selected position and a check test was recorded and measured.

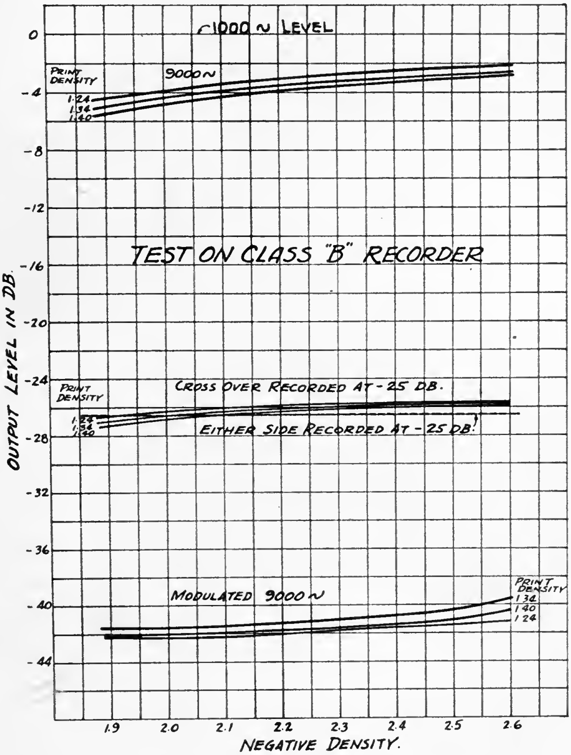

FIG. 3. Cancellation, cross-over and 9000-cycle test on class *B* recorder.

The recorder was now ready for production tests which started with modulation tests made over a range of print and negative densities to obtain a family of cancellation curves. It was immediately apparent that class B push-pull has the same laboratory processing tolerances as class A. A typical set of cancellation curves made on class A and class B recorders and processed simultaneously is shown in Fig. 3. Random parallel recordings were then made of music scoring and stage production material over a protracted period. Since variation in laboratory processing affects the phase relationship of the class B push-pull track similarly to the rotation of the aperture, the same type of cross-over test described above was used for laboratory control. An azimuth test negative was made at the checked aperture setting similar to the test used in aligning the class B aperture and a print put through with the daily recordings made on that particular recorder. The measurements derived from these daily tests were carefully tabulated and gave indications of the tolerances allowable before distortion became detectable. For daily prints, it was decided that ±1 db did not produce objectionable distortion. For master dubbing prints azimuth tolerances were set at $\pm ^1/_2$ db. All these random parallel recordings definitely manifested the elimination of distortion due to noise-reduction systems and a decrease in film background noise by at least 6 db.

With this initial success, it was decided to record an entire production on class B push-pull. Throughout the production no difficulty was experienced in maintaining our established processing tolerances. The sound recordist was relieved of noise-reduction system adjustments, which simplified his duties. The dubbing master prints obtained from this production were unusually quiet and the quality of the sound was definitely improved due to freedom from film background "hash" and the elimination of noise-reduction distortion. Although the release prints are recorded on standard track, there still remains a definite improvement on these two objectionable factors.

Following the preliminary production test, all production recorders were converted to class B push-pull and all reproducing heads on the lot were carefully aligned with the original standard recorder. Weekly tests are made on all reproducers, and new azimuth tests are made on each recorder before going on a production. Once the optical systems are accurately aligned and locked down, it has been found unnecessary to make any readjustments.

Since changing over to the class B system fourteen pictures have been recorded. In general an improved naturalness and smoothness in sound quality has been noted and less difficulty has been encountered in obtaining satisfactory dubbing prints. This results in simplifying and speeding up the re-recording operation since less changes in equalization are necessary to smooth out the sound quality from scene to scene. The dubbing mixer also has more latitude in bringing up low-level takes without introducing objectionable noise.

In conclusion, the advantages of class *B* push-pull may be summarized as follows:

(*1*) Elimination of distortion introduced by noise-reduction systems.

(*2*) Decrease in background noise by at least 6 db, thereby providing a greater volume range.

(*3*) Wide processing tolerances facilitating the control of production negative densities and providing a uniformly higher-quality track.

(*4*) Elimination of all noise-reduction apparatus which facilitates the operation and maintenance of the recording equipment.

Acknowledgment is made to A. C. Blaney of RCA Manufacturing Company for his helpful assistance in effecting these conversions and establishing standards of control.

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A TRANSMISSION SYSTEM OF NARROW BAND-WIDTH FOR ANIMATED LINE IMAGES*

A. M. SKELLETT**

Summary.—*A new method of transmission and reproduction of line images, e. g., drawings, is described which utilizes a cathode-ray tube for reproduction, the spot of which is made to trace out the lines of the image 20 or more times a second. The steps of the complete process are: first, the transcription of the line image into two tracks similar to sound-tracks on moving picture film; second, the production from these tracks of two varying potentials by means of photoelectric pick-up devices; third, the transmission of these potentials; and fourth, their application to the cathode-ray deflector plates to effect reproduction. Satisfactory transmission of fairly complex images, e. g., animated cartoons, could be effected within a total band-width of 10,000 cycles.*

In transmitting images by television the entire field is scanned many times per second. If the image is a line drawing or animated cartoon the greater part of the transmission is wasted in sending blank areas. The method to be described for transmitting images of this kind sends only the actual lines of the drawing and as a consequence requires only about one one-hundredth of the band-width that would be used if the transmission were by television. The essential principle involved is the tracing of the lines of the drawing by the bright spot of the reproducing cathode-ray tube twenty or more times a second. The spot simply follows repeatedly the same path that was followed by the artist's pencil when the drawing was made.

In order that the spot be directed along the lines of the drawing, suitable varying potentials must be applied to the two sets of deflector plates in the tube. These potentials will be proportional to the X and Y coördinates of the points that lie along the lines of the image. For instance, in Fig. 1, in order that the reproducing spot may progress over points *1*, *2*, *3*, *4*, *etc.*, along the lines of the drawing, potentials must be applied to the horizontal and vertical deflector plates which are proportional to the X and Y coördinates of these points.

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* Presented at the 1939 Fall Meeting at New York, N. Y.; received Sept. 1, 1939.

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

In transmitting an animated cartoon or drawing the following steps are required. First, from each drawing or frame, variations of the X and Y coördinates of the points of the image are recorded as variable-area tracks on motion picture film. This is the transcription process. Second, the film is fed into apparatus similar to sound pick-up apparatus which produces varying potentials proportional to the area of the tracks. Third, these two potentials (the X and Y) are transmitted to the receiver where they are applied to the cathode-ray tube to reproduce the original images.

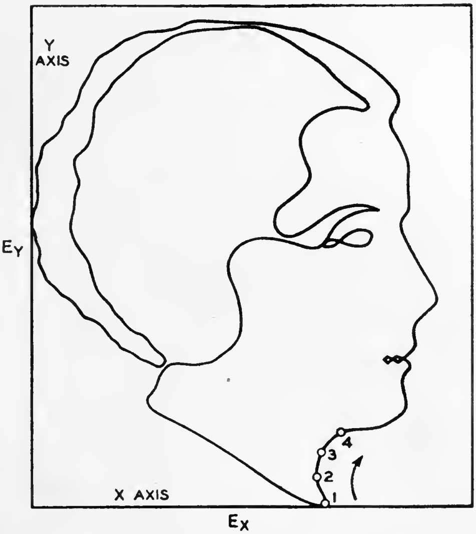

FIG. 1. Resolution of a simple image into a single line. Total band needed for transmission, 2000 cycles.

The transcription process is facilitated by the transcriber which is shown in schematic form in Fig. 2. It is shown arranged to transcribe from an animated cartoon on moving picture film. One frame at a time is projected on the ground-glass or equivalent screen and the stylus is manually made to follow the lines of the drawing. In doing so the sliding vanes are made to move in proportion to the X and Y coördinates so that the requisite variable-area tracks are recorded on the uniformly moving film.

Fig. 3 is a schematic diagram of the complete apparatus. Starting with film or drawings the transcriber reduces these to the film record of variable-area tracks. This is then fed into the converter where photoelectric equipment converts the tracks into the X and Y potentials that are transmitted to the receiver. In a practical set-up there will generally be recorded on the same film another track which carries the sound record to accompany the images.

