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The Society of Motion Picture Engineers

Its Aims and Accomplishments

The Society was founded in 1916, its purpose as expressed in its constitution being the "advancement in the theory and practice of motion picture engineering and the allied arts and sciences, the standardization of the mechanisms and practices employed therein, and the maintenance of a high professional standing among its members."

The membership of the Society is composed of the technical experts in the various research laboratories and other engineering branches of the industry, executives in the manufacturing, producing, and exhibiting branches, studio and laboratory technicians, cinematographers, projectionists, and others interested in or connected with the motion picture field.

The Society holds two conventions a year, spring and fall, at various places and generally lasting four days. At these meetings papers dealing with all phases of the industry—theoretical, technical, and practical—are presented and discussed and equipment and methods are often demonstrated. A wide range of subjects is covered, many of the authors being the highest authorities in their particular lines of endeavor. Reports of the technical committees are presented and published semi-annually. On occasion, special developments, such as the S. M. P. E. Standard Visual and Sound Test Reels, designed for the general improvement of the motion picture art, are placed at the disposal of the membership and the industry.

Papers presented at conventions, together with contributed articles, translations and reprints, abstracts and abridgments, and other material of interest to the motion picture engineer are published monthly in the JOURNAL of the Society. The publications of the Society constitute the most complete existing technical library of the motion picture industry.

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MOTION PICTURE ENGINEERS

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SYLVAN HARRIS, EDITOR

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PROGRESS IN THE MOTION PICTURE INDUSTRY

REPORT OF THE PROGRESS COMMITTEE*

Summary.—*This report of the Progress Committee covers the year 1934. The advances in the cinematographic art are classified as follows:*

(I) Cinematography; (II) Sound Recording; (III) Sound and Picture Reproduction; (IV) Film Laboratory Practice; (V) Application of Motion Pictures; (VI) Publications and New Books; Appendix A—General Field of Progress of the Motion Picture Industry in Great Britain; Appendix B—General Field of Progress of the Motion Picture Industry in Japan.

INTRODUCTION

When the Committee undertook its annual task of preparing the Progress Report for 1934, it looked at first as though there might be a considerable dearth of new material. However, when the Committee settled down to active work, the prospects for a good report seemed brighter than at any time during the past three years, and when the contributions from the individual members of the Committee were assembled into the following general report, many new items of interest and of progress were seen to have come into evidence during the past year.

It is true that there were no very outstanding achievements in the cinematographic art during 1934, but there was much consistent progress in improvements of equipment and technics of operation. It is of interest to note, for example, that transparency background work nearly attained perfection during the past year. In the field of studio illumination the use of a new mercury arc is reported to have great possibilities. Considerable progress is reported in the use of camera accessories to facilitate the photography of difficult shots, thereby adding more realism to the scene.

The use of color in motion pictures continued to receive considerable emphasis during the past year, some very popular cartoons and two-reel variety subjects having been made exclusively in color. In the field of sub-standard films considerable progress has been noted in recording and reproducing sound, but ultimate progress in this

* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

field is hampered by the inherent difficulties of securing a sufficiently wide frequency range. A great many new substandard projectors were announced during the year.

In the field of sound recording, progress in the United States was almost at a standstill during the year while the battle over the validity of the Tri-Ergon patents was raging in the courts. In spite of this, however, considerable progress is reported in the gradual extension of wide-range and high-fidelity recording in the theaters of the country. Audiences appear to be becoming more sound-conscious, and the reaction of the public to the excellent recording in Columbia's *One Night of Love* augurs well for high-grade productions of this type in the future.

In the field of sound reproduction, the successful introduction of all a-c. operated theater equipment during the past year seems to offer the possibility of improved and simplified equipment at a considerable saving to the exhibitor. Of interest, also, to the exhibitor is the introduction of copper oxide three-phase full-wave rectifiers for supplying power for projector arcs in theater booths. In the field of film laboratory practice there is little progress to report during the past year, and the same is true in the field of application of motion pictures.

The committee is happy to be able to include a very excellent report on progress in the motion picture industry in Great Britain, as outlined in *Appendix A*. The very substantial progress of the motion picture industry in Great Britain is entirely consistent with the remarkable success of British-made pictures in the United States and other countries during the past year. A separate report listed in *Appendix B* covers progress of the motion picture industry in Japan.

The committee wishes to thank the following firms for supplying photographs for use in the report: Paramount Productions, Inc., W. C. Hollins Electric & Engineering Co., Eastman Kodak Co., Bell & Howell Co., RCA Manufacturing Co., Bell Telephone Laboratories, Inc., and Electrical Research Products, Inc.

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SUBJECT CLASSIFICATION

(I) CINEMATOGRAPHY

(*A*) *Professional*

(*1*) *General.*—Strictly speaking, there were no outstanding developments in cinematography in 1934, but a general forward movement in several phases of photographic work indicates a widespread interest that presages marked advancement in the near future.

Perhaps the most needed piece of equipment in the industry is a silent camera. The leading camera manufacturers are working hard, but are not yet able to supply the industry with a camera that fulfills the sound and weight requirements of the studios. The Silent Camera Committee of the Academy of Motion Picture Arts and Sciences has been gathering material and data that should prove helpful when properly catalogued and made available to those interested.

In the meantime each studio has been working industriously toward further perfecting their "blimps" by making them quieter and of lighter weight. Some of the "blimps" are sufficiently quiet to meet the most stringent demands of the sound departments, but the weight has been reduced comparatively little, leaving a real need for a one-man unit.

The operation of the "blimps" has been simplified greatly by adding follow-focus and parallax-correcting finders, electrical synchronizers, more accessible matte and diffuser accessories, and better free-heads. Such improved blimps may be operated as quickly as the old silent cameras, with the one exception of changing set-ups, requiring additional man-power.

Projection printers have grown from two old Bell & Howell cameras on a discarded lathe bed into a complicated mechanism that will do unbelievable things to a negative after the cameraman has turned it into the laboratory—it has become the Aladdin's Lamp of the cameraman's wildest dreams. Zoom lenses have made great advances during the past year and, although not yet perfected, a zoom lens can be expected in the near future that will operate at an $f/2.3$ speed from a 35-mm. angle to a 150-mm. angle, making possible a single lens doing the work of at least six lenses of the present type.

Projection or transparency background work has nearly attained perfection during the year. The hot spot, though it still exists, has become a minor difficulty; perfect synchronization and matched lighting have blended composites into a much more beautiful whole than was ever before possible. Improved technic has widened the scope of transparency projection until "location trips" have become one-man jobs, the cast restricting their trips to the studio stage, a large piece of ground glass furnishing the requisite locale of desert, mountains, or foreign countries. Excellent examples of this work are shown on Figs. 1 and 2.

Lighting equipment is being improved in the incandescent field by designing the reflectors so that, instead of following parabolic or mathematically known curves, they describe unrelated curvatures. By this means the shadow of the filament or "ghost," is eliminated and the outer field of illumination is blended until it loses its defining circle of light, thus simplifying group lighting.

There seems to be a renewed activity in stereoscopic research, but nothing really commendable has come to the attention of the Committee.

Considerable agitation has developed relative to a change of film speed from 24 to 20 frames per second, the object being to effect a

FIG. 1. Projection background shot (from *The Menace*, a Paramount production).

large saving in the cost of film. Its proponents claim that neither sound nor picture will suffer by such a change, but that production costs will be lessened by at least half a million dollars a year. The burden of argument against such a change lies largely with the sound departments. Photographically, nearly every picture released has speed changes varying from extremely low speeds to speeds several times the normal, without infringing upon the laws of persistence of vision.

Colored glass of known filter values has been substituted for clear glass in several large combination exterior-interior sets with excellent results, enabling the cinematographer to "shoot" from an interior to an exterior without "burning up" the exterior scene. This is not new in principle, but cheap glass may now be obtained, so that its use becomes practical.

(2) *Films and Emulsions.*—The high standard of emulsion sensitivity, freedom from halation, and the wide range of color sensitiveness established several years ago for panchromatic films for general use have been maintained during the past year. New materials have been limited chiefly to those designed for special processes. A fine-grain panchromatic film known as Background Superpan was added to the list of materials used for projection background pho-

FIG. 2. Projection background shot (from *Mississippi*, a Paramount production).

tography. Other new emulsions included a high-contrast film for making travelling mattes for special process photography, a medium-contrast fine-grain duplicating negative film, and two fine-grain high-contrast sheet films for commercial photography. Improved emulsions sensitized to the infrared were also announced. The characteristics of Agfa Superpan negative motion picture film were discussed in a paper by Arnold.[1]

A rather novel emulsion for making direct duplicates by direct printing was described by Koch.[2] Exposures varying from 4 seconds to 6 minutes, using a 40-watt bulb at 25 cm. were found necessary because of the low sensitivity of the emulsion. Schweitzer[3] reported that this film was slightly fogged in manufacture, the latent image being destroyed upon exposure to light. Many articles were published during the year in the German technical journals dealing with fine-grain development. One of the many articles dealing with this problem is that by A. von Barsy,[4] who states that in practice the fine-grain development has proved to be of value, whereas Luppo-Cramer[5] expresses the opinion that, if the developer is sufficiently diluted and the development time correspondingly increased, any formula can be used for the fine-grain development.

Of especially great interest are those articles[6] that deal with new methods for determining the graininess of photographicfi lm. I. Eggert and W. Küster of the I. G. Farbenindustrie propose to determine the graininess by means of the Callier effect, and their proposal caused A. Narath of the Klangfilm Laboratory to investigate this method.[7, 8]

A comprehensive group of papers[9,10] by several Russian scientists dealing with various aspects of emulsion manufacture were published by the Kino-Photo Institute of Moscow and the Photo-Kino Industry. The subjects discussed included optical sensitizing, emulsions without ammonia, aging of emulsions, ripening, effect of washing upon light sensitivity, *etc.*

An investigation[11] was initiated by Sheppard, Wightman, and Quirk upon the temperature coefficient of photographic sensitivity. Among other results, it was found that the optical sensitizing effect produced by dyes persisted at −190°C. but was affected in much the same degree as the blue-violet sensitivity of the less sensitive grains. Webb[12] reported on the effect of temperature upon the reciprocity law failure in photographic exposure and stated that at very low intensities, such as are occasionally used in astronomical research, speeds of certain emulsions can be increased several-fold by lowering the temperature.

The photographic activity of gelatin was shown by Rabinovitch and Titoff[13] to be proportional to its content of labile sulfur as determined by the method of Sheppard and Hudson. Bekunoff[14] reported that hydrolysis of gelatin had very little effect upon the photographic qualities of emulsions made from it.

The output of raw motion picture films in Russia was increased considerably in 1934 over 1933, as part of the expansion program of the second five-year plan.[15] During the year, the first plant for manufacturing film was established in Denmark.[16]

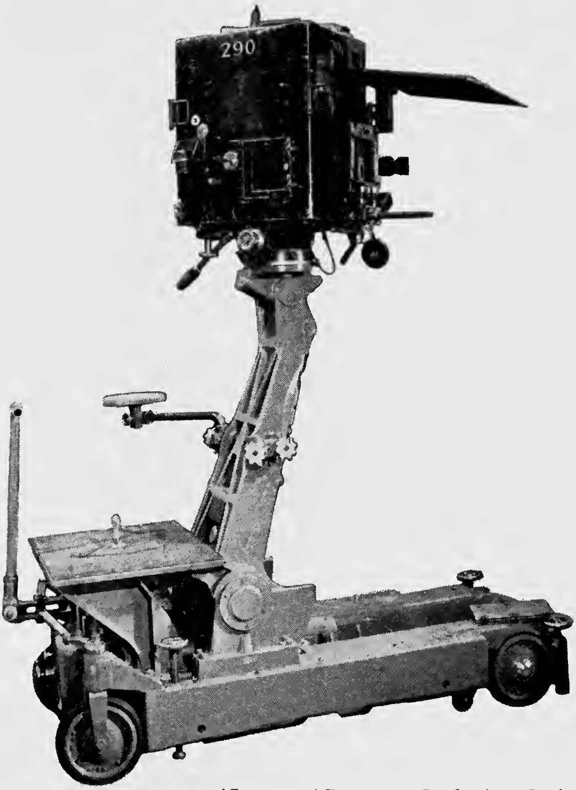
Patent protection was granted [17] on several additional schemes for introducing anti-halation layers in films. Pederson[18] patented a method of reënforcing the perforation area of motion picture film which consists in attaching armored strips having sprocket holes spaced by the same distance as the film perforations.

(3) *Cameras and Accessories.*—The year 1934 saw little in the way of new professional camera equipment. Any advances could be considered only as modifications of previous designs, rather than as new departures in design or technic of operation. From England, W. Vinten, Ltd., announced the adaptation of a 40-inch Dallmeyer lens to a Vinten Model *H* camera, 1000-ft. magazines and motor. The lens is mounted upon a special platform which also carries the camera, and the whole is carried upon a gyroscopic tripod. This camera has been extensively used in newsreel work.

A new departure in blimp construction is described in *American Cinematographer.*[19] It consists essentially of a silenced Mitchell Camera rebuilt as an integral part of a light sound-proof housing. All controls and meters are operated or are visible from outside the case, which needs to be opened only for loading. A single lens, rather than a turret, is utilized. The weight of the outfit is stated to be 116 pounds when loaded and ready for use. Bell & Howell have announced[20] that their portable 35-mm. Eyemo Camera has been adapted so as to be used interchangeably for regular motion picture work or for taking single exposures at set intervals for aerial mapping work.

Paramount Productions, Inc., have designed the tripod perambulator illustrated in Fig. 3. It is elevated electrically to a height of eight feet from the floor, controlled by a rheostat operated by the cameraman. It eliminates tripod, high-hats, perambulators, and all other blimp supports except for high parallel shots. It is claimed that the use of this device speeds up production at least an hour per day. The blimp shown in the illustration operates entirely from outside controls, the follow-finder and follow-focus being controlled from a calibrated lens.

The year 1934 has had nothing startling to offer in the way of new camera lenses. The number of patents issued[21] indicates that developmental work is going along at its usual pace in this field, but that few of these new constructions have reached the market in the form of finished objectives. R. Kingslake has written a history of the development of the photographic lens[22] that should be of value to all those interested in lens design. J. A. Dubray has published an article on chemical focus in cinematography,[23] and McFarlane has described the use of supplementary lenses with 16-mm. cameras.[24] The automatic control of diaphragm openings in photography by means of a photo-cell in the camera finder is proposed in a recent patent.[25]



(Courtesy of Paramount Productions, Inc.)

FIG. 3. Camera dolly crane.

(4) *Studio Illumination.*—One of the lamp manufacturers (General Electric) has developed a new type of tubular lamp known as the *Lumiline*, which consists of a tubular bulb $1^1/_4$ inches in diameter and either 12 or 18 inches long, with metal caps sealed to the glass at the ends of the bulb, through which contact is made. The socket consists of a small cap containing the contact, covered with insulating

material which is "buttoned" onto the ends of the lamp. When lamps are placed in line, the break in the light-source is scarcely more than $^1/_2$ inch, thus making practically a continuous line of light. The lamp is intended for general illumination as well as for decorative lighting, and is available in a number of colors in 40- and 60-watt ratings.

In last year's report it was mentioned that experimental work was

(Courtesy of Mole-Richardson, Inc.)

FIG. 4. 1000-ampere choke-coil.

(Courtesy of Eastman Kodak Co.)

FIG. 5. Kodascope model *L*,

being done upon a high-intensity mercury vapor lamp. This lamp is now commercially available in the 400-watt size with 14,000 lumens' output. It will undoubtedly prove to be of value in the motion picture industry, particularly for process work. Its technical features were described by Buttolph.[26]

Two other lamps have been developed which may be of interest to the motion picture industry for certain lighting effects. The first is a three-light lamp, containing two filaments. It is provided with a special three-contact mogul-screw base, making it possible, by proper switching, to obtain three levels of illumination. The lamp is available in the 150- to 200-watt and 200- to 300-watt sizes. The other lamp is a high-speed flashing lamp of 1000-watt rating, the bulb of which contains hydrogen instead of the usual argon or nitrogen. It is possible to transmit flashing signals at twice the speed that was possible with the mechanical shutter.

The Corning Glass Works has developed a special blue-glass filter, known as their *Lunar White* No. *570* which, when used with the Movieflood lamp announced a year ago, gives almost perfectly white light. This combination of lamp and filter is particularly applicable for color motion picture photography, which, in general, requires substantially equal quantities of the three primary colors. The details of the glass and its application to studio lamps was discussed in a paper by R. E. Farnham.[27]

The interest in carbon arcs for studio lighting is quite pronounced at the present time, due to the new Technicolor pictures. In order to render the operation of the arcs sufficiently quiet for sound pictures, L. Kolb, of M-G-M, recently built a number of choke-coils of 1000-ampere capacity. Fig. 4 shows similar coils built by Mole-Richardson Co., Inc. Each coil contains 300 feet of 1,000,000 circular mil copper cable, making 36 turns, and has an air core. Such a choke-coil has the advantage of taking care of a large number of arc lamps from its position near the power-house. The ordinary choke-coil, made for individual lamps, must be carried to the motion picture set and located near the lamp it serves.

Along this same line is the announcement that the W. C. Hollins Electric and Engineering Company of Los Angeles has developed a dry type of electrolytic condenser to replace the regular electrolytic condensers in present use in the West Coast studios. Each unit weighs approximately 25 pounds, and has a capacity of 2500 microfarads. One unit is sufficient for each end of a generator. These condensers are used in conjunction with choke-coils to eliminate commutator ripple. The advantages claimed for the "dry type" condenser are lightness of weight, no care is needed, lowness of price. They have recently been installed in several of the West Coast motion picture studios.

(5) *Color.*—A renewed interest in color processes was apparent among several of the producing organizations. A number of two-

color cartoons were made by various companies in the United States and Europe. The Gaspar process was used in making several three-color cartoons shown at Berlin and London last fall. This process utilizes a film composed of three dyed emulsion layers coated upon one support. The film is exposed successively to each one of a set of color separation positives. The three silver images are developed, fixed and washed, and the film is then passed through a bath containing thiocarbamide, by means of which the dye in each layer is rendered colorless in conjunction with the silver in the layers, the amount of bleaching being proportionate to the amount of the silver deposit. The silver is then rehalogenized and fixed out. There remains a subtractive three-color picture image composed of dyes.[28]

The improved Technicolor process was used in making a large portion of the products supplied by Walt Disney.[29] A two-reel color picture entitled *La Cucuracha* was released in September in the United States, made by the three-color Technicolor process, and a complete feature was announced for release during 1935. These represent probably the first three-color subtractive pictures, apart from cartoons, made for commercial showing in this country.[30]

Having found that silver chloride treated with a solution of a diazotate can be readily converted into silver diazotate, the I. G. Farbenindustrie Aktiengesellschaft worked out a method of making color prints from silver images.[31]

(*B*) *Substandard*

(*1*) *General.*—The past year was marked by decided progress and interesting developments in this field, principally due to progress made in manufacturing and supplying equipment for recording and reproducing sound on substandard film; the use of substandard film sizes for motion pictures has been largely extended from the former amateur field to that of the commercial[32] and educational field.

Further improvements made in manufacturing fine-grain emulsions and the general introduction of special fine-grain developing formulas have resulted in an increased interest in the possibilities of the negative-positive processing method in competition with the reversible process.

While the 16-mm. size is rather exclusively preferred by American users and film manufacturers, it will be found that in Europe the market for 9.5-mm. film, originally suggested in France, is given much attention, as well as that for 17.5-mm. film. The newest development stimulated by the introduction of the 8-mm. projector by Eastman in the United States has led to the manufacturing of 8-mm. reversible film in Germany.

(2) *Films and Emulsions.*—Several new 16-mm. films have been produced in the United States. Plenachrome, a new 16-mm. orthochromatic reversible film, is manufactured by the Agfa Ansco Corp. The same firm introduced a fine-grain 16-mm. panchromatic negative film. The Eastman Kodak Co. supplied a low-priced panchromatic 16-mm. reversible film.

In Germany the I. G. Farbenindustrie (Agfa) has issued a new type reversal film called *Isopan Umkehrfilm*, the speed of which is greater than that of the *Novapan* film, a product of the same firm, and which also has a finer grain.[33] The Agfa "Ozaphan" film was brought upon the market during the last year. Agfa have already built up a great library of these films, and every month the amateur can buy newsreels taken on this material at a very low price. A rather complete report covering the photographic characteristics of European substandard films recently developed, including filter factors, has been published in England, naming the films manufactured and distributed by Eastman, Agfa, Ilford, Gevaert, Pathé, and Bolex.[34]

(3) *Cameras.*—A great number of new amateur cameras were introduced or improved during the past year. A 16-mm. camera driven by an electric motor has been marketed by Amigo, Berlin.[35] A camera for 16-mm. cassettes has been introduced by Niezoldi and Kramer.[36] The same firm announces the first 8-mm. camera produced in Germany.[37] Another 8-mm. model has recently been manufactured by the French firm, Establissements Emel. Keystone also constructed an 8-mm. camera.[38]

A new Zeiss 16-mm. camera called the Ikon *Movikon* camera has been developed, using daylight spools. It can be operated at various speeds and is probably the first cinematographic camera which has a distance meter, coupled with the taking lens. The sector of the rotating shutter is adjustable. The Siemens camera, which is already well known, shows some further improvements. Model *C* has four speeds and is now fitted with a Meyer-Siemens anastigmat $f/1.5$.

(4) *Projectors.*—A large number of new or improved models have been offered by manufacturers in the United States and abroad furnishing greater illumination, mechanical flexibility, and compactness. Eastman announced the Kodascope *L* (Fig. 5) for 16-mm., which is supplied with various lenses and lamps up to 750 watts.[39]

The Bell & Howell Co. met the trend for greater wattage by manufacturing Model *130* with a 1000-watt lamp. Improvements incorporated in this model consist of a special cooling system employing two fans and an air-conditioned panel through which the film is driven and is humidified. The optic consists of a Cook lens $f/1.65$[40] (Fig. 6). A similar model, *129*, with a 750-watt lamp, is

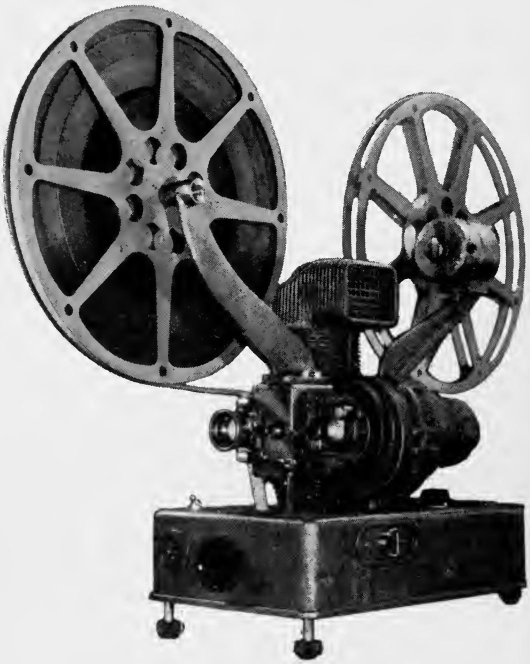


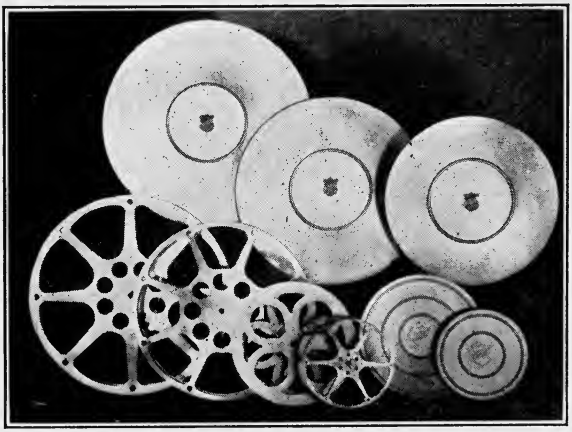
FIG. 6. Bell & Howell 16-mm., 1000-w. projector.

also available.[41] In both models new "stream-line" styles have been developed.

The Victor Animatograph Corp. announced the 16-mm. Super *Hi-Power* projector with a 750-watt lamp.[42] Abroad, Lytax, in Germany, completed the *Super P* projector, a rather universal equipment, as it allows projection of 8-, 9.5-, 16-, and 1.75-mm. films and, in addition, projection for 5 × 5 cm. stills.[43] An improved model of the well-known Niezoldi and Kramer line has been announced which is called the *Niezo H. S.*[44] Agfa have issued a new projector, the *Movector Super 16*, which can be used for projecting 16-mm. reversal film, lenticulated film and Ozaphan film.

Of special interest are the arrangements intended to reduce the projector noise. This is achieved by directly coupling the ventilator and the rotating shutter with the axis of the motor. The rotating shutter turns twice for each frame; for sound projection it is used as a one-blade shutter, and for the projection of silent pictures it works with two blades at a speed of 16 frames a second.

The Bell & Howell Company announced a series of reels of varying capacities: 1600, 1200, 800 feet for 16-mm., and 200 feet for 8-mm. films (Fig. 7). All reels are equipped with prongs which automatically hold the film at the central core. The interesting innovation consists in using spring steel for the reels instead of the conventional aluminum



(Courtesy of Bell & Howell Co.)

FIG. 7. Spring steel reels.

insuring against warping or distortion even if the reels are submitted to accidental shock, at the same time maintaining lightness and rigidity.

(5) *Color.*—Subtractive two-color processes have been used to some extent commercially but no decided progress or new principle has been made known in this field. In England the Spicer-Dufay color process has been announced as available also for 16-mm. reversible film. Several technical papers describing this process, which employs a color mosaic screen, and includes processing formulas as well as methods applicable for making duplicates, have been published.[45] A demonstration of the Dufaycolor regular mosaic

process on 16-mm. film was given in April, 1934, at the Spring Meeting of the Society. The screen rulings were about 1000 to the inch.[46]

During the year, Agfa introduced an improved color-film of increased sensitiveness and balanced for daylight exposure without a filter.[47] This was made available in amateur camera sizes and as 35-mm. motion picture films for Leica, Contax, and similar cameras.

(6) *Sound Recording.*—Although in the United States the variable-width recording system is given preference in connection with sub-standard film, in Germany the variable-density system is found to be in greater use.[48] Since the singly perforated 16-mm. film became standard, the leading film manufacturers have supplied the market with the corresponding types. Direct recording on 16-mm. film has been the subject of much study and research, but in spite of all efforts the problem has not yet been satisfactorily solved. The RCA Manufacturing Company has done outstanding pioneering work in this field. Other than the RCA 16-mm. sound camera,[49] and the Berndt-Maurer 16-mm. sound recorder,[50] no new apparatus has been announced in the United States.