The frequency-band necessary for the transmission of a drawing can be determined from Fourier analyses of the complex wave-forms generated by the transcriber. The lower limit of the band will be the frame frequency and the spectrum will consist ideally of the harmonics of this frequency. We need to know how many of these harmonics are necessary for good transmission. The harmonics of lower frequency determine the overall shape of the larger features of the drawing and the higher harmonics determine the shape of the finer details. Thus if we cut off the higher harmonics in order to narrow the band-width, the sharpness of corners and points and the shape of the smaller details will suffer but the general form of the image will not be changed.

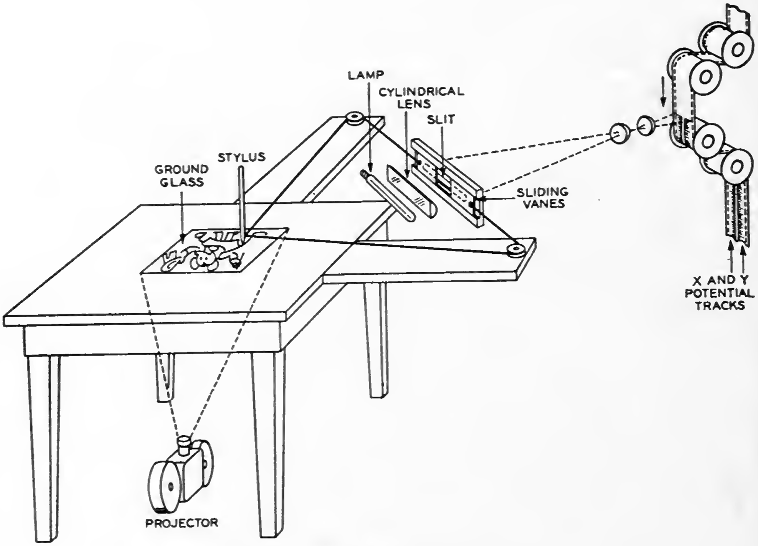

FIG. 2. One form of transcriber.

We must determine, therefore, how much fine detail is necessary for satisfactory reproduction. This may be done by an application of Fourier analysis that will not be attempted here.[1] It is obvious that the more complex the figure the greater will be the band-width required for satisfactory reproduction. The estimated band-width necessary for satisfactory reproduction of Fig. 4 is 10,000 cycles wide. This is made up of two 5000-cycle bands, one for the X and one for the Y potentials.

A complete analysis of a drawing results not only in this band of frequencies but also in a direct-current component. It is necessary to transmit this latter component also. It determines the centering of the image in the field. As an example of its importance, consider an image which consisted of a figure of some complexity and a very simple background. Then if the figure started to walk from the center to the side of the field, the absence of this component in the transmission would hold the figure near the center and the background would slide away from him in the opposite direction.

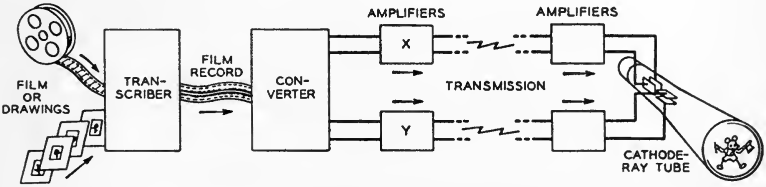

FIG. 3. Arrangement of complete apparatus.

This component would automatically be recorded in each of the X and Y film tracks. It is represented by the average area of the variable-area tracks.

In the transcription process the image must be resolved into a single continuous path for the cathode-ray spot. This requires that there must be parts of the path traversed by the spot which are not visible; *e. g.*, in Fig. 4 the spot must not be visible when it goes from one eye to the other. There are two ways of accomplishing this. Either the electron beam may be cut off or it may be made to traverse the path at speed 10 times or more greater than its normal velocity. The latter method is preferred since it does not result in an increase in total band-width.

The main advantage of this method lies in its economy of frequency band-width. Television requires a band several million cycles wide and in consequence new means of transmission have had to be developed for it. This method requires a band of the same order as that used for high-grade sound reproduction and suitable transmission facilities are therefore already available. In urban districts the 10,000 cycles needed for an image of the complexity of Fig. 4 could be handled over a single special telephone line. Some equalization would probably be required for the longer circuits. For long-distance transmission two circuits of at least program transmission grade which are now equalized to 5000 cycles would be required. These circuits might require some supplementary delay equalization.

The kind of images that may be transmitted are limited to those which may be reproduced by line-drawings but this takes in a fairly large field. A certain amount of shading is possible in the same way that it is realized in a pen-and-ink drawing. The kinds of images that are particularly suitable for transmission are drawings, diagrams, and maps with or without animation and animated cartoons. These might include animated drawings depicting the working of equipment, fashion sketches, *etc.* About seven words of average length of script could be handled at a time by a 10,000-cycle band and this might prove advantageous for sending signatures and foreign language characters which could not readily be handled by ordinary existing communication facilities. Sketches, primarily of news value, including those of famous people, places, ceremonies, fashions, *etc.*, could be made by an artist at the location of a news event such as a trial,

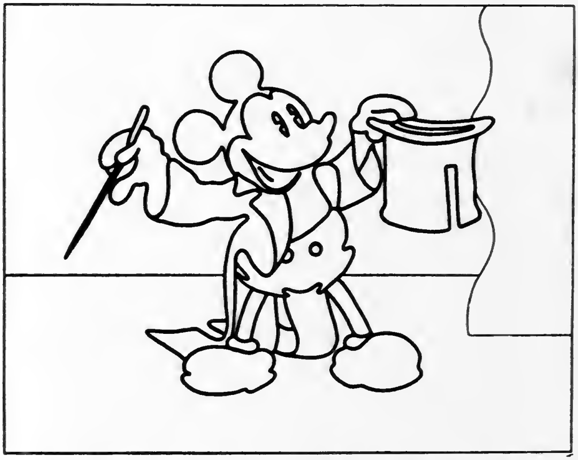

FIG. 4. **Total band needed for transmission of this image is 10,000 cycles wide.**

football game, *etc.*, and transmitted simultaneously with the drawing of the sketch. This last would require a transcriber somewhat different from the one that has been described. There are several possible ways of doing this.

[The images shown at the meeting demonstrated the sort of reproduction that is achieved. For these the X and Y tracks were recorded on disks. This disk was mounted on a motor shaft and spun before two photoelectric cell pick-up units which fed the X and Y potentials to separate amplifiers. The outputs of these amplifiers were connected to the horizontal and vertical deflecting plates of the cathode-ray tube. The speed of rotation was slowed down so that one could follow the spot as it traversed the lines of a drawing.—Ed.]

FIG. 5. Photograph of an image reproduced by first experimental apparatus.

DISCUSSION

MR. BATCHELOR: What rate of image repetition did you assume in order to achieve a 10,000-cycle transmission band?

MR. SKELLETT: Twenty-four frames a second.

MR. THOMAS: Can these simple line drawings be transmitted rapidly enough to give the effect of moving objects?

MR. SKELLETT: The apparatus is designed to transmit ordinary cartoons, such as a Mickey Mouse or Donald Duck film, just as it is.

MR. BRADY: How large an image can you produce?

MR. SKELLETT: If we had a projection cathode-ray tube, such as is used in television, we could enlarge it to about 9 × 12 feet.

MR. KELLOGG: Is there any way of making the original record of the frequencies to be transmitted other than by tracing the original drawing? Can you take a completed picture and scan it, without any human intervention?

MR. SKELLETT: We have not been able to figure out a way of doing it. The only way we have been able to transcribe the drawings is to run the stylus manually over the lines of the drawing. That takes about as long as it would for the artist to draw the original picture, or perhaps a little less.

MR. BATCHELOR: What is the speed of the film past the pick-up aperture?

MR. SKELLETT: Ninety feet per minute.

MR. BATCHELOR: You can slow it down but do not have to speed it up?

MR. SKELLETT: Yes.