The problem of reducing 35-mm. sound records to 16-mm. for reproduction has been given increased attention during the year. The results and principles of the investigations in this field have been published in a number of papers and indicate that the problem has come very close to a practical solution.[51]

The various possibilities of either reaching the final composite 16-mm. sound-and-picture print by optical reduction or by means of re-recording from the 35-mm. original on to 16-mm. film have been thoroughly studied. Both methods have their advantages and disadvantages which, balanced against each other, have most of the authors and investigators deciding in favor of optical reduction. In connection with this work the question of suitable printing equipment is naturally being investigated also, resulting in the announcement of improved printers for optical reduction. Thus, A. F. Victor[52] and G. A. Busch[53] described a continuous optical reduction printer; in England, W. Vinten, Ltd.,[54] also announced an optical reduction printer from 35-mm. to 16-mm. film; and in Germany, Arnold and Richter.[55] A 16-mm. contact printer has been manufactured by Berndt-Maurer,[56] and by Phillips Laboratory in New York.[57]

(7) *Sound-Film Production.*—The progress achieved in perfecting methods for successfully producing 16-mm. sound-film motion

pictures, and their importance in the field of commerce, industry, education and entertainment, has encouraged an additional number of manufacturers to market new sound projectors. The following sound-film projectors have been announced:

Ampro (16-mm.);[58] Electronic Devices Corporation (Edco) (16-mm.);[59] De Brie (16-mm. and 17.5-mm.);[60] British Thompson-Houston Corporation (16-mm.);[61] Agfa, Lichton Movector (16-mm.);[62] Siemens Lichton (16 mm.);[63] Donelli (Italy) (17.5 mm. with single center perforation);[64] Sales Producers, Ltd., London (16-mm.);[65] Photokinox, Zeiss Ikon (16-mm.).

(II) SOUND RECORDING

(*1*) *General.*—There was no outstanding accomplishment in the field of new sound recording equipment during 1934. This is probably due to the fact that major equipment suppliers were embroiled in litigation over the Tri-Ergon patents and hesitated to go ahead with new equipment lines until these patents were finally settled one way or the other. Both the Tri-Ergon patents having been held invalid by the Supreme Court, the decks should be cleared for action this year and it is hoped that some worth-while things may be announced a year from now.

Considerable attention was given by the public to the sound recording in Columbia's *One Night of Love*, featuring Grace Moore. This picture marked the initial attempt to use the new vertical cut recording system in sound pictures. The songs and orchestral selections were first recorded on wax and later transferred to film in the re-recording process. This gave a final film indistinguishable from an original film recording and superior to a film-to-film re-recording. The successful use of vertical cut by Columbia has stimulated its use in other West Coast studios.

(*2*) *Recording Equipment.*—RCA Photophone announces a new accurate monitoring device for use by the mixer. It consists essentially of a strip of neon lamps. The device has been tested over a period of several months in an eastern studio, and has been found to be very satisfactory. It indicates instantaneous levels with an accuracy permitting full modulation of the track without overshooting. It is expected that the device will prove to be effective in preventing over-modulation when recording musical selections in which it is desired to utilize the full range of possible modulation without overshooting. Modern reproducing equipment requires that this be prevented.

A new system of recording on film was demonstrated which should serve to improve the fidelity and reduce the background noise of the extended frequency range of musical recordings. The new method can be employed for original recordings that are to be re-recorded for making final negatives. The original recording may be made either in the form of a positive which is almost completely exposed throughout the sound-track area, or in the form of a negative from which prints can be made for reproduction. The sound-track is divided into two parallel sections, each being exposed on only one-half of the sound-wave. One portion of the sound-track is then a record of negative half-cycles, and the other of the positive half-cycles. The form of the track is illustrated in Fig. 8. For silent

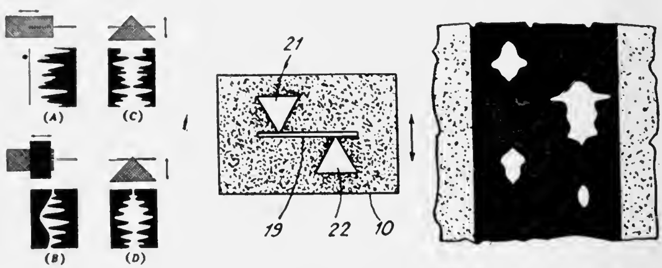


FIG. 8. RCA double sound-track.

intervals, there is practically no exposure when making positives. No biasing system is required, as with the noiseless recording systems used at the present time; it will still be required for making negatives from which release prints are to be made.

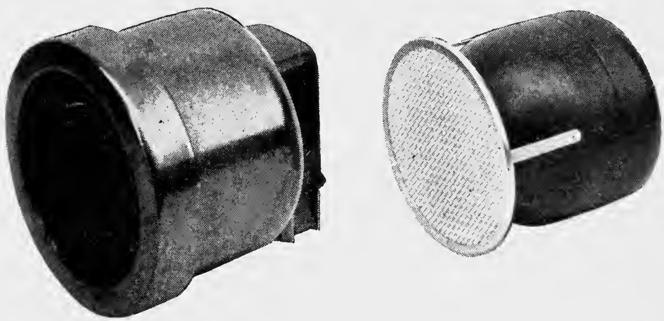
In reproduction, the light on each track is impressed upon separate photo-cells or separate cathodes of a single cell. The cathodes are connected to opposite ends of a transformer winding. Imperfections in the tracks affecting both in the same way are balanced out. This eliminates distortion which might otherwise be present if reproducing from an original recording.

The volume range with this type of recording is 55 db. without audible background noise, when used with systems having an effective frequency range to 9500 cycles. Only minor modifications of present recorders and reproducers for re-recording are required to utilize this sytem.

There has been an increasing demand for a small microphone that can be more easily concealed on the set in scenes that require that it be within the camera angle. This demand is being met with the new non-directional moving-coil microphone shown in Fig. 9, which was recently designed by the Bell Telephone Laboratories. The microphone is not only small and convenient to use, but has an exceptionally flat response characteristic over the audible frequency range that is only slightly affected by direction.

A sound-track engraving apparatus for engraving variable-width sound-tracks upon film was reported in *Electronics*.[66]

Warner Brothers-First National report marked success in using a resonant shunt across the light-valve. It is claimed that the shunt



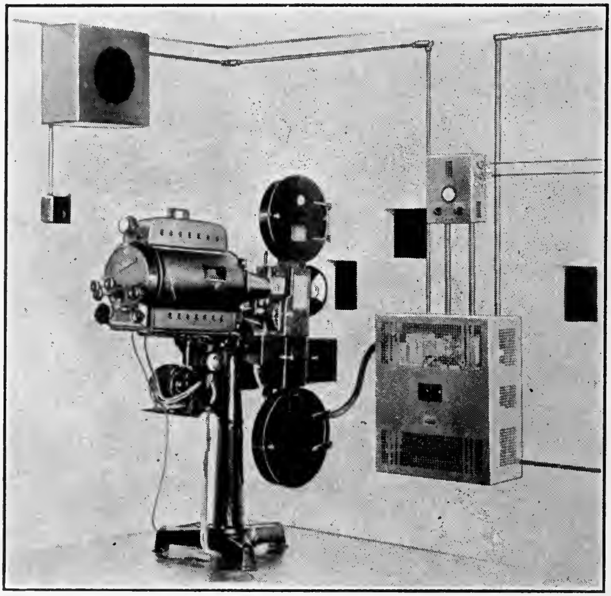
(*Courtesy of Bell Telephone Laboratories, Inc.*)

FIG. 9. Non-directional dynamic microphone.

practically eliminates transients and results in a recording that is much cleaner and free from overloads.

(3) *Accessories.*—An apparatus for measuring and analyzing flutter in recording and reproducing machines has been developed by the Electrical Research Products, Inc. It will measure frequency variations over a range from about 0.04 to 3 per cent, the indicated percentage being practically independent of the flutter rate. It is compact and readily portable, being contained in two small cases weighing about thirty-five pounds each. It is operated from a 110-volt, 50- or 60-cycle power source, and is adaptable for use in the field as well as in the laboratory.

An improved design of the Electrical Research Products, Inc., noise meter has recently been announced. The equipment is about the same as before, except that provision has been made for measurements where a flat frequency response is required instead of the 40-db. loudness ear response. In order to accomplish this, it has been necessary to redesign the amplifier to have a uniform response, and then provide the ear-weighting characteristic in the form of a separate network that may be switched in or out of the circuit by operating a key. In order to obtain uniformity throughout the system, the standard Western Electric moving-coil microphone has been substituted for the special noise transmitter.



(*Courtesy of Electrical Research Products, Inc.*)

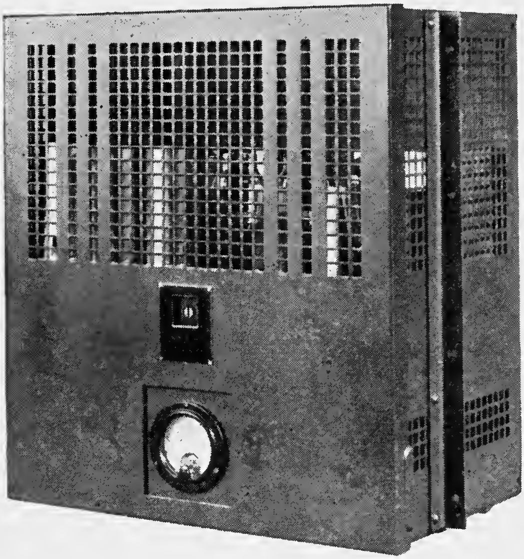
FIG. 10. All a-c. theater sound projector.

(III) SOUND AND PICTURE REPRODUCTION

(*1*) *Sound Equipment.*—While no radical innovations in sound reproducing equipment have been introduced during the past year, consistent progress in simplifying and cheapening equipment has been made.

The Electrical Research Products, Inc., developed during 1934 a new sound system for theaters under 600 seats, to be known as the *No. 5 type* (Fig. 10). The outstanding features of the equipment are increased power, improved frequency response, operating simplicity, and reduced installation expense. The important equipment components are the well-known *206 type* reproducer set, a compact amplifier-rectifier assembly for front-wall mounting between projectors, and a composite stage loud speaker consisting of two units in a horn-baffle arrangement. The loud speaker system is furnished in two different types, the choice depending upon the shape of the auditorium.

The *86-A* amplifier has recently been developed by the Western



(Courtesy of Electrical Research Products, Inc.)

FIG. 11. All a-c. theater sound amplifier.

Electric Company for theater reproduction. The principal features of this amplifier which distinguish it as an advance in the art are its high gain (97 db.) with practically a flat characteristic from 40 cycles to 10,000 cycles, its high power output capacity (15 watts), and its small size. The amplifier proper is of the chassis type, weighing only 35 pounds. The amplifier is entirely a-c. operated, and has power supply for auxiliary amplifiers. It is normally mounted with auxiliary equipment in an attractive aluminum, gray-finished cabinet $19 \times 19 \times 10^5/_8$ inches in size, arranged for rack or wall mounting (Fig. 11).

RCA Photophone announces that theaters have continued to install their high-fidelity equipment. There are over 1000 installations in the United States. The later musical recordings having a greater difference in the recorded level of speech and music, and requiring a greater gain in power output for adequate reproduction, are impressing upon exhibitors the need for improved reproducing equipment that is free of system noise at the higher gains required and capable of reproducing loud passages without distortion.

FIG. 12. RCA loud speaker system.

The same company announces also that a new stage speaker has been made available for theater use (Fig. 12). It is especially suitable for theaters giving stage performances, because the entire assembly can be flown with the screen. In all installations it is especially convenient; in many installations, the assembly can be placed directly upon the floor behind the screen. When it is necessary to elevate the speakers for proper sound distribution, the assembly can conveniently be placed upon a simple platform. The speaker assembly consists of a large folded horn for reproducing frequencies below 125 cycles, and two or three small speakers or directional baffles for the range from 125 to 9500 cycles. The large folded horn serves to support the smaller units, which are hinged to the large horn in such a way that they can be conveniently tilted to the required angle.

(2) *Projectors and Accessories.*—H. A. DeVry, Inc., announce a projector "made from the ground up" for *both* sound and picture. The DeVry engineers have designed both picture and sound mechanisms as a unit, and have thus been able to eliminate many unnecessary parts. The silent-chain drive is substituted for meshed gears; rear barrel shutter is incorporated in the stock equipment, and the Robertson fly-wheel is utilized for filtering out vibrations.

The unit is furnished in several models, for Mazda lamp, or for either high- or low-intensity arcs. All machinery is inclosed in a dust-proof metal case, the projector presenting a handsome streamline effect from floor to magazine. Controls are accessible, however, from the outside. The unit may be used in the largest as well as in the smallest theaters.

The General Electric Company has produced a three-phase full-wave copper oxide rectifier for supplying power to projector arcs in theater booths. Two sizes are available. The smaller is designed for use with the 6- and 7-mm. trim and will deliver 40 to 50 amperes at an arc voltage of 30 to 35 volts. The larger unit is designed for the 6.5- and 8-mm. trim and will deliver 50 to 65 amperes. These ratings are in accordance with the standards established by the Projection Practice Committee of the S. M. P. E.

The over-all efficiency of either of these units is better than 70 per cent. According to findings of the Projection Practice Committee, the high efficiency of the polyphase type of rectifier will show a saving of 5 to 10 cents an hour in the cost of current as compared with other types of power supply. This means that the rectifier will pay for itself in one or two years in current saving alone.

The Morelite Company, Inc., of New York have placed upon the market a reflector arc lamp called *Sun-Lite Model D.* It is claimed that this lamp gives steady and uniform screen illumination in spite of the sensitiveness of the Supro copper-coated carbons employed.

The Projection Practice Committee of the S. M. P. E. has proposed the use of glass mirror guards as a means of preventing loss of light due to reflector pitting in reflector arc lamps.[67]

For 35-mm. projection in small theaters and auditoriums there has recently been developed by the General Electric Company a 2100-watt, 60-volt projection lamp, containing a bi-plane filament and the new bi-post base. This lamp gives the highest screen illumination attainable with any filament lamp in the 35-mm. projector and gives more than double that of the heretofore generally used 900-watt, 30-ampere projection lamp.

With rims and spokes of clock-spring steel, DeVry has manufactured a de luxe film reel, which will not remain bent under pressure or blows, and consequently saves the life of film by its permanent, true alignment. The reel holds 2000 feet of film. A novel feature is the sliding attachment of the spokes to the hub which allows expansion under strain and prevents warping, dishing, *etc.*, common with the usual reel. Automatic clipping is accomplished by wells in the hub. The operator merely presses the film slightly over the well with the finger. Prongs catch the perforations automatically with a non-slip grip.

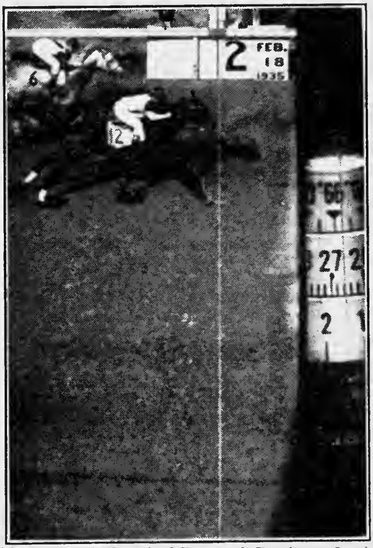
From Germany comes announcement that the Zeiss Ikon A. G. have made various valuable improvements to their projectors called *Ernemann IV*, *Ernon IV T*, and *Ernemann VII*. Especially interesting is that for theater machines: film reels have been issued which take 1300 meters of film. These reels are now available for all the projectors made by Zeiss Ikon. Furthermore, all their apparatus is now fitted with a so-called "protector" arrangement, which is a fire protection arrangement cutting off the light-beam when the film stands still, although the machine continues to run. All the machines are fitted with a rotating shutter between the light-source and the gate, and are obtainable for right-hand and left-hand handling. It should be mentioned that all the Zeiss Ikon projectors use the new Zeiss Ikon lamps.

The Klangfilm Company have also improved their apparatus. There will also be found a description of the new *Europa* soundhead built by Klangfilm, which is fitted with a rotating sound-gate.[68]

The well-known projectors of the firm of Eugen Bauer G. m. b. H., Stuttgart, namely, *Super 7*, *Standard 7*, and *Standard 5*, are now fitted with the so-called Bauer Doppel-Ausgleichs-Gerat. During the last year this "Doppel-Ausgleichs-Gerat" was tried very successfully in several large theaters. It is said to insure a great security of operation and a very high quality of sound reproduction. The main features of the construction are the special type of driving mechanism, the possibility of incorporating it in the projector, the use of a double-way clutch and a special micro lens with optical slit, and finally, a highly effective photo-cell.

(IV) FILM LABORATORY PRACTICE

It is unfortunate that we are unable to report many items of progress either in laboratory equipment or technic. The release print situation in this country remains decidedly spotty. It is quite apparent that producers do not take the release print seriously. This is a regrettable situation because, after all, the public sees only these prints. Further educational work to impress producers with the necessity of giving the release print more attention is apparently in order.



(*Courtesy of Electrical Research Products, Inc.*)
FIG. 13. Horse race finish at Santa Anita track.

In the line of laboratory equipment, Metro-Goldwyn-Mayer Studio reports the use of a turbulator in their sound and picture negative developing machines. The use of this turbulator practically eliminates the so-called "directional effect" and appears to produce a picture and sound negative of distinctly improved quality. With this turbulator in use, H&D strips sent through "heads first" are indistinguishable from those sent through "tails first."

(V) APPLICATIONS OF MOTION PICTURES

(*1*) *Education.*—The growth of sound motion pictures in educational work in the United States has been hampered by the lack of suitable films and by the failure of the equipment makers to solve the problem of providing sound-film reproducers at a price that the average school can afford. In Europe considerable progress is reported in the use of 16-mm. sound pictures in the public schools. The movement is strong in Germany, where the Government is sponsoring a campaign of propaganda in the schools to further the aims of the Administration. Sweden also reports progress in the use of motion pictures as an adjunct to elementary education.

(2) *Race Timing Devices.*—The Electrical Research Products, Inc., in coöperation with the Eastman Kodak Company, have developed and introduced into the horse racing sport an electrically controlled precision timing and judging system. The equipment photographs the time of predetermined intervals of the race and also photographs the finish and the total elapsed time (Fig. 13). It consists of a high-speed 16-mm. camera, placed at the finish line and directly connected to a rapid film processing and enlarging equipment. Integral with the camera is an electrically controlled clock which is started by an interruption of the light-beam focused upon the photoelectric cell situated at the start of the race. Interval times are photographed by similar successive interruptions of the light-beams focused upon the photoelectric cells at other points along the track. The equipment can be operated to deliver in less than three minutes after the finish of a race a print of the finishing frame showing the elapsed time and the order of the finish.

(VI) PUBLICATIONS AND NEW BOOKS

With few exceptions, the periodicals of interest to the readers of motion picture literature have been continued. In the field of visual education, an interesting publication was overlooked when compiling the 1932 report. This is the journal, *Sight and Sound* (London), which was initiated in 1932. A small publication bearing the name *Journal of the Motion Picture Society of India* (Bombay) made its first appearance in January of this year as the official organ of the Motion Picture Society of India. A new periodical known as *Amateur Cine World* was added to the list of amateur publications. *Personal Movies* (Canton, Ohio) was discontinued at the end of 1934.

A list of the principal books that have been published since the last report of the Committee (April 1934) follows:

(1) Year Book of Motion Pictures (1935), 16th Edition; *Film Daily*, New York, N. Y.

(2) Motion Picture Almanac (1934); *Quigley Publishing Co.*, New York, N. Y.

(3) Kinematograph Year Book (1935); *Kinematograph Publications, Ltd.*, London.

(4) Abridged Scientific Publications of the Kodak Research Laboratories (Vol. XV); *Eastman Kodak Co.*, Rochester.

(5) Publications from the Scientific Laboratory, Agfa Photographic Division

(Veröffentlichungen des wissenschaftlichen Zentral Laboratoriums, Agfa Photographischen Abteilung) (Vol. III); *I. G. Farbenindustrie Aktiengesellschaft*, Hirzel, Leipzig.
(6) Yearbook of the Cine-Amateur (Jahrbuch des Kino-Amateurs—1935), edited by W. Frerk; *Photokino Verlag.*, Berlin.
(7) The Photographic Darkroom; E. J. Wall, *American Photographic Publishing Co.*, Boston.
(8) Photographic Technic (La Technique Photographique), 2nd Edition; L. P. Clerc, *Montel*, Paris.
(9) Chemistry of Developers and Development (in Russian); V. I. Shiberstoff, *Government Printing Office for Light Industry*, Moscow.
(10) Cinematographic Technic (La Technique Cinematographique), 4th Edition; L. Lobel and M. Dubois; *Dunod*, Paris.
(11) Filming with the Cine Kodak Eight (Filmen mit Cine Kodak Acht); A. Stuler, *Knapp*, Halle.
(12) Physics of Sound Films (Physik des Tonfilms); A. Haas; *Teubner*, Leipzig.
(13) Sound Motion Pictures; J. R. Cameron, *Cameron Publishing Co.*, Woodmont, Conn.
(14) Modern Acoustics; A. H. Davis, *Macmillan Co.*, New York.
(15) Applied Acoustics; H. F. Olson and F. Massa, *P. Blakiston's Sons & Co., Inc.*, Phila., Pa.
(16) Home Processing; P. W. Harris, *Geo. Newnes, Ltd.*, London.
(17) Making Home Movies; D. C. Ottley, *Geo. Newnes, Ltd.*, London.
(18 Projection Room Regulations and Practices; R. Ruedy, *National Research Council*, Ottawa, Canada.
(19) Motion Pictures in Education in the United States; C. M. Koon, *University of Chicago Press*, Chicago.
(20) Two New Systems of Cinematography in Relief (Due Nuovi Sistemi di Cinematographia in Relievo); G. Jellinek, *Libreria Editrice Politechnica*, Milan.
(21) The Physics of Electron Tubes; L. R. Koller, *McGraw-Hill Book Co.*, New York.

APPENDIX A

General Field of Progress of the Motion Picture Industry in Great Britain

General.—For the British Motion Picture Industry, the year 1934 has been a year of progress. The output of British films has been high, nearly 300 having been registered, including about 200 of 3000 or more feet in length. Theater box-office receipts have reflected the improved industrial situation prevailing throughout the country, and new theaters continue to open at a steady rate of about 100 annually. There have also been extensive and significant developments in the home entertainment, educational, and industrial fields.

Producers and Studios.—During the year, a number of new producers have appeared, and existing producers have extended the premises. The Blattner Studios, Elstree, have been acquired by Messrs. Joe Rock and Leslie Fuller, and equipped with a "Visatone" sound recording system. Interworld Studios, Isleworth, have been opened as service studios, with Western Electric sound. Additional stages have been constructed at Twickenham Film Studios, with "Visatone" sound, and Associated Talking Pictures (RCA High Fidelity Sound). London Film Productions rented various sound and silent stages during the year, including one at British & Dominions Studios, Elstree, who have now extended their lot by ten acres. London Film Productions are Western Electric licensees. Warner Bros.-First National Productions have also built fresh preview and cutting rooms, workshops, *etc.*, the exterior of the new buildings providing suitable settings for a variety of outdoor shots. This producer has also become a Western Electric licensee. The Welwyn Studios, associated with British International Pictures, have been equipped with an Ambiphone sound recording system.

Photography and Film Laboratories.—Much interest has been shown in color photography and projection during the year. One studio produced a picture (*Radio Parade*), in which certain sequences were photographed using the Spicer-Dufay color process; another producer is experimenting with the Hillman process and a laboratory has been installed for the processing of industrial cartoons produced by the Gasparcolor Process. Spicer-Dufay are also experimenting with 16-mm. film, and tests of this system for newsreel work have been made. Apart from those required by color photography, no technical changes in film processing of major importance appear to have been seriously considered. No new types of motion picture film were marketed during the year, but the problem of loss of sound in printing, aggravated by the extended high-frequency ranges now recorded, has stimulated research into the cause of printer slippage and its possible cure by reducing the perforation pitch of sound negative material. Paramount Sound News have brought anti-halation stock into use, to increase the high frequencies.

The larger laboratories have given further attention to the control of both positive and negative developers by sensitometric means, and at the end of the year three laboratories were equipped with the Eastman Type *2-B* Sensitometer. Over the year, the average gamma to which negative picture was developed was 0.65, while positives were developed to 2.10–2.40. One laboratory has installed new developing equipment made at its own works and capable of operating satisfactorily at a speed of 180–200 feet a minute. Messrs. Watson & Sons, London, have developed a photoelectric densitometer with automatic curve-plotting attachment, for use with an Eastman sensitometer, and from Germany comes the announcement of a new photoelectric microdensitomer with alternative photoelectric or photographic recording.

The local manufacture of cameras and associated equipment continues to expand, among the most striking products during the year being the *Skyhi* camera cranes. These cranes are pneumatically driven, and will rise to a height of 20 feet from the ground. They may be made to rise at speeds up to 200 feet a minute, and a setting mechanism is provided to enable any rate of rise to be repeated automatically. In each crane the boom and its platform can be rotated through 360 degrees, and the forward platform through 180 degrees. The weight of a crane is about $3^1/_4$ tons. It is completely silent in operation.

Sound Recording Equipment.—During the year, in addition to the developments referred to above, other new and improved sound recording equipment has been produced. British Acoustic Films, Ltd., have introduced a "Full Range" recording equipment operating from a-c. mains, with "noiseless recording." This firm has also produced an improved light-weight combined sound and picture camera, and a new ribbon microphone.

The Phillips-Miller recording system has been on trial at Elstree and at the British Broadcasting Corporation's laboratories in London. In this system, a recording sapphire inscribes a variable-width track in a black coating carried on a 17.5-mm. film. The track can be used for reproduction immediately after recording, and can be printed without any processing.

In the newsreel field, both Gaumont News and Pathé News have acquired Vinten cameras, and Gaumont News have also adopted British Acoustic sound. In view of the restriction of the number of transmitters imposed at important public ceremonies, the British newsreel companies are finding it convenient to use common input channels for their main sound recording amplifiers.

Exhibitors and Theaters.—Among the exhibitors in England, the year generally has been characterized by some increase in returns, as already mentioned, but the trade has also been faced with an increase of competition, due to new cinemas and to free propaganda and advertising shows. Overbuilding principally affects those exhibitors who have failed to keep pace with the taste of the public. The churches are beginning to become film minded, and in some districts, developments due to this and to "clean film" campaigns are causing concern. In view of this competition the appearance of a number of films of high artistic merit and unquestionable taste has been opportune, and such films appear to appeal to a large public.