TELEVISION CONTROL EQUIPMENT FOR FILM TRANSMISSION*

R. L. CAMPBELL**

Summary.—*A television film chain with particular reference to amplifier, sweep and power circuits in the film pick-up unit is described.*

Many improvements in television circuits have been made possible by recent advances in circuits and circuit components in radio and allied electronic fields. Application of some of the newer ideas to motion picture film pick-up equipment has resulted in improved performance and simplicity of operation.

Circuit arrangements which permit flexibility in transmission standards are considered and their application discussed. Also the anticipation of possible future improvement in picture quality is indicated in some circuit capabilities.

The unlimited photographic possibilities offered by modern motion picture technic can provide much excellent entertainment which can not be conveniently televised satisfactorily in "live" form. Television programs (utilizing high-definition transmission) which consist of first-grade film presentations now have good entertainment value.

Therefore, television film pick-up equipment is of major importance in any development of a television service to the public. The object of this paper is to describe the major circuit components of a television movie chain and to discuss some of the circuits peculiar to television film pick-up equipment.

Apparatus Layout.—A diagrammatic arrangement of the apparatus used in connection with experimental transmission of film programs from Station W2XVT is shown in Fig. 1. The film projector is located in a room (fireproofed) adjacent to the main equipment room. In the latter room are located the F. P. U. (film pick-up unit), synchronizing generator, monitors, control console, mixing and line equipment, and sound equipment. Video and sound signals are supplied to the transmitter room by the latter equipment.

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* Presented at the 1939 Fall Meeting at New York, N. Y.; received October 7, 1939.

** Allen B. Du Mont Laboratories, Passaic, N. J.

The relation of the other apparatus in the main equipment room to the F. P. U. is as follows: The vertical and horizontal sweep waves are formed in the synchronizing generator and fed to the F. P. U., where they are applied to their respective sweep amplifiers. Blanking pulses are fed to the blanking amplifier in the F. P. U. also from the synchronizing generator. With the aid of these control signals the F. P. U. converts the images from the projector into video signals which are then transferred from the output of the unit to the mixing and line equipment, and to the monitors, by coaxial cables. The background or d-c component is inserted at the transmitter for the purpose of controlling the background illumination at the receiver.

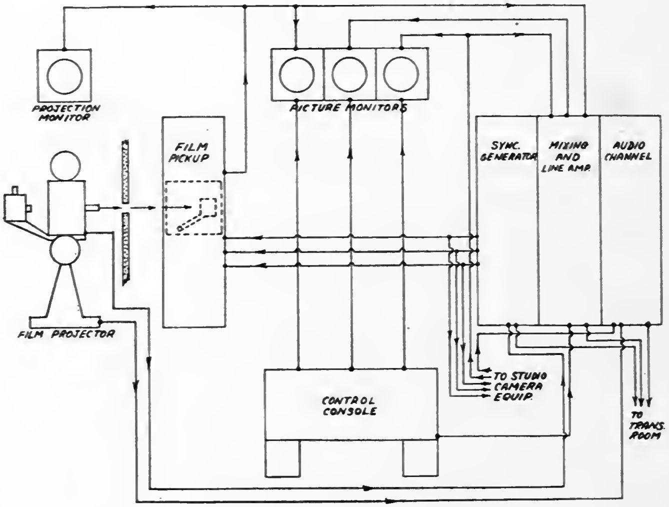

FIG. 1. Functional diagram of movie chain.

Positive timing of the scanning waves with the action of mechanical and optical components on the projector is accomplished by means of a timing pulse generated by means of a photocell pick-up on the projector which is used to control the synchronizing generator. This timing pulse is automatically switched into the synchronizing generator control circuit whenever the projector is in operation. Thus any suitable power-source having constant speed and meeting the requirements necessary for good sound reproduction may be used to drive the projector.

The audio from the projector sound-head is fed to the speech equipment where it is cut over to the sound-channel simultaneously with the switching of video signals from the corresponding F. P. U.

Fig. 2 shows a synchronizing signal generator which controls the scanning functions of the F. P. U. The various outputs of this unit are terminated in multiple connections, so that other equipment such as studio cameras, monitors, *etc.*, may be supplied from it as well.

Film Pick-Up Unit.—The many considerations involved in the choice of methods and apparatus for use in television motion picture film pick-up hinge upon the requirements the equipment must meet. Briefly these requirements are as follows:

(*1*) Produce the best possible television picture from ordinary commercial 35-mm film.

(*2*) Simplicity of operation as far as possible is desired because of the number of rather involved circuits.

(*3*) The apparatus should be arranged in some convenient constructional form as regards accessibility from an operation and service point of view.

(*4*) Flexibility of circuit performance so that future changes in standards, and consequent improvement in performance, can be adopted with a minimum of changes.

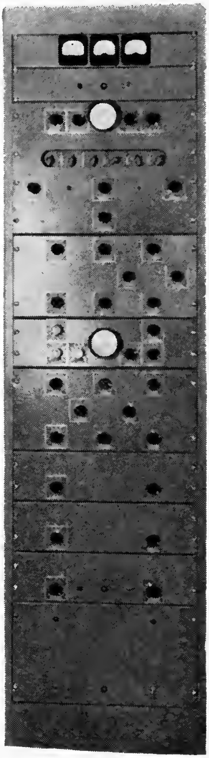

FIG. 2. Synchronizing generator.

Fig. 3 shows a Du Mont Type *504A* F. P. U., and Fig. 4 is a block diagram of the entire unit. Film is projected onto the iconoscope mosaic through an opening in the side of the cabinet. The sweep circuits located in the lower part of the rack furnish the scanning power for the iconoscope. The amplifier system consists of two units, the preamplifier, located in the iconoscope housing, and the output amplifier located immediately above.

Blanking pulses are supplied to the blanking amplifier, located within the iconoscope housing, from the synchronizing generator, and this amplifier in turn feeds the iconoscope grid. The chief purpose of this arrangement is to guard against flyback traces registering on the mosaic, and consequently appearing in the picture. The blanking circuit operating on the video amplifier is also supplied from this circuit. Correction of any "dark spot" signal generated by the iconoscope is accomplished by feeding a compensating signal to the amplifier from the shading panel, located just below the iconoscope panel.

The shading compensating voltage is made up of a mixture of wave-forms related to the horizontal and vertical sweep voltages. The controls on the panel provide for adjustment of amplitude and phase of each of the components of shading compensation, and also the amount of total shading signal.

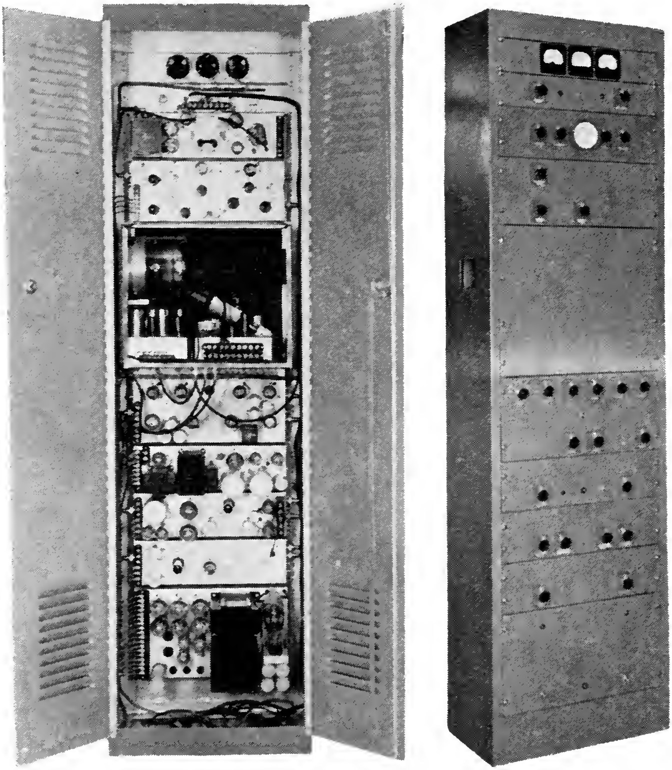

FIG. 3. Film pick-up unit.

A monitor oscillograph is included on the unit for the purpose of indicating the signal wave-form and amplitude. This monitor is useful also in adjusting the shading compensation.