Technically, there have been no very great developments in the standard of projection, but the leading exhibitors appear to be keeping in mind the possibility of the introduction of wide film in the next few years. During the year, new projectors have been introduced by British Acoustic Films and the British Thomson-Houston Co.

On the acoustic side, the principal feature has been a steady improvement and increase of the frequency range in sound reproduction. The Western Electric Company reports a steady stream of conversions to Wide Range, and toward the end of the year this company announced that all future installations would normally be Wide Range. In addition, all future systems will be all-mains, thus eliminating the need for batteries. RCA High Fidelity reproducing equipment has been improved to give better frequency and acoustic response, and both British Acoustic and British Thomson-Houston systems have been adapted to cover the extended frequency ranges now demanded in reproduction.

Industrial and Educational.—During the year, there has been a considerable increase in the number and quality of 16-mm. sound-film equipments available, and organizations exist for servicing and providing shows at moderate charges in any part of the country. One large tobacco firm financed eight thousand propaganda shows, and the Electrical Development Association has now commenced a campaign with specially produced films of high merit to sell electricity. The production of educational films has commenced on a fairly large scale, the Kodak Company being well to the fore with an important collection of medical films. There is some confusion in this field, due to the existence of three alternative standards, the D. I. N., the S. M. P. E., and the Pathé.

Amateur and Commercial.—The Kodak Company reports that the most important advance during the year for amateurs has been the improvement and cheapening of artificial illuminants, affording the amateur an immensely increased range of activity at reasonable cost.

In this connection, the General Electric Company, London, have come into prominence with their Photoflood lamp. Moreover, together with the illumination advances, faster lenses have been introduced for 16-mm. and 8-mm. work, and having regard to the possibilities of supersensitive panchromatic film and the use of filters, the prospects of development in the use of cinematography by amateurs and professional portrait or commercial photographers are very bright. For commercial photography, the ultra-high-speed Eastman camera with Western Electric timing device is finding many important applications.

Broadcasting.—Radio broadcasting during 1934 has both contributed to and derived much from the stock-in-trade of the motion picture industry. Gaumont British arranged for the radio transmission of a newsreel film of the finish of the England-Australia race. The television report of the Selsdon Committee foreshadows a new source of competition to exhibitors. Film subjects, such as Walt Disney's famous productions, contribute to the delights of an evening radio program; radio features form attractive subjects for film producers, and so on.

Altogether it would seem that although the past year has been mainly one of consolidation for the industry, the future presents the possibility of several very important advances.

APPENDIX B

General Field of Progress of the Motion Picture Industry in Japan

The chief development in the motion picture industry of Japan during 1934 was increased activity in sound production. The total footage of pictures produced was between 5 and 10 per cent lower than in 1933, but the recorded footage was very much higher. The producers are finding it increasingly difficult to market silent pictures, the exhibitors asking that the picture be at least scored. Forty per cent of the sound pictures produced in 1934 were scored. These scored pictures offer poor competition to an "all talkie" or synchronized picture, however, as indicated by the 10 most popular pictures for 1934: 5 all talkie; 1 part talkie; 1 sound (scored); 3 silent.

Theater returns were exceptionally good during the first half of 1933 but dropped off considerably during the latter half, due partly to the disastrous typhoon that occurred in the summer. The studios lost a number of stages, interfering with production. Also, the purchasing power was noticeably reduced in the areas hit by the storm.

Several new and modern theaters were opened in Tokyo in 1934 and one in Osaka. These theaters are showing mainly imported pictures. Last year there were more pictures imported than any year since the advent of sound, about 275 from the United States and 50 from Europe. European pictures are quite popular in Japan. In a list of 16 best pictures put out by the Educational Department there were 6 from the United States, 5 from Germany, 2 from France, and 3 from Japan. Of the 10 most successful pictures as listed by *Movie Times*, 8 were produced in the United States, one was assembled and scored locally by Fox Movietone, and one was imported from France.

Among local productions, so-called modern pictures continued to gain over the costume plays which were not so long ago the main source of material for the movies.

With the coming of sound there has been quite an increase in the number of modern cameras in use. There has also been a number of better class stages erected for the purpose of producing sound pictures. In the laboratories the use of continuous machinery has increased and other laboratories are under construction which will use nothing but continuous equipment. As these modern equipments and methods have come more into use and the technicians have become better acquainted with sound, the general technical quality of the pictures has showed a marked improvement.

Sixteen-mm. pictures have come into more extensive use for educational and propaganda purposes. At present there is very little 16-mm. sound, but several laboratories are experimenting upon reducing 35-mm. sound pictures to 16-mm.

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[40] *Amer. Cinemat.* (Nov., 1934), p. 326. *Camera* (Jan., 1935). *Internat. Phot.* (Feb., 1935).
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[42] *Amer. Cinemat.* (Sept., 1934).
[43] *Kinoamateur* (Dec. 1, 1934), No. 12.
[44] *Ibid.*
[45] *Camera* (Jan. 7, 1934). *Phot. J.* (Jan., 1935), p. 28.
[46] *J. Soc. Mot. Pict. Eng.*, **XXIII** (July, 1934), No. 1, p. 14.
[47] *Photofreund*, **14** (Aug., 1934), p. 279.
[48] *Filmtechnik*, **18** (1934), p. 8.
[49] *J. Soc. Mot. Pict. Eng.*, **XXIII** (Aug., 1934), No. 2, p. 87.
[50] *Movie Makers* (Feb., 1935), p. 78.
[51] *Amer. Cinemat.* (March, 1935), p. 114. *J. Soc. Mot. Pict. Eng.*, **XXIII** (Aug., 1934), No. 2, pp. 96, 108. *Ibid.*, **XXIV** (Jan., 1935), No. 1, p. 63. *Ibid.*, **XXIV** (Feb., 1935), No. 2, p. 95. *Phot. J.* (June, 1934), p. 471.
[52] *J. Soc. Mot. Pict. Eng.*, **XXIII** (Aug., 1934), No. 2, p. 96.
[53] *Movie Makers* (Jan., 1935), p. 10.
[54] *Phot. J.* (June, 1934).
[55] *Kinotechnik*, **15** (March, 1934), p. 86.

[56] *Amer. Cinemat.* (March, 1935), p. 114.

[57] *Ibid.* (Nov., 1934), p. 326.

[58] *Movie Makers* (Jan., 1935), p. 10.

[59] *Ibid.* (Feb., 1935), p. 91.

[60] *La Cinemat. Franc.*, **16** (1934), p. 830. *Photohaendler* (July 24, 1934), p. 458.

[61] *Film für alle*, **8** (1934), No. 12, p. 366.

[62] *Photowoche*, **24** (1934), No. 13, p. 623.

[63] *Ibid.*

[64] *Filmtechnik*, **10** (1934), No. 2, p. 23.

[65] *Home Movies and Home Talkies*, **3** (1934), No. 6, p. 232.

[66] *Electronics* (Feb., 1935), p. 52.

[67] *J. Soc. Mot. Pict. Eng.*, **XXIII** (Dec., 1934), No. 6, p. 365.

[68] *Filmtechnik*, **20** (1934), p. 237. *Ibid.*, **4** (1935), p. 42. *Kinotechnik*, **8** (1935), p. 135.

TELEVISION AND MOTION PICTURES*

ALFRED N. GOLDSMITH**

Summary.—*Ultra-short-wave television transmissions with pick-ups using electron scanning, together with cathode-ray tube reception, are regarded as likely to be acceptable for television broadcasting to the public. Comparison of the received television pictures with theater and home motion pictures indicates superiority of the latter but shows that satisfactory entertainment should also be obtainable from the former. For various physical and psychological reasons which are listed, the vogue of the theater is likely to continue, provided motion picture methods are constantly kept up-to-date and that television technic is studied and utilized to such an extent as may prove practicable.*

It must be admitted that the relationship between motion pictures and television has, in the past few years, been made the subject of numerous effusions which, even from a charitable point of view, must be characterized as highly imaginative and distinctly misleading. It is unfortunate that the present and future correlation of these important fields should have been made the subject of casual publicity releases or of selfishly inspired propaganda. The subject is of considerable importance and fully merits thoughtful and impartial analysis. Such analysis requires, on the other hand, an unusually complete knowledge of the commercial activities and engineering methods of the two fields which are involved and perhaps something of a gift of prophecy as well. For these reasons, the task of presenting a necessarily brief and summarized analysis of the relations between motion pictures and television must be approached with some diffidence and hesitation. Of necessity, numerous important factors must be omitted and others must be comparatively slighted within the limited space of such a presentation as this one.

It is, nevertheless, proposed in the following:

(*a*) to consider the methods likely to be used in television-telephone broadcasting into the home;

(*b*) to compare the results likely to be achieved by television-telephone broadcasts into the home with the results attainable by theatrical sound motion pictures;

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** New York, N. Y.

(*c*) to consider the probable points of contacts between these fields, and to explore the possibilities of coöperative effort between them; and

(*d*) to consider the possible general effects of the wide-spread acceptance of television-telephone broadcasting into the home on the motion picture theater.

In studying *a*, the first of these topics, it is necessary to adopt some standard for "television"—a term having widely different meanings to various people. It is proposed to accept "standards" which represent what may reasonably be expected to be attained on a large scale within the next few years provided mass production of equipment for television-telephone broadcasting reception in the home is carried out. The term "television-telephone broadcasting" is used because it is naturally assumed that the television picture will be consistently accompanied by the corresponding sound or telephonic material. While some of the details of home television-telephone reception will be given below under the study of topic *b*, it may be postulated here that such television will be accomplished by the use of

(*i*) an electronic pick-up rather than a mechanico-optical pick-up. (Such pick-ups include the iconoscope and the dissector tube.)

(*ii*) an ultra-short wave transmitter or transmitters for the television and telephone portions of the program.

(*iii*) a coaxial-conductor cable, or its equivalent, or an ultra-short-wave radio relay system, for the syndication of the program material for network operation; and

(*iv*) an electronic receiver of the cathode-ray type, with a fluorescent image screen, rather than a mechanico-optical receiving system. It is impracticable within the limits of this paper to discuss the principles, design, construction, or operation of the complicated devices mentioned above.

Proceeding to the study of topic *b*, there will be given an itemized and instructive comparison of the practical results to be expected by home television-telephone reception as compared with motion picture theater performance.

(*1*) *Mode of Picture Production.*—The methods of producing the pictures are entirely different in the two cases, odd as that may seem. The theater picture is projected as a complete unit, one entire frame at a time. The delineation is produced and limited by aggregates of silver grains in the developed positive image. The television picture is produced by a luminous dot (or "dot-element"), the brightness of which is accurately controlled as it passes in succession over a series of parallel and closely adjacent lines until it has covered the entire area of one frame. In the theater case, the entire picture is on the screen at the same time, to be succeeded by darkness prior to the projection of the next frame, and so on. In the television case, there is never anything more than a more or less bright dot upon the screen! The television picture depends even more upon persistence of vision than the theater picture, being, in fact, nothing more than a flickering and flying dot. It must be added that certain technical details of television picture production have not as yet been standardized. However, the above-cited features appear likely to be permanently present.

(2) *Number of Picture Elements.*—The number of picture elements determines the detail or (roughly) the story-telling capabilities of the picture. In round numbers, the theater picture has something of the order of 5,000,000 picture elements, whereas even a good home television picture will probably have something like 150,000 elements. This is a ratio of 30 to 1 in favor of the theater picture. However, it must be noted that the entertainment value of a picture in motion (whether produced by projection or by television) is not in direct proportion to the number of picture elements which it contains, so that we are not entitled to draw the conclusion that theater pictures, though more detailed in structure, are necessarily far more entertaining (particularly on the small home screen) than television pictures. Probably a television picture in the home will be described by most as a "fair home movie."

(3) *Grain or Line Structure.*—Theater pictures of reasonable size from a suitable positive show negligible grain if viewed at moderate and practicable distances, and of course show no line structure (for monochrome pictures). Television pictures show no grain structure, but may show a slight line structure if viewed too closely. However, high-detail television pictures, viewed at normally comfortable distances, will show practically no line structure—and certainly no objectionable line structure.

(4) *Color of the Picture.*—Theater pictures are normally black in the shadows and white (blue-white or yellow-white) in the highlights. When projected from toned or tinted positives, they show the corresponding hue. Television pictures are also practically black in the shadows, but the highlights may be bright yellow, greenish yellow, or even a practically neutral white. The latter color will probably become common practice in television as development of the art proceeds.

(5) *Possibility of Full-Color Pictures.*—It is readily possible today to produce theater pictures which show substantially the colors of

nature or at least an acceptable approximation thereto, although there are definite economic handicaps in production and reproduction of such pictures. Television in full colors seems to be an almost impracticable proposition in the present or likely early state of that art, although small-scale demonstrations of its abstract possibility have indeed been given.

(6) *Size of the Picture.*—Theater pictures range in size from, say, 6 by 8 feet to perhaps 18 by 24 feet, or even more in special cases. Thus, their area is between 48 and 32 square feet. Home television pictures range from about 6 by 8 inches to perhaps 18 by 24 inches or, in special cases, somewhat more (though generally at the cost of picture detail and brightness). Thus their area lies between about 0.3 and 3 square feet. On this basis the area of the theater picture is about 100–160 times that of the home television picture. A more normal comparison would be with the approximate 30 by 40-inch home motion picture, having an area of about 8 square feet or, say, about 5 times that of the average television picture.

(7) *Picture Brightness.*—Theater pictures are generally adequately bright for viewing in a darkened auditorium (that is, an auditorium with illumination about 0.5 foot-candle). The television pictures are also sufficiently bright to be viewed in a dimly lighted room—but dark window shades will be required for daylight hours, and for the evening as well if the street lighting outside the home is at all bright.

(8) *Flicker of the Picture.*—The theater picture consists of 24 frames per second, each of which is generally projected twice before the next frame reaches the screen. Flicker is absent, although traces of an effect depending upon picture sequence are still found in the case of rapidly moving objects and in the stroboscopic backward-turning of the wheels of pictured vehicles. Television pictures may be projected in two sets of 30 pictures each, the two sets being projected in 1 second. Interlaced scanning may be used, and under these conditions a substantially flickerless picture is obtained. Despite the projection of 60 half-detail pictures per second by this method (equivalent closely to 30 full-detail pictures per second), it is possible to use ordinary 24-frame-per-second motion picture film for the television subject without undue difficulty by the use of technical expedients which can not be here described.

(9) *Viewing Distance.*—Taking an optimum viewing distance of 4.5 or 5 times the picture diagonal, theater pictures may be most

conveniently viewed from 45 to 135 feet from the screen, while home television pictures will be viewed from about 4 to 11 feet from the screen. This is a ratio of viewing distances of about 11 to 1 in the two cases.

(10) Audience Size.—Long experience has demonstrated that the comfortable size for theater audiences ranges from 500 to 5000 persons, with perhaps some doubt at one extreme or the other. The corresponding home audience may be expected to include from 3 to 15 persons, a ratio in favor of the theater of about 200 to 1. It must not be inferred, however, that the economic ratio for the two fields is anything like as high as this—indeed it has not yet been determined just what will be the cost per person per hour of entertainment for home television-telephone broadcasting.

(11) Synchronism of Picture with Sound.—In the theater, the picture and sound are correctly associated within $^1/_{24}$th of a second, assuming proper editing and threading. In the case of home television-telephone programs, the synchronism is even closer (though this is not noticeable as an advantage), and is entirely correct and automatic. Some rather romantic writers on the subject have dilated upon the "marvel" of the synchronism of picture and sound in such programs. As a matter of fact, considering the fundamentals of the processes employed, it would be even more marvelous if synchronism were not attained for television-telephone broadcasting reception.

It is not practicable at this time, before mass production of television equipment has been initiated, to give a reliable comparison of the cost of theater and home equipment. In a general way it may be said that theater equipment costs in the thousands of dollars and home equipment about the same number of hundreds of dollars, thus giving a cost ratio of perhaps 10 to 1. Here again some caution must be used in interpreting such figures since there are numerous other economic factors involved in a valid comparison.

While it is not feasible within the limits of this presentation to give even an outline of the various methods employed in modern television, some numerical data concerned with picture detail may be included as of present interest. These consist, first, of a personal opinion, in motion picture terminology, of the value and characteristics of television pictures having various numbers of dot-elements composing them. The figures are understood to be merely generally descriptive, but it is believed they are instructive in judging the "motion picture value" of various television systems:

Elements in Picture	*"Motion Picture Value"*
10,000	A fair close-up of one person (head and shoulders).
20,000	Two persons in a moderately good close-up (though without fine detail).
40,000	Fair medium shots.
80,000	Good medium shots and fair long shots.
160,000	Excellent close-ups of several persons, good medium shots, and acceptable long shots (except for unusual "pageant" subjects and the like).

Taking the last-mentioned type of television picture, and assuming flickerless transmission, it is found that the required "side-bands" produced by the picture modulation of the ultra-short-wave carrier have a width of the order of 1.5 megacycles (or about 150 times the frequency band required for high-fidelity 10,000-cycle sound reproduction)!

Passing to topic *c* above, namely, the contacts and coöperative possibilities between motion pictures and television, it is clear from the beginning that there can be a close connection if such is desired. A person viewing a small picture in motion with synchronized sound might find some difficulty in knowing whether he was viewing a sound motion picture projected from film or a television-telephone broadcasting reception. He might be even more puzzled if the subject matter were, say, a newsreel used to control the television-telephone transmitter, an entirely feasible procedure. Obviously the technic of producing a television-telephone broadcast program will closely resemble that of producing a sound motion picture. Methods of costuming, make-up, script construction, "camera" technic, sound pick-up, set construction and illumination, and the like may well be similar in the two fields, though probably not with the same degree of elaborateness in the case of television. There is one respect in which they will necessarily differ if an original performance (rather than a film record) is broadcast. This is a limitation of television-telephone broadcasting, namely, the possibility of only one "take," *viz.*, the one that is broadcast. In motion picture production, any reasonable number of takes may be made; not so in broadcasting, where the radio wave irrevocably carries the selected performance to all homes.

As has been mentioned above, sound motion picture films may be excellent subject matter for programs from some stations, and may even afford one means of syndicating programs in somewhat the same way electrical transcriptions (phonograph disk records of programs) are now used. It is not believed, however, that television-telephone syndication will be fully satisfactory unless there are also actual interconnecting wire or radio networks between the outlet stations, since there will be many occasions (for example, a speech by the President, a political convention, an evening prize fight, and the like) when the public can hardly be completely satisfied by any radio performance which does not take place at the same time as the actual event. Indeed it must be admitted that this is one of the outstanding capabilities of radio broadcasting which it would be unwise to discard.

Many persons are convinced that television broadcasting will whet the appetite of the "lookers," and, so far from diminishing the theater audience, will build it up by arousing interest among children and adults alike in the probably more elaborate and highly developed offerings of the theater. It is also clear that the theater can, to a considerable extent, utilize radio advertising by television-telephony, for example, by the sponsored transmission of trailers of one sort of another. Radio will then offer the theater a remarkably effective method of submitting its "sample line" to the public.

This brings us to topic *d* above, namely, the possible effect upon the theater of the wide-spread acceptance of television-telephone broadcasting. We are inclined to be definitely optimistic as to this. The argument that television broadcasting may keep people out of the theater does not appear to have much weight. Consider, for example, the following controlling principles:

(*1*) Intrinsically the home is certainly not so good a showplace as the theater. It is more difficult to suppress natural and man-made noises in the home; here manners tend to be more "free and easy" than is desirable for showman-like presentations; the problem of setting up the theater in the home is far from simple when furniture must be moved to afford a good view of the screen and the home folks and guests located in the corresponding convenient viewing positions; and home lighting is rarely as controllable or suitable for picture presentation as is the case in the theater. Indeed, the customary surroundings of the home are not especially favorable for the creation of a world of illusion, which has always been the successful function of the theater. It is not maintained that there will not be value and interest to the home presentation—quite the contrary. It is stressed, however, that the home has certain disadvantages of long standing for program presentation which can not be disregarded.

(*2*) Conversely, the theater has a number of definite and inherent advantages as a showplace. It arouses the interest of the audience by heavy theater advertising in the press, by the play-up of the "fan magazines," and by other exploitation methods known to skillful managers, thus creating in the prospective audience the proper mood of pleasurable anticipation. The marquee and lobby of the theater, ablaze with light and motion, and with attractive photographs of selected scenes from the picture displayed within, further attract the audience. Within the theater, suave but real discipline is maintained by the ushers—a task calculated to daunt the bravest in the home. Furthermore, the price of admission, exacted at the box-office just before entry, is a powerful deterrent to lack of interest on the part of the audience. It takes a poor picture indeed to force the audience to cheat itself by inattention.

The program in the theater generally is a well-planned arrangement of elements which fit together and which take as long as may reasonably be required to get the desired effect. In broadcasting, because of certain administrational problems, the successive elements of the evening program are coördinated only with the utmost difficulty, if at all, and necessarily run in 15- or 30-minute slices—a not always convenient or artistic time. At the present time, with the occasional obnoxious exception of excessively prolonged or unduly fulsome blurbs relative to approaching attractions, the theater screen is practically free from advertising, whereas advertising and the sponsored program are at present the commercial basis of the maintenance of broadcasting. The elaborate perfection of some feature pictures will be duplicable only rarely within the necessary economic limits of broadcasting. To the preceding factors may be added the air-conditioning of many theaters and the attempts at comfortable theater seating, lighting, and the like. All in all, theaters may be expected to be attractive places of the public regardless of other entertainment media.

(*3*) If we consider some deep-seated characteristics of human beings, it becomes further evident that the theater has certain ways of holding its own alongside a successfully developed television-telephone broadcasting set-up. People are interested in change. If they are in the home a good deal—and most of them are—they naturally will seek some of their entertainment and diversion elsewhere. The remarkable vogue of the automobile in which many persons wander rather aimlessly from one place to another largely for the sake of motion is a case in point. People are also gregarious and somehow seem to have their emotional responses enhanced by crowd enthusiasm. One can readily observe this at sporting events, political rallies, revivalist meetings, and other occasions where collective enthusiasm or emotional responses are developed. Then too, people are distinctly conservative in their pleasures and not prone to abandon hastily anything which for a number of centuries has proved a trusted source of entertainment and amusement. It seems most likely that the theater and television-telephone broadcasting will each be successful fields in their own domain, and that the theater need not be unduly apprehensive over the advent of television.

Nevertheless, it must in all candor be emphasized that film producers and theater managers must not be merely content with past achievements. To hold their positions of leadership in their chosen fields, they must steadily improve and frequently experiment. It is necessary that they shall use whatever good ideas or methods may spring from television broadcasting, for example. A merely superior or indifferent attitude toward new arts or toward improvements in their own older art may prove a first-class passport to diminished public acceptance and ultimate oblivion. Of necessity the motion picture industry must also fully avail itself of all the skilled advice and guidance which it can secure only from the relatively few experts who are acquainted with both the theater and broadcasting. Few things would be more dangerous to the motion picture industry than dependence upon certain of the pathetically absurd misstatements which have been widely circulated by some of its members. However, given its natural advantages, a forward-looking attitude, real initiative, and careful planning, there appears to be little doubt that the motion picture theater can hold an enviable position of public acceptance and resulting prosperity in the future as in the past.

THE THEATRICAL POSSIBILITIES OF TELEVISION*

H. R. LUBCKE**

Summary.—*By analyzing the capabilities of television and of the theater, it is shown that they are best adapted to serve different needs. Television is indicated as an adjunct to radio broadcasting in creating the "theater of the home." The use of motion picture film for television presentations is predicted, and mention of work in this direction by the Don Lee Broadcasting System is made.*

The theatrical possibilities of television lie in the future. By that is meant the use of television equipment in the theater, as we know the theater today. The possibility of television's engulfing and destroying the motion picture industry is remote.

If we examine the capabilities of television and of the motion picture, we find that they are best adapted to serve different needs. Television, through the agency of broadcasting, is adapted to reproduce a few events for many individuals in many small groups; in other words, to reach the public in the home. The motion picture and the theater are adapted to reproduce a few events to many individuals in a few large groups; that is, to entertain the public in the theater.

Television can exhibit as many different events simultaneously as there are broadcast stations equipped for the purpose, which will be comparatively few in number. The theater can produce as many plays simultaneously as there are theaters, which is the usual practice. We shall look to television as a source of news and timely presentations, and to the theater for highly artistic productions of the classics.

Television *can* present events as they happen, as well as present recorded on enacted versions thereof; and by enlarging its screen from home to theater size, it would be possible to present them also in the theater. It has been rumored that such a project is under way in England, as a private enterprise, and that transmissions are to be received from Ireland.

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** Don Lee Broadcasting System, Hollywood, Calif.

The great need for television is, however, to bring sight to the American radio, so that it may become a *complete* medium of expression, as was accomplished in motion pictures in bringing sound to the silent screen. It is in this field that television will develop. And in this field its theatrical possibilities will become known.

The five years of television activity in which the Don Lee Broadcasting System has been engaged, and the work done by the Radio Corporation of America and others, have been directed toward producing television broadcasting transmitters and home receivers—not in the development of theatrical television equipment.

FIG. 1. Sample frames from the television version of *Hawkins and Watkins, Incorporated.*

The fruition of this activity will bring about the "theater of the home," as we might term it. This will *not* be a duplication of the present theater. There will be no mass psychology, no gathering together of people for the common purpose of being entertained. The individual will be addressed in his home, and his attention will be demanded for shorter periods of time—for fifteen to thirty minutes instead of from ninety to one hundred and twenty minutes.

The programs will undoubtedly be supplied without charge. The combination of radio and television comprises the greatest advertising medium of all time; and as such it will be exploited, regardless of cost and other difficulties. It will be exploited wisely and on a high plane by the leaders of the broadcasting industry. It will be some time, however, before the smaller broadcasters enter the field.

Theatrically, television provides proper expression for drama, comedy, news, and what might be called the "short story." The short period of any one program will develop this new treatment on the order of a more complete radio drama. Large spectacles, extended outdoor plays, and performances of symphony orchestras are not suitable for television broadcasting. Their stories can be told in other ways; and the new technic involved will become that of television.

We shall expect to see theme pictures as we now hear theme songs. We shall be interested in them as we now follow the actions of the little girl and her fuzzy dog upon the billboards. We shall see institutional presentations. We shall be educated as to how products are made and how processes are carried out.

The motion picture industry will record many of these programs upon film. Film lends itself peculiarly to the production, transmission, and distribution of television programs in ways that are quite apparent. Production can be done piecemeal and the result edited. The television projector for transmitting motion picture film has been brought to the highest state of perfection of any of the transmission devices. Positive prints can be sent country-wide for simultaneous release, or on a tour of the country in the interests of economy.