Power for all units on the rack except the iconoscope and monitor oscillograph is obtained from the power-supply panel located at the bottom of the rack. The *B* supply from this panel is electronically regulated, and is metered for output current and voltage. The iconoscope power supply is also of the electronic regulator type, and has means for controlling the beam current and focus potential on the tube.

In order to prevent accidental burning of the iconoscope mosaic in the absence of proper sweep signals from the synchronizing generator or failure of the sweep amplifiers, protective circuits are incorporated to operate from the deflecting coils. Absence of the proper sweep current in either or both the horizontal and vertical deflecting coils automatically prevents the iconoscope beam from reaching the mosaic. Additional interlocking is provided on the power system, which prevents the power to the iconoscope from being applied until plate and filament voltages are applied to the sweep amplifiers.

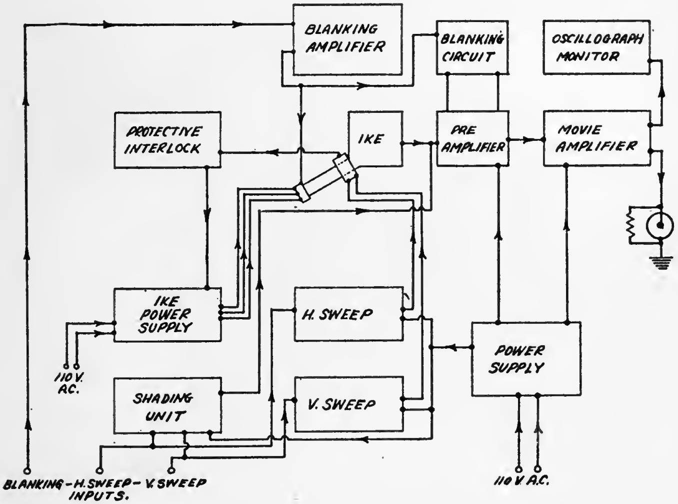

FIG. 4. Functional diagram of film pick-up unit.

In any television system there are several forms of distortion which act considerably to reduce the picture value of the final reproduced image. We are primarily concerned with those distortions which may occur in the F. P. U. Table I indicates the chief forms of distortion and their possible causes.

TABLE I

Distortions Likely to Occur in the Film Pick-Up Unit

Type Distortion	How Manifested	Possible Causes
Frequency	Loss of detail; streaking; fuzziness.	Inadequate frequency response in amplifier circuits.
Phase	Ghosts, blurred images, relief-effects.	Poor transient response; resonances within transmission band.
Contrast	Loss of contrast.	Iconoscope overload; amplifier overload; frequency response poor; improper background component transmission.
Space	Original geometric proportions not reproduced.	Non-linearity of either or both sweep circuits. Improper "Keystone" correction; aspect ratio improperly adjusted.
Background	Background distorted by uneven shading.	Poor shading correction. Extraneous pick-up by amplifier circuits of hum; sweep voltages, etc.; Improper light distribution caused by reflections or strays.
Noise	Fine and coarse "grain" effects.	Insufficient light input; low photoelectric sensitivity; abnormal tube noise; abnormal H.-F. response.

While distortions occurring in the video amplifier are important from the standpoint of detail and contrast, scanning distortions are equally important, and can cause serious, unpleasant effects. Thus it can be seen that the design of sweep-amplifier circuits must be treated with as much care as the video amplifier circuits in order to insure all around good television performance.

Video Amplifier.—The nominal transmission band for high-definition television pictures extends from about 20 cycles to 4 megacycles. The video chain in the film pick-up unit (F. P. U.) was extended slightly beyond this range in order to insure maximum transmission efficiency. The video amplifier chain is comprised of twelve stages in all, of which three are used as impedance transformers or "cathode followers," and operate at less than unity gain. The remaining tubes operate at relatively low values of stage gain in order to maintain stable operation and frequency response.

At low signal levels, the type *1852* tubes, which have exceedingly high transconductance, are employed. The use of such tubes makes it possible to employ degeneration as a means of improving the frequency-response without too great a sacrifice in stage gain.

Fig. 5 shows a typical video stage employing degeneration. This type of circuit is desirable because of the unloading effect of input capacity, that is, the grid circuit capacity, by virtue of the degeneration. This permits the use of a higher plate resistor in the preceding stage than if no degeneration were present.

Adjustable compensating inductors are used to equalize the response at high frequencies. The amplifier response is easily adjusted during test by means of the movable powdered-iron core inside the coil. Once set, these adjustments need not be disturbed, their sole purpose being to provide accurate compensation for circuit capacities once a stage is wired. With the above circuit, no difficulty is experienced in getting the desired response which extends from approximately 5 cycles to at least 5 megacycles with a reasonable gain factor.

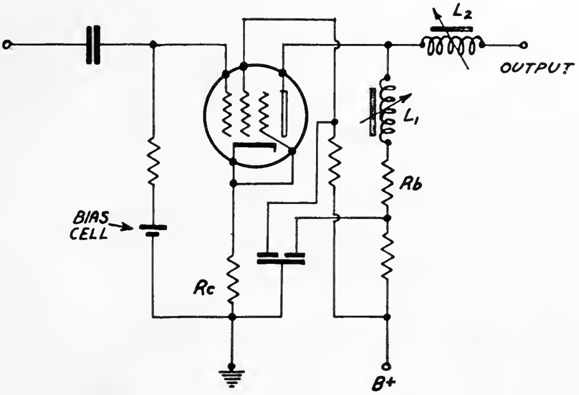

FIG. 5. Typical video stage.

The blanking circuit in the amplifier chain is of interest because of an arrangement that effects the blanking of the iconoscope signals during flyback periods of scanning without employing a saturation characteristic to limit the blanking signal. Blanking by means of a saturation-type limiter usually introduces non-linearity and consequently is likely to distort contrast.

The blanking signal consisting of a square-topped wave, whose duration is adjusted to cover the allowed flyback time, is inserted in the amplifier in sufficient amplitude so as to "swamp" the unwanted iconoscope signal during this period. However, this excessive signal would normally overload the succeeding stages in the system unless the amplitude were limited or reduced considerably.

By means of an electronic switch arrangement to complete an inverse feedback circuit, which is operated by the blanking signals, the amplifier is made highly degenerative during the blanking interval. Only during the blanking interval is the feedback circuit completed, so that unwanted signals from the iconoscope are suppressed during this time. Blanking for both horizontal and vertical flyback periods is accomplished by means of this circuit without purposely introducing distortion and loss of contrast.

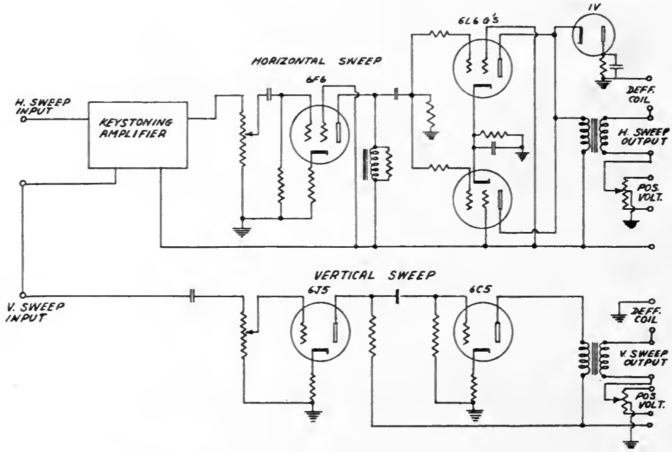

FIG. 6. Film pick-up sweep circuits.

A spurious signal of considerable amplitude is introduced by the pulsations of light from the projector shutter, which occur during the vertical blanking period when the picture-storage system of projection is used. In this case the degenerative type of blanking circuit requires a considerable amount of feedback, which is not always feasible. Correction for the shutter pulse may be accomplished by feeding in a neutralizing pulse ahead of the blanking circuit.

FIG. 7. Televised close-up; 441 lines.

FIG. 8. Televised long shot; 441 lines.