As an example of what has been done in this field, the story for the television version of the Mack Sennett comedy *Hawkins and Watkins, Incorporated*, a two-reel talking comedy with Matt McHugh and Forrester Harvey in the principal roles, was shortened from twenty minutes to eleven minutes. The object was to present the comedy in shortened form, so that it could be given, with suitable announcements, in the standard fourteen and one-half minute radio period. The script was reduced from 80 pages of 91 scenes to 8 pages of 15 scenes. Few scenes were used, to lower the production cost.

Particular attention was paid to costuming, make-up, lighting, and photographic composition. The effort was in the nature of a test to find what filming was particularly desirable; and many principles and practices in this direction were established.

In such manner will theatrical showmanship become a part of television—not to address a single audience in a tangible theater, but to address the scattered audience of radio—not alone to entertain, but incidentally and pleasantly to sell the goods and wares of our country. Radio, the motion picture, and the stage will contribute to, and be engaged by, this new enterprise. Television will become a new entertainment industry and, as such, can not be considered as a destroyer of existing entertainment enterprises.

DISCUSSION

Chairman Rackett: How long have you been broadcasting motion pictures from your local studio?

Mr. Lubcke: Our television transmitter, *W6XAO*, officially went on the air Dec. 23, 1931, and we have been broadcasting television programs since that time. On May 21, 1932, we demonstrated the first television image ever received in an airplane. A self-synchronized cathode-ray receiver was used. We have transmitted more than 7,000,000 feet of motion picture film, through the coöperation of the Paramount and the Pathé organizations, including Paramount features, Paramount shorts and Pathé Newsreels, as well as certain flash news events. Through the courtesy of Pathé News we broadcast scenes of the Los Angeles earthquake soon after it happened; and through Paramount News, the Stanford-U. S. C. football game on Armistice Day two years ago, three hours and forty-five minutes after it was played.

MR. GLUNT: Within the territory covered by the station, how many persons are equipped to receive such broadcasting?

MR. LUBCKE: The number is in the hundreds rather than in the thousands or millions. We have prepared mimeographed information which is sent upon receipt of a stamped self-addressed envelope to anyone hearing our signal or who is otherwise interested. This gives technical information and references sufficiently complete so that a somewhat experienced person can construct a television receiver. Through such service receivers have been built from time to time by various persons, some residing as far east as Pomona, La Verne, and Montebello; others as far north as Santa Paula, some 50 or 60 miles, air line; some within the city; and others in other areas surrounding greater Los Angeles.

MECHANOGRAPHIC RECORDING FOR MOTION PICTURE SOUND-TRACKS*

J. A. MILLER**

Summary.—*The mechanographic system of recording known as the Millerfilm is described. It makes use of a special film having a coating of clear material upon the base, which, in turn, is covered by an extremely thin layer of opaque material, approximately 2 microns thick. The cutting tool is a specially prepared sapphire, the edges of which make a very oblique angle with the surface of the film, cutting a hill-and-dale sound-track. The track is cut "clean," the demarcation between the opaque and transparent portions being very sharply defined; the opaque portions have a very high density, and the transparency of the clear portion is uniform.*

From time to time there have been presented to the Society papers dealing with the methods and problems in connection with recording sound for motion picture accompaniment. In the beginning these papers had to do with recording on wax and of late with the photographic processes of recording on film. There is still a third method which has not yet been described before this Society and which is destined to play an important role. The introduction of this method is the reason for this paper.

It is perhaps best that we review briefly the history of sound recording so we may all know the long and tedious paths that have led up to the present stage of the art, and thus better visualize what is apt to happen in the next few years. The first sound recording and reproducing machine was built by Edison in 1876, which makes the industry now 60 years old. This first machine was a metal cylinder mounted upon a shaft with a flywheel and a hand-crank for turning. The surface of the cylinder was grooved, and over it was stretched a thin sheet of tin-foil to receive the recording. The sound box was of the hill-and-dale type and the needle did the recording at the same time that the tin-foil was pressed into the groove of the cylinder. Work upon the machine was discontinued from time

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** American Mechanographic Corp., New York, N. Y.

to time on account of the development of the electric lamp, and it was not until the 80's that Edison perfected the well-known Edison phonograph.

It is interesting to note that at this time C. E. Fritts was working upon a method of recording sound upon film photographically, and in 1880 he filed his first patents. These patents were issued in 1917, long after the inventor's death and after being in the patent office for the record time of thirty-seven years.

In 1891 the mechanographic system was invented, and in 1898 came the telegraphone, or magnetic system.

Thus it will be seen that from the beginning of the present century

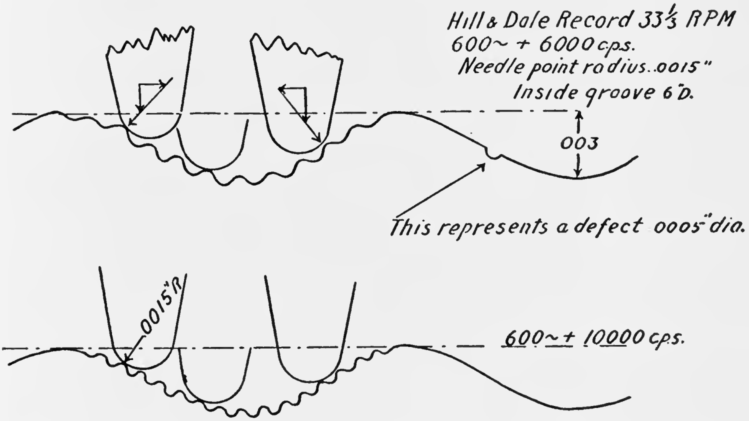


FIG. 1. Showing deformation of surface of record by high unit-pressure at point of contact, where rapid changes occur in the pressure angle, and defects causing surface noise.

we have been engaged only in perfecting the processes that were invented much earlier. Although patents have been granted on other systems they have never reached a commercial stage, so they will be ignored.

The four present-day commercial methods may be defined as follows:

Mechanical—Wherein the recording and reproducing are done mechanically.

Photographic—Wherein the recording is done photographically and the reproducing is done optically.

Mechanographic—Wherein the recording is done mechanically and the reproducing is done optically.

Magnetic—Wherein the recording and reproducing are both done magnetically.

The progress toward perfection of these methods can be traced with respect to the perfection of materials and the reduction of physical limitations of processes and equipment. It must be borne in mind that in recording sound a measurement of one ten-thousandth of an inch is a large measure, and other physical characteristics must be correspondingly limited. Many times it has been necessary to await the invention of auxiliary equipment, such as the vacuum-tube amplifier.

With primitive equipment it was much easier to arrive at, say, a 90 per cent result by the mechanical method than by any of the others. That is the reason why it led the field in development and commercial

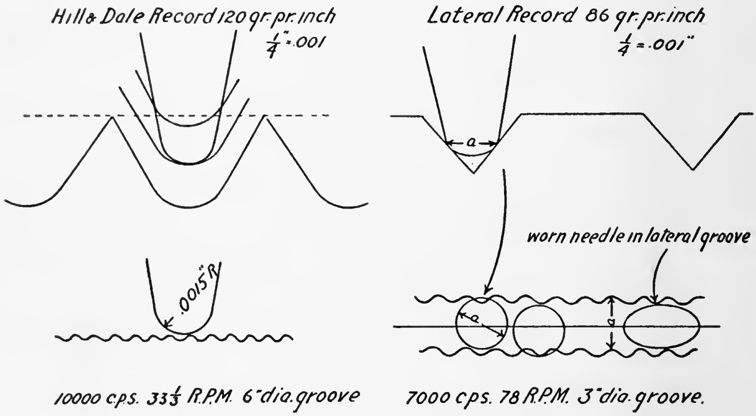


FIG. 2. Illustrating shock excitation and cause of distortion.

adaptation. With present-day equipment, however, it is easy to attain a 90 per cent result with any of the four systems listed above; but as far as motion picture recording is concerned, the mechanical (or disk) system has been eliminated and the telegraphone is not adaptable, so we can consider principally the other two systems, the photographic and mechanographic. Under the heading of photographic we must include the variable-density and the variable-width systems of recording, in considering the limitations of each. All the systems have inherent limitations, and perfection becomes increasingly difficult with each additional improvement; and furthermore, consideration must be given to the adaptability of the system to the purpose at hand.

In magnetic recording a hard steel wire is used as the record material. As the wire is run through a steady magnetic field, the recording magnets act to fix the molecules in a definite state. The fixed magnetic field can be compared to the *C*-bias of a vacuum-tube. In order to produce good quality it is necessary that the recording magnets be in contact with the wire. The limitations of the system are, therefore, the magnetic hysteresis of the wire and the mechanical irregularities of the surface of the wire, which produce ground-noise. There is also the difficulty that a high modulation at a given stretch of the wire will be transferred to an adjoining turn of wire, thus appearing as an echo. The quality of the recording can be quite good, but in order to keep the surface-noise down the preparation of the wire becomes very expensive. The wire is very difficult to repair when it breaks and, in general, the system is adaptable to very few kinds of work.

With mechanical recording we have witnessed a most peculiar development, wherein Edison very early in his work arrived at a hill-and-dale recording upon wax, with an acetate pressing; and now after fifty years of intense research we have arrived back exactly at the same point. Adding to the descriptions in many of the early Edison patents a chapter on modern vacuum-tube amplifiers, one has the whole story. The limitation of the mechanical system lies mainly in the playback mechanism. The recording is done with a sapphire having a straight-line cutting edge, whereas the reproducing is done with a ball-pointed needle. If a small pointed needle is used, the radius of the ball may be one and one-half thousandths of an inch. Of course, if a hard record is used with a steel needle, the point endures only for about two revolutions; but if a sapphire or diamond is used upon acetate, then the point remains, and the surface of the

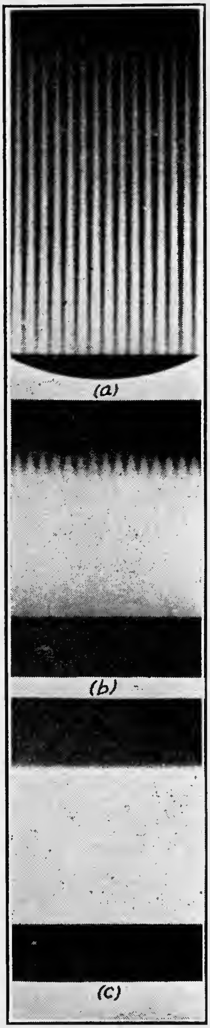


FIG. 3. Illustrating the limitations of photographic recording: (*a*) 6000 cps., full modulation; (*b*) 6000 cps., modulation reduced 25 db. from sound level of *a*; (*c*) unmodulated. *40x.*

record is deformed by the extremely high unit pressure at the point of contact, especially at points where rapid changes occur in the pressure angle as shown in Fig. 1. The change of the pressure angle causes rectification of the main wave and shock-excitation of secondary degrees of freedom of the moving element of the reproducer, giving a very sharp and unnatural effect to the high frequencies. Shock excitation may occur also in the record material itself: the elasticity of the material can not be ignored at the higher frequencies. In addition, the surface of the material is not completely homogeneous, and thus causes surface-noise (Fig. 2).

With variable-density film recording, the limiting factors are numerous, such as lens dispersion, width of recording slit, fogging and spreading of the image in the emulsion. In addition, there are critical factors that must be accurately met, but can not be listed directly as limiting factors, such as light exposure, uniformity of the emulsion, matching emulsions from negative to positive, printing exposure, development time, *etc.*

With variable-width recordings the limitations are lens dispersion, film image spreading, fogging, emulsion irregularities and width of the recording slit. In fact, with these two systems Kellogg's[1] simile can not be improved upon: "We have given our painter not only too big a brush but a piece of blotting paper upon which to make the picture, and paints that run" (Fig. 3).

The physical limitations of the photographic processes have been so reduced during the past five years that it is really remarkable what can be achieved by these methods, which were regarded as hopeless as late as 1928; but it is unfortunate that such a large proportion of recording is so far below the top level that has been attained. The reasons for poor and medium quality recordings are not easily ascribed to their proper source, and consequently there has grown up the familiar chorus we have all heard so often: the placement was wrong, the piano was bad, the recorder was wrong, the film was bad, the laboratory spoiled it, the gamma was wrong or perhaps the reproducer was "haywire." One of these things doubtless was at fault; but it is a long road to travel before one finds out he is on the wrong road.