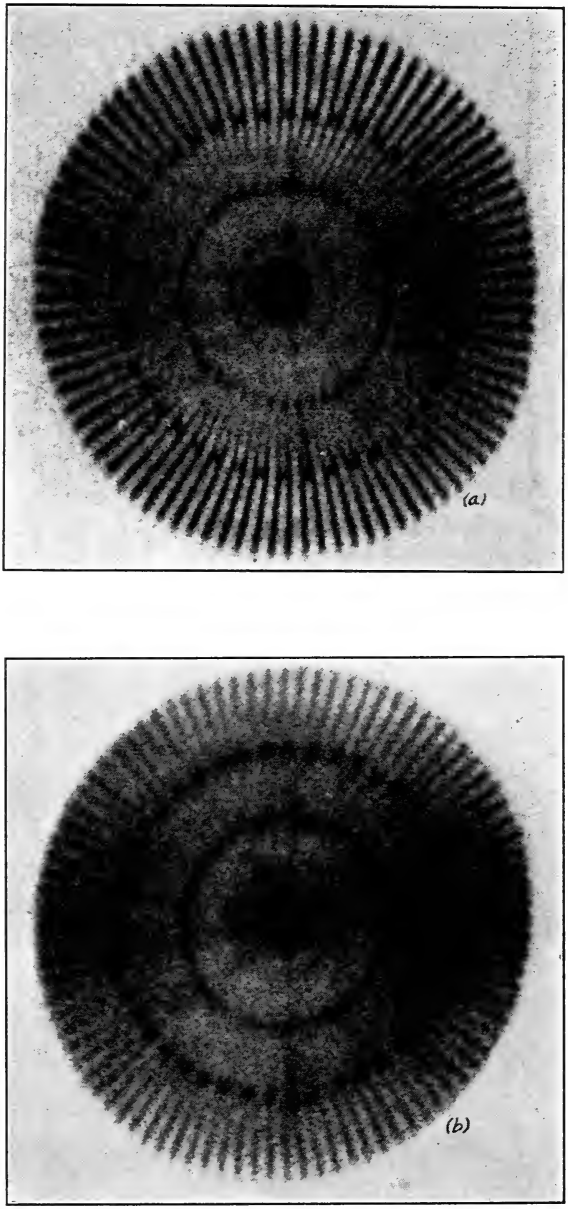

FIG. 9. Comparison between 441 and 625 line detail: (*a*) 625 lines, (*b*) 441 lines.

Sweep Circuits.—The sweep units in the F. P. U. are, for the most part, amplifiers having suitable output systems for properly scanning the iconoscope. Since the actual scanning wave-forms originate at the synchronizing generator these circuits do not require synchronization, and can be operated over a considerable range of scanning frequencies. Some correction is necessary for the output sweep waves, due to the slant of the iconoscope plate with respect to the beam axis. The keystone effect on the horizontal is compensated for in the input amplifier on the horizontal sweep panel.

A schematic diagram of both sweep circuits is shown in Fig. 6. Inverse feedback by means of cathode degeneration is employed in these circuits for the purpose of maintaining low distortion and thus preserving the applied wave-forms as nearly as possible. The application of sawtooth scanning waves to magnetic deflection circuits has been discussed elsewhere and need not be gone into further here.

From the above it can be seen that several worth-while aids toward obtaining better performance are closely related to improvements in radio and sound practice within the past few years. A television system of five years ago did not have the benefit of these improvements, and consequently was somewhat cumbersome and gave not too reliable performance.

Controls.—While adjustments to the amplifier and sweep panel controls may be necessary at regular intervals if only for the purpose of checking the previous adjustments, there is little occasion to manipulate these controls during operation. The same is true of the iconoscope potential controls in most cases. However, shading-panel adjustments are necessary from time to time in order to correct spurious background variations due to different lighting conditions on moving film. These adjustments are usually made at the F. P. U. shading-panel during the film transmission, but it is sometimes desirable to operate from a remote shading unit at the control desk.

High-Definition Performance.—Because of the flexibility of the amplifier type sweep circuits, no difficulty is experienced when scanning standards other than 441 lines, 60 fields interlaced are employed. The objectionable line-structure present when pictures of reasonable size are reproduced, together with the lack of sharpness and consequent loss of contrast in scenes having high-detail content originally, are faults that can be corrected only by increasing the number of picture elements transmitted.

The number of picture elements theoretically possible for television systems is shown below for corresponding numbers of scanning lines.

Scanning Lines	Approximate Pictures Elements
240	60,000
441	200,000
625	400,000
882	780,000

It does not appear likely, in view of the extreme band-width now employed, and in view of noise problems and other factors, that higher definition may be economically attained by a further increase in band-width at the present time.

Since the band-width of a television channel is proportional to the number of picture elements times the repetition rate, it follows that for a fixed band-width a reduction in repetition rate is necessary if more picture elements are to be transmitted. The present standards call for 60 half-pictures per second which when interlaced give 30 complete frames per second.

Reducing this repetition rate to half the above value, either by lowering the field-frequency rate, or by increasing the interlace ratio, we automatically double the number of picture elements that may be transmitted over a given channel. The number of elements transmitted per second remains practically constant, but as long as the rate of repetition is sufficiently high to stop motion, there is no difficulty here.

A problem of flicker is introduced, however, which no longer can be overcome by relying upon retentivity characteristic of the human eye. It is a well accepted fact that objectionable flicker can not be tolerated in a high-quality television image. Recent developments, however, have indicated promising results for a method of flicker elimination by means of a "remembering characteristic" at the receiver. This places the responsibility of flicker elimination upon the apparatus rather than upon the observer's vision-retentivity characteristics.

Pictures having approximately 300,000 elements have been produced experimentally by means of the above-described equipment. Objectionable flicker was not present in the received picture, although the total frequency-band employed was approximately 4 megacycles.

The definition of a 441-line television system is of sufficient quality to register good close-ups and other subject matter having a limited amount of detail. Fig. 7 shows a close-up from a newsreel shot which was televised at 441 lines. In Fig. 8 is shown a 441-line image of a subject having a considerable amount of detail.

A comparison between 441- and 625-line resolution is shown in Fig. 9 by means of a test-chart which indicates the resolution performance of the system beyond 400 lines. The enlargements shown are photographs of an area slightly larger than an inch in diameter on a television screen which has a total picture size of approximately 8 × 11 inches. Registration of the two outer circles of radial lines is considered sufficient for sharpness performances for small and medium-size screen projection. It is easily seen that horizontal resolution can be extended in a television system by means of improved amplifier response and scanning-spot size. Vertical resolution, however, depends upon the number of effective scanning lines in the system. Increased definition performance must then necessarily involve the use of more scanning lines.

The ultimate number of picture elements that can be transmitted depends to a great extent upon what progress can be made along the line of flicker elimination by means other than merely speeding up the scanning rate. Progress in this field will enable television systems to reproduce images comparing very favorably with the original pictures as recorded on 35-mm film.

In conclusion, the writer gratefully acknowledges the valuable efforts of the Transmission Equipment staff of his company, the extremely valuable assistance on projector developments by the technical staff of Paramount News under the direction of Mr. A. J. Richards, and the many helpful criticisms and suggestions of Mr. Allen B. Du Mont.

THE TIME TELESCOPE*

C. P. VEBER**

Summary.—*The "time telescope" or combination time-lapse and photoelectric exposure control machine speeds up imperceptible motion. The variable-exposure control with exposure modulator gives either a gradual change in density, or equal average frame densities regardless of spectral or intensity changes in subject lighting. It corrects for failure of film to follow the reciprocity law. Photoelectrically regulated, it automatically exposes the subject properly regardless of changes in color, area, and average light intensity during or between exposures. Long periods of time between exposures make possible the use of a small fixed diaphragm (f/256).*

The "time telescope" or combination time-lapse machine and photoelectric exposure control is an instrument for "boiling down" normally imperceptible actions and changes occurring over very long periods of time, so that, for instance, the growth of a plant, or the erosion and gradual disintegration of a road or bridge may be speeded up enormously. It is a scientific instrument, in the same class as the telescope or microscope, except that it magnifies time, instead of dimensions. It is the opposite of the "time-microscope," a machine that slows down extremely fast motion, which was developed by Edgerton, Germeshausen, and Grier, of the Massachusetts Institute of Technology. The "time telescope," has been in course of development for the past five years at Rutgers University.

It is a robot-like machine (Fig. 1) used to control a motion picture camera, so that the individual frames or pictures comprising the strip of finished film, are taken one by one with fairly long intervals of time, or "time-lapse periods," between them. When these pictures are projected one by one at the usual speed to produce the illusion of motion, 16 pictures per second, or 24 for sound-track film, enormous time magnification is obtained. For instance, a time-lapse period of 20 minutes between exposures will give a time magnification of 24,000 when the series of pictures is projected at the rate of 20

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 10, 1939.

** Department of Biophotography, Rutgers University, New Brunswick, N. J.

every second. Besides timing the interval between exposures, the instrument times the exposure period of each frame, photoelectrically if desired, so that at the proper instant the camera shutter is opened, and after the correct amount of light has been permitted to fall on the film, the shutter is automatically closed again. For instance, a single frame exposed at high noon might require an exposure of one-half second, in which case the shutter automatically stays open for exactly one-half second. Another frame of the same picture series might, at night, under artificial light, require an exposure of two minutes, and the shutter opening and closing is regulated accordingly. Thus the exposure times will continually change according to the amount of light falling on the subject during each exposure period. Thus the camera is controlled by the "variable-exposure" method. This control is photoelectrically automatic and requires no supervision. Each frame or selected portion thereof is made to have the same average density as all other frames in a long sequence, so that a steady and flickerless image will be produced on the screen. Or, by means of the exposure modulator control, successive frames may gradually change in average density, so that the image when projected may become gradually lighter or darker, to produce the

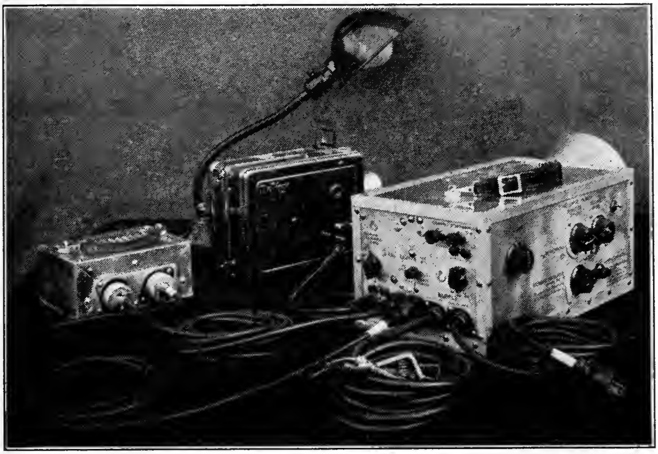

FIG. 1. Apparatus for time-lapse studies, including heavy-duty relay for unusually heavy lighting requirements.

effect of approaching night or dawn, or of a cloud passing over the sun.

The control mechanism automatically exposes the subject properly, regardless of changes in color, area, and average light intensity during or between exposures. Long periods of time between exposures make possible the use of a small fixed diaphragm (*f*/256.0), one advantage of the photoelectrically controlled exposure time. A variable diaphragm is not adaptable here due to the exposure range and the changing depth of field. Neutral density and filter wedges cause duplication and complication; for instance, a shutter and film control are necessary in any case.

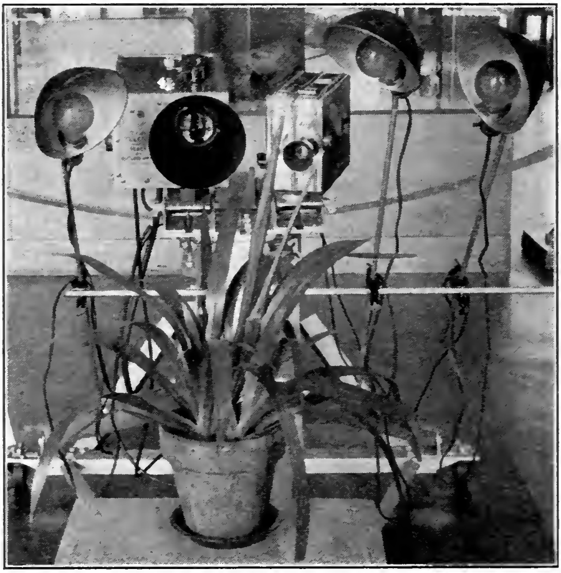

FIG. 2. Time-lapse set-up, including the time telescope, camera, lights mounted on dolly, plant subject in foreground, as exhibited at the Newark (N. J.) Museum.

Aside from its first and, at the present time, main use—making time-lapse motion pictures of flowers and growing plants—the instrument can be used for many purposes (Fig. 2). It is being used to speed up and record various biological phenomena, such as the migration of pigment in the chromatophores of animals, and other growth processes. It may be used to record in perceptible motion the slow flow of plastic solids, or the erosion and disintegration of roads, bridges, earth features, and structural materials. Rotting and spoilage of food, mixing of contiguous surfaces of solids, effects of temperature and humidity changes, rusting, wear and pitting, corrosion, studies of crystal formation, studies of efflorescent and deliquescent chemicals.

In its most elementary form, as described in *Photo-Technique* (July, 1939), the principle of operation of the time telescope depends upon the charging and discharging of an electric circuit containing a condenser and resistor. This circuit, in turn, ionizes a gaseous discharge lamp, such as a neon bulb, which actuates the desired control elements. The charging and discharging rates of these circuits determine the operating times for the control of the photographic equipment. While the complete diagram is highly complicated, it may be broken down into simple elements for purposes of explaining the underlying mode of operation. Essentially, the fundamental circuit consists of two parts: (*1*) the time-lapse circuit, which controls the interval between exposures; and (*2*) the exposure circuit, which controls the duration of the exposure as a function of the intensity and quality of the light.

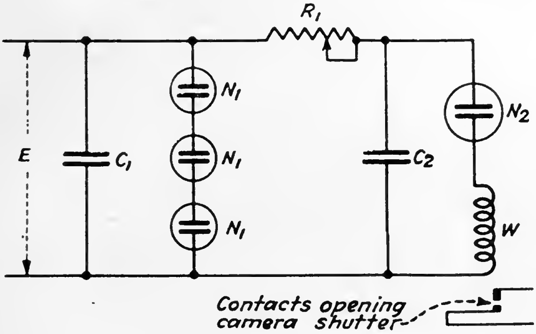

FIG. 3. Schematic arrangement for determining time-lapse period. (*Courtesy Photo-Technique.*)

The time-lapse circuit is shown in its most elementary form in Fig. 3. A voltage E charges the condenser C_1 to a voltage determined by the neon voltage-regulating tubes N_1. The circuit is so arranged that the source of voltage is removed as soon as C_1 becomes fully charged. The condenser C_1 now discharges through the resistor R_1 and the condenser C_2, building up a voltage across the latter. The rate at which the voltage across C_2 builds up depends upon the resistance R_1 and the capacitance of the condenser C_2. When the voltage across C_2 reaches a critical value, the neon tube N_2 ionizes, and in the conducting state, permits a pulse of current to flow through the relay winding W_1 recharging C_1, thus starting a new time-lapse cycle and actuating the contacts that open the shutter of the camera, thereby initiating the exposure.

Just before the shutter is opened, another relay (not shown) allows the condenser C_3 to charge (at the same time C_1 is charged) in the exposure-time circuit (Fig. 4). The charge on C_3 discharges through the phototube P into the condenser C_4, and when the voltage across N_4 reaches the breakdown value this neon tube becomes suddenly conducting, triggers off N_3, and permits a pulse of current from C_3 to flow through the relay winding W_2, actuating the contacts that close the shutter of the camera. During and after the exposure period, condenser C_2 of the time-lapse circuit is being charged, and as soon as it reaches the breakdown potential of N_2 the cycle is repeated. The exposure time depends upon the resistance of the phototube P, and this in turn depends upon the light falling upon it. Consequently, the light falling upon the subject, which is focused on the phototube P by means of the optical system of the time telescope, thus controls the exposure time. The relays W_1 and W_2 can also be made to control the lamps used for artificial illumination if desired.