With these things in mind we survey the field to see exactly what it is we want in the way of a recorder for a motion picture track, and then check against what is available. First, as has been proved by practice, the sound-track must be upon the same film with the picture. This eliminates from consideration both magnetic and mechanical systems. Now, assuming the same quality among the other methods, I should say choose a variable-width track, because the critical conditions of recording are more easily fulfilled, and it is much safer to transfer photographically from the negative to the positive. This is especially important where dupe negatives are used in the foreign markets. The next thing that is necessary is an immediate playback, and by this I do not mean the playing back of some makeshift record taken on an entirely different recording system, but the immediate playback of the finished record which is to be used for production purposes. The full importance of this is not realized until it is seen in actual practice. So far, the director of a picture has not been the director of his sound; and in many instances he has had to make the best of a bad situation, which could have been avoided by checking the recording directly after it was made. Not only can the quality of the picture be improved by due application of this principle, but the cost of production can be reduced also. In order to make this point concrete, mention might be made of two pictures which were released with an interval of time between, in which the same operatic star appeared, the first picture a failure and the second a grand success. Non-technical persons whom I have interviewed have agreed that the sound of the first was bad and that of the second exceptionally good, whereas technical men have told me that the first was good and the second so bad that changes in the reproducing equipment were necessary before the picture could be shown in the theater. This is only one example where sound may have been the cause of failure of a picture. There are other more outstanding examples and a close study of the situation might be very surprising. In view of this fact the author wishes to state that in his opinion it is the duty of the engineers to place into the hands of the director of the picture the tools best suited to his trade, and not to assume the responsibility for the psychological coördination of sound and picture: at the earliest possible moment the engineer should make it possible for the director to assume this responsibility. The director is endowed with a temperament more closely attuned to that of the public than is possible of attainment by a technical person, and it is therefore better business for everyone concerned to rely upon the director in this respect. It should not be inferred from this that the importance of the recording business as such should be under-rated; in fact, recording should not be regarded simply as a "spare wheel" for the motion picture industry but as an essential and coöperating art, older in years, but as yet drawing only two cents of each motion picture dollar.

The next step in our survey then brings us to the mechanographic system as the only means of achieving all the desired results described. By means of this method it is possible not only to play back the completed record as soon as it is recorded, but to play the record while it *is being recorded*, with a delay corresponding to four frames of the picture. We are also able by this method to reduce the paint brush to which Kellogg referred to an irreducible minimum and to eliminate the blotting paper.

The first mechanographic machine was built in Berlin in 1891, and consisted of a paper strip coated with a black layer into which was cut a lateral groove, thus removing the black layer within the groove. Upon this groove was cast a strong light, which passed through the paper and through a lens which focused a half-image of the track upon a slit, behind which was placed a selenium cell which in turn operated a telephone receiver. Considering the materials available at that time it will be realized that that was a big step: but with present-day knowledge it is easy to see how the physical limitations of the equipment and materials would admit of only the most primitive results. Nothing further seems to have been done with the system until 1930, when Berthon reinvented it, and in conjunction with Nublat, developed a machine that was put upon the European market as a phonograph, and known as the Nublat machine. The later models of this machine, instead of cutting into a black layer, were made to cut through the center of a thin black film, thus making a sound record upon the edge of each half when the film was split. Printing was done with cylindrical optical enlargement in order to increase the amplitude of modulation. The results attained were only fair, as might be expected on account of the severe physical limitations. It will be seen that at a frequency of 6000 cycles and at standard motion picture speed, and with a cutting tool having a heel angle of 45 degrees, it is possible to cut to an amplitude of only 0.002 inch, whereas an amplitude of 0.080 inch is required for motion picture film. At the same time, if it were possible to reach practical amplitudes the power required would be enormous; in fact, several kilowatts would be required to record up to a frequency of 10,000 cycles per second. Although the machine was introduced upon the phonograph market in France, the quality was not good enough for the motion picture field.

It was not until 1931 that the invention was made which now makes it possible to attain with the mechanographic system better results than with any other system. The system now used, known as *Miller-film*, makes use of a special film having a coating of clear material upon the base, which, in turn, is covered by an extremely thin layer of opaque material, approximately two microns thick. For all ordinary purposes the film is very tough and durable: in fact it can not be scratched by the fingernail. The cutting tool (Fig. 4) is a specially

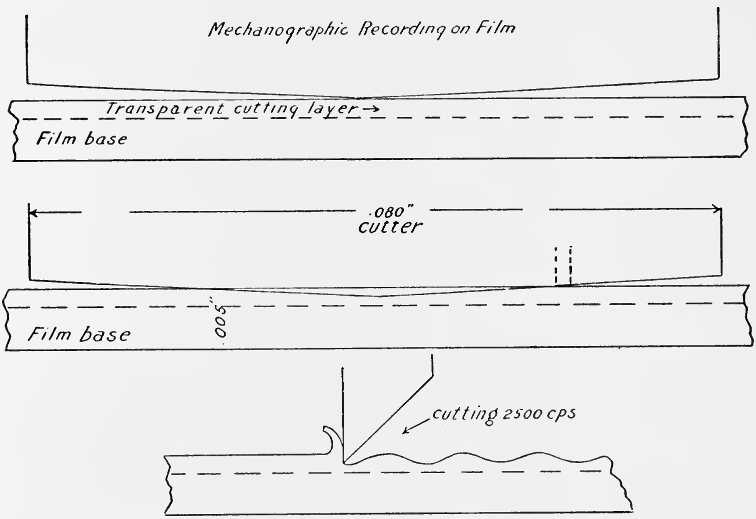


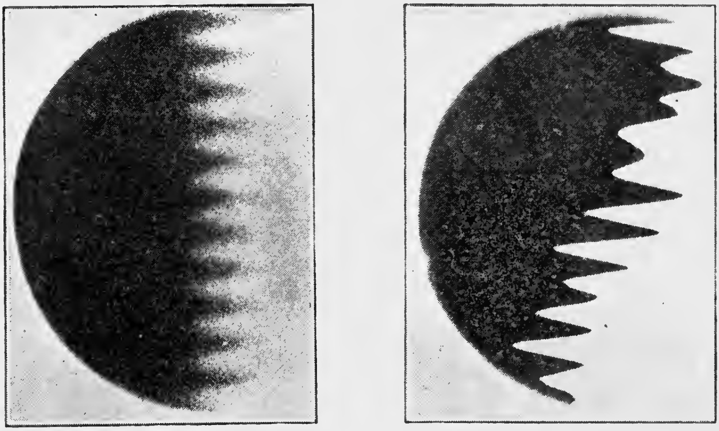
FIG. 4. The cutting tool used in the mechanographic system.

prepared sapphire, the edges of which make a very oblique angle with the surface of the film. Instead of cutting a lateral track as heretofore, the track is hill-and-dale. It will now be observed (Fig. 4) that a very small movement of the cutting tool in the vertical direction produces a great change in the quantity of black layer that is removed. Thus is attained a mechanical amplification of from fifty to one hundred times, comparing the movement of the cutting tool to the variation of the width of track cut. Instead of having to move the cutting tool 0.080 inch for full modulation of the sound-track, it is now possible to attain full modulation with a tool movement of 0.001 or 0.002 inch. This forms the basis of the

FIG. 5. Comparison of lines of demarcation between opaque and transparent sections of record; (*a*) photographic negative; noise reduction, zero modulation, variable-width; (*b*) mechanographic; zero modulation; (*c*) photographic positive; low modulation. *300x.*

development, but in order to bring it to the point where it could be applied commercially it was necessary to cover much unexplored territory. In the first place there was no film that could be used, even for a test; no cutters were available that would answer the requirements; and no machine that would carry the load necessary for this work. In fact, the only thing available in sufficient quantity was advice to the effect that the system could never be made to work, and that was present in abundance.

Many tests were conducted to determine what material could be applied to a film that would be flexible, transparent, and have the same cutting characteristic as wax. Upon the surface of such a layer must be placed an extremely thin layer of opaque material having a fine grain structure which will cut with a smooth surface, have sufficient strength to withstand damage, and have a definite line of demarcation between the opaque and transparent sections. This was a complete research problem in itself, but film is now available that fulfills all these requirements; and when it is cut, as can be seen in Fig. 5, the line of demarcation is much more definite than can be achieved photographically. The importance of this fact must not be overlooked, as the limitation of all systems depends upon the definiteness of this line of demarcation on an unmodulated track. If the maximum modulation of the track is of 0.080 inch, and the desired range 125 db., then the first 100 db. must be included within modulation peaks not exceeding 0.004 inch high, which does not allow for much irregularity in the line of demarcation. It is possible to obtain film of this sort with the black pigment in colloidal form and of such concentration that grain size is no longer a factor as in the photographic process. The edge to which a sapphire cutter can be ground is microscopic; whence there is no limitation that corresponds to the width of the recording slit, so that frequencies as high as 25,000 cps. can be recorded (Fig. 6). Of course, in reproduction, the width of the reproducing beam enters as a detrimental factor, but in this case it is not so important as in recording, and is far better than any needle could be. Irregularities of the emulsion are no longer present, and even the surface of the film



(*a*) (*b*)

FIG. 6. 6000-cycle recordings; original negatives: (*a*) photographic sound-track; (*b*) mechanographic sound-track. *100x.*

where it has been cut is much improved over a plain emulsion surface.

The cutter was the next item of importance, and required a wide departure from current practice inasmuch as it has to be a constant-amplitude device. In order to gain sufficient movement at high frequencies it is necessary to tune the element to a high audio frequency. A cutter has been produced that will record up to 10,000 cycles per second with a power consumption of about two watts. From this it is easy to understand the impracticability of the old mechanographic system with a lateral groove. The movement of the element would be fifty times greater, whence the requisite power would be in pro-

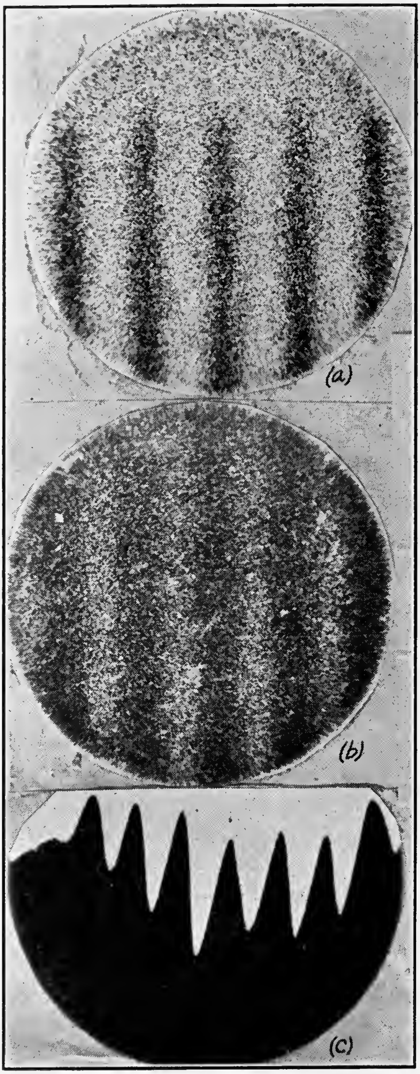


FIG. 7. Illustrating the advantage gained in noise-reduction due to irregularities in the transparent portion of the film, and the sharp demarcation in the mechanographic recording: (*a*) SMPE standard, tips, 6000 cps.; (*b*) SMPE standard, base, 6000 cps.; (*c*) mechanographic sound-track at point where 7000 cps. occurs.

portion to the square of this figure, or 2500. In addition, the efficiency would be only one-tenth as great, on account of the additional air-gap, which would make the power ratio 25,000 to one. In other words, instead of two watts, the cutter would require about fifty kilowatts. The details of construction of the cutter can not be given at the present time, but the response curve of a typical example can be constructed flat within two db. for 30 to 8000 cycles or from 30 to 10,000 as desired.

The machine itself offered several problems inasmuch as the work done upon the film by the cutter must not interfere with the uniformity of movement of the film. An ordinary sized flywheel prevents any variation in speed of the driving sprocket, but special provision must be made to prevent slippage of the film on the sprocket. Several means of doing this have been developed.

A study of an original record of the process leads to many interesting observations. More than one track can be recorded upon the same piece of film. Cutting and re-recording can be done from the original. Short ends can be utilized. There is no darkroom loading of magazines. Examination of the track shows that the groove is cut clean, the surface is as smooth as glass, the opaque portions have a density too high to measure, and that the transparency of the clear portion is uniform.

Experiments with film of varying degrees of resolution leads to the conclusion that, whereas the fundamental tone, the power, and, to some extent, the

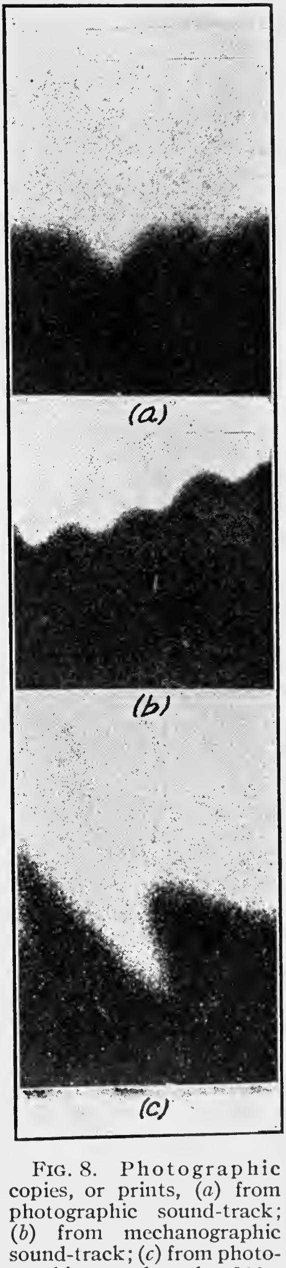


FIG. 8. Photographic copies, or prints, (*a*) from photographic sound-track; (*b*) from mechanographic sound-track; (*c*) from photographic sound-track. *300x.*

character of speech are governed by modulations of high amplitude, the realness or lifelike quality is governed by modulations of very low amplitude. That is, a voice can be recorded loud and clear, with perfect intelligibility, but it may be still unrecognizable as to the original speaker. This is also seen in a recording in which there is room tone or echo. If the amplitude of the reverberations is high, they cause confusion, but if their amplitude is low and they lie in the valley between high amplitudes of the original sound, they add character to the sound. In the case of a spoken word the time occupied by these low amplitude