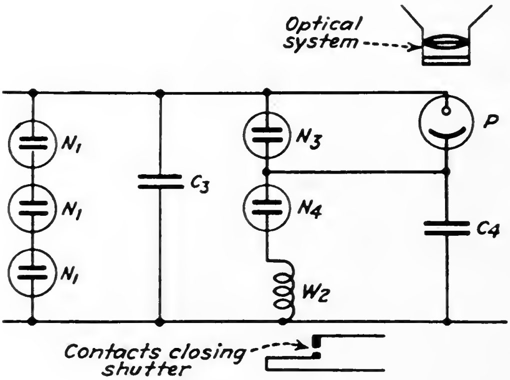

FIG. 4. Schematic arrangement for determining time of exposure. (*Courtesy Photo-Technique.*)

NEW MOTION PICTURE APPARATUS

During the Conventions of the Society, symposiums on new motion picture apparatus 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 NEW CLASSROOM 16-MM SOUND PROJECTOR*

A. SHAPIRO**

The new Ampro classroom 16-mm sound projector has been designed to meet the following requirements:

(*1*) *Light in Weight and Easy to Set Up.*—This is important because it is not practicable to keep the projector always set up for use in the classroom and if the instrument is not easy to handle and use, the teacher will be reluctant to operate it.

(*2*) *Simple in Operation.*—It must be sufficiently easy to operate so that teachers and pupils will have no difficulty in using it properly.

(*3*) *Quietness of Operation.*—Noise in the classroom is distracting and makes intelligibility of sound difficult. While a blimp will help to reduce this noise, it involves enclosing the machine and thereby making the component parts less accessible.

(*4*) *Natural Sound Free from Distortion.*—Poor sound will cancel the good effects produced by the picture and make it difficult for the pupils to concentrate.

(*5*) *Brilliant Illumination.*—At best, showing pictures in a classroom where perfect darkness is rarely obtained requires maximum illumination.

The new projector, in a single carrying case $19^1/_2$ inches long, $10^1/_2$ inches wide, and $15^1/_2$ high, has a total weight of 49 pounds, including speaker, cords, and 1600-ft take-up reel. To set up, the projector is placed either on a table or on the upturned bottom half of the carrying case, the reel arms are swiveled into position and connections made to speaker and line current (Fig. 1).

Operating controls are all centered on an illuminated panel. This panel contains starting and stopping switch, lamp switch, volume and tone control and hiss eliminator. The latter is designed to compensate for low line voltages so that full volume can be obtained at all times, within a line voltage range of 100 to 125 volts.

Threading is simplified by using only two sprockets (Fig. 2), the film being threaded in a straight line without film cross-overs. All metal parts in contact with the film are relieved for sound-track and picture areas in order to avoid any pos-

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* Presented at the 1939 Spring Meeting at Hollywood, Calif.; received April 19, 1939.

** The Ampro Corp., Chicago, Ill.

sibility of scratching. Tension on the film is applied by pressure on its edge and also on that side of the film where the sprocket-holes are located. Thus the line of force of the pull-down movement is coaxial with the film tension, thereby providing steady movement and avoiding excessive strain on the film.

One of the most troublesome details in threading a sound projector is the necessity of insuring an exact spacing of twenty-five frames between the aperture and the scanning beam of the corresponding sound-track. This difficulty is due to the fact that the lower loop of necessity varies in size (Fig. 3). To avoid this an automatic loop-former has been developed. After threading through the aperture, the film is kept taut before being threaded around the sound-head and then to the take-up sprocket. The automatic lower-loop-former is then released, forming a lower loop of fixed size. In this way there are always exactly twenty-five frames between the aperture and the scanning beam of the corresponding sound-track.

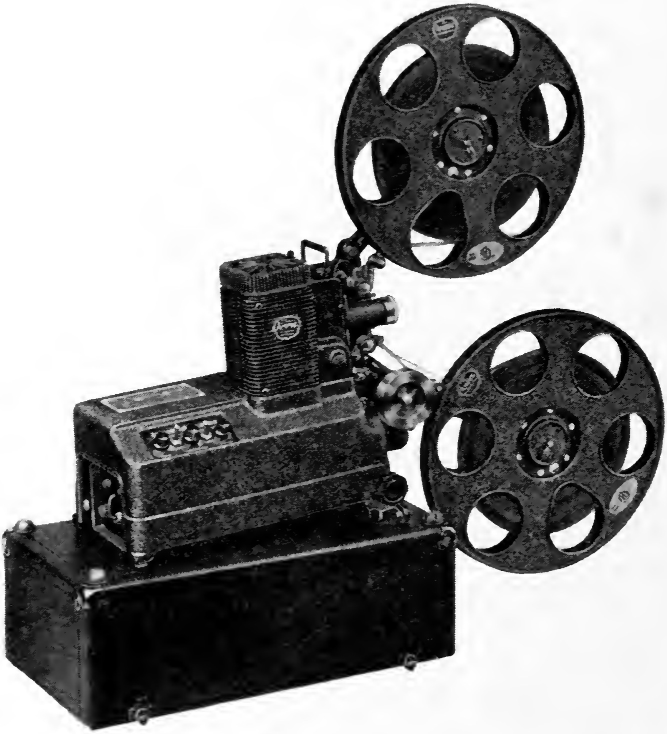

FIG. 1. Projector set up for use, mounted on upturned lower half of carrying case.

Quietness has been achieved by developing a pull-down mechanism having a cam operating at 1440 rpm, as compared with speeds of 2880 and 4320 rpm found in other projectors. The design of this cam is such that an $8^1/_2$:1 ratio is obtained between the period during which the film is stationary and that during which it is moving. This results in high light efficiency comparable to that obtained in projectors operating at much higher speeds. Another factor in obtaining quietness is the development of a ventilating fan delivering a large volume of air at a low velocity. By reducing the speed of the mechanism and also the air noises, the operation of the new model is extremely quiet. In fact, without a blimp this machine is quieter than previous models enclosed in blimps.

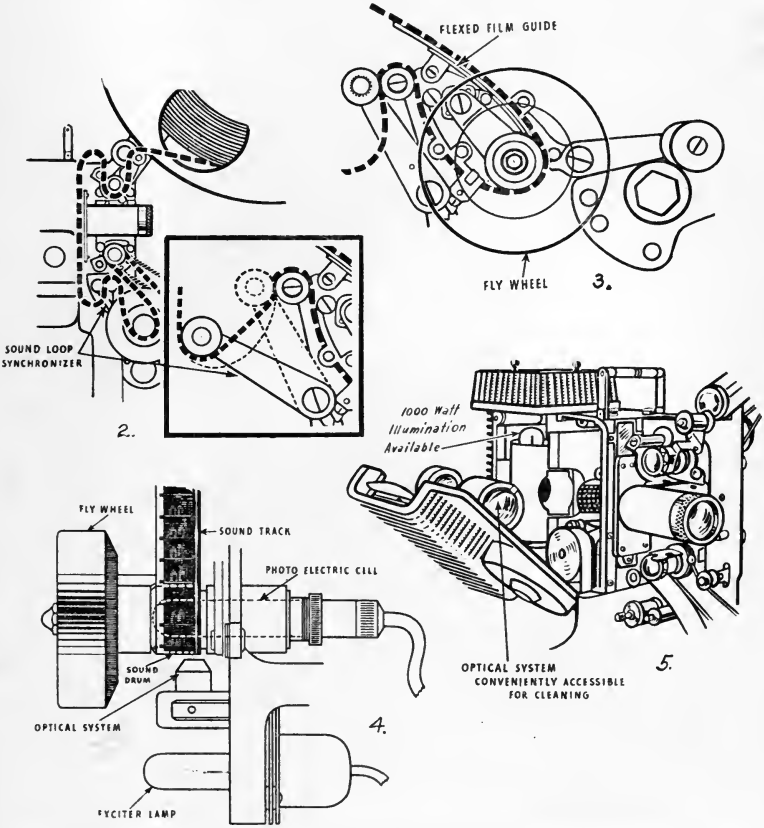

FIG. 2. Showing simplified threading through aperture gate and sound-head.
FIG. 3. Close-up of film path through sound-head.
FIG. 4. Arrangement of sound system.
FIG. 5. Showing optical system mounted in front cover to facilitate cleaning reflector and condenser lenses.

High-quality sound depends to a great extent upon uniform and steady movement of the film while it is passing by the scanning-beam. Ordinarily, this is accomplished by means of a flywheel and an electrical governor to compensate for variations in line voltage. This new model, however, uses a special shaded-pole motor which, for uniformity of motion, surpasses the electrically controlled governor. This is in addition to an accurately balanced flywheel mounted on aeroplane type grease-sealed ball-bearings. The bearings lie between the flywheel and the revolving sound-drum. In this way a balance is maintained, giving excellent dampening action (Fig. 4).

A prefocused exciter lamp is used, which can be instantly interchanged without adjustment (Fig. 5). The path of light from the exciter lamp to the photocell is direct without the use of a reflecting mirror. The sound-head is removable from the projector as a single unit in order to facilitate servicing. The film is guided to and from the rotating sound-drum by curved film-guides, which, by their convex forms, flex the film in constant arcs so as to void lateral vibrations that would impair sound quality.

The amplifier is a class *A* type designed to be used with metal tubes. Four tubes are used. The power output tube is a *6L6;* the driver tube *6N7;* the voltage amplifier *6J7;* the rectifier tube *5W4.* The output obtained is $7^1/_2$ watts with a total harmonic distortion of less than 5 per cent.

The projector is supplied with a standard 750-watt medium base prefocused projection lamp. However, ventilation is sufficient to take care of a 1000-watt lamp. Standard lamp sockets are used so that no special lamps are required.

The loud speaker is contained in the upper half of the carrying case and consists of an 8-inch permanent-magnet dynamic speaker of high-fidelity type. Fifty feet of rubber-covered speaker cable with telephone jacks for easy connection to the amplifier and speaker are provided. Extensions can be added if desired. There is provision for plugging in either a microphone or a phonograph.

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.

American Cinematographer	
20 (Oct., 1939), No. 10	
Cinecolor Makes Contribution to Color (p. 443)	W. T. Crespinel
British Journal of Photography	
86 (Sept. 1, 1939), No. 4139	
Progress in Colour (pp. 552–553)	
86 (Sept. 8, 1939), No. 4140	
Progress in Colour (p. 563)	
Communications	
19 (Sept., 1939), No. 9	
Fundamentals of Television Engineering. Pt. VI: Synchronization (pp. 19–21)	F. A. Everest
Electronics	
12 (Sept., 1939), No. 9	
The Time Telescope (pp. 24–27)	B. Dudley
International Photographer	
11 (Sept., 1939), No. 8	
Studio Grip Equipment (pp. 8–10)	G. M. Haines
Kinotechnik	
21 (Aug., 1939), No. 8	
Berechnung der Neigung des Zuschauerraums eines Kinotheaters für ungehinderte Sicht. (Calculation of a Method for Lowering a Motion Picture Auditorium for Clear Vision) (pp. 195–196)	H. Frieser and H. Scharffenberg
Internationale Normalisierung der Bildwandausleuchtung (International Standardization of Screen Illumination) (pp. 196–199)	H. Joachim
Algemeine Diskussion (General Discussion) (pp. 199–200)	

Bericht über die Behandlung der Frage der Bildwandleuchtdichte von Kinotheatern auf der Tagung der Internationalen Beleuchtungs-Kommission—Scheveningen 1939 (Report on the Question of Motion Picture Screen Illumination at the Meeting of the International Illumination Commission, Scheveningen, 1939) (pp. 200–201) O. Reeb

Tafeln zur Geschichte der Kinematographie (Historical Pictures of Various Types of Film) (pp. 201–207)

Zur Geschichte der Kinematographie (History of Motion Picture Theatres) (pp. 208–209) R. Thun

Zur Sensitometrie der Umkehrentwicklung von Tonaufzeichnungen (Sensitometry of Reversal Development of Sound Recording) (pp. 209–215) R. Gorisch

Ein Neuer Projektor für Diapositive der Fa. Bauer (F. Bauer's New Lantern Slide Projector) (p. 215)

Bericht über das deutsche Metallfilmverfahren (Report on German Metal Film) (p. 221)

Photographische Industrie

37 (Sept. 6, 1939), No. 36

Vergleichende Messungen des Oberflachenwiderstandes von Filmen gegen mechanische Beschadigungen (Comparative Measurements of the Surface Resistance of Films to Mechanical Injury) (pp. 1001–1002)

Photographische Industrie

37 (Aug. 23, 1939), No. 34

Tonaufzeichnung mit Schwingkristallen (Sound Recording by Means of Vibrating Crystals) (pp. 957–959)

SOCIETY ANNOUNCEMENTS

AMENDMENTS TO THE BY-LAWS

At the meeting of the Board of Governors held on July 13th, a new By-Law consisting of three sections pertaining to the appointment and terms of committees, and a new form of By-Law VI, relating to elections, were proposed and approved. These were published in the September, 1939, issue of the JOURNAL on pages 347 to 349.

The new proposed By-Law and the amended By-Law VI were submitted to the Society in meeting on October 16th, the first day of the 1939 Fall Convention, were approved as published, and are therefore now in effect

At the meeting of the Board of Governors held on October 15th, proposed new paragraphs *c* and *d* of Section 3 of By-Law I, relating to "Membership" were approved as follows:

(*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 unanimous approval of the entire membership of the appropriate* Admissions Committee. In the event of a single dissenting vote or failure of any member of the Admissions Committee to vote, the application shall be referred to the Board of Governors in which case approval of at least three-fourths of the Board of Governors shall be required.*

(*d*) *Applicants for Associate membership shall give as reference at least one member of higher grade in good standing. Applicants shall be elected to membership by approval of a majority of the proper Admissions Committee."*

In addition, new Sections *4* and *5* were proposed for the new By-Law on "Committees" (Sections *1, 2,* and *3* of which have already been approved as described above). The newly proposed Sections *4* and *5* are as follows:

Sec. 4.—Standing committees of the Society shall be as follows, to be appointed as designated:

(*a*) *Appointed by the President and confirmed by the Board of Governors:*
- *Progress Award Committee*
- *Honorary Membership Committee*
- *Journal Award Committee*
- *Admission Committees**
  - (*Atlantic Coast and Midwest Sections*)
  - (*Pacific Coast Section*)
- *European Advisory Committee*

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* See proposed Sec. 5 *infra.*

(b) Appointed by the Engineering Vice-President:
Sound Committee
Standards Committee
Studio Lighting Committee
Color Committee
Theater Engineering Committee
Exchange Practice Committee
Non-Theatrical Equipment Committee

(c) Appointed by the Editorial Vice-President:
Board of Editors
Papers Committee
Progress Committee
Historical Committee
Museum Committee

(d) Appointed by Convention Vice-President:
Publicity Committee
Convention Arrangements Committee
Apparatus Exhibit Committee

(e) Appointed by Financial Vice-President:
Membership and Subscription Committee

Sec. 5.—Two Admissions Committees, one for the Atlantic Coast and Midwest Sections, and one for the Pacific Coast Section, shall be appointed. The former Committee shall consist of a Chairman and six Fellow or Active members of the Society of which four shall be members of the Board of Governors. The latter Committee shall consist of a Chairman and four Fellow or Active members of the Society including all officers or members of the Board of Governors of the Society residing in the Pacific Coast Section."

All the amendments given above were approved by the Society in meeting on October 16th, the first day of the 1939 Fall Convention.

46th SEMI-ANNUAL CONVENTION

CHALFONTE-HADDEN HALL, ATLANTIC CITY, N. J., APRIL 22nd TO 25th, INCL.

At the meeting of the Board of Governors, held at New York on October 15th, Atlantic City was selected as the site of the 46th Semi-Annual Convention of the Society, to be held April 22nd to 25th, inclusive. Tentative arrangements are being prepared by W. C. Kunzmann, *Convention Vice-President;* and the Papers Committee, under the direction of J. I. Crabtree, *Editorial Vice-President,* and S. Harris, *Chairman* of the Committee, will begin its work of preparing the papers program shortly.

Members are urged to keep the dates of the Convention in mind, and those who contemplate preparing papers for the meeting are requested to communicate with the office of the Society as early as possible.

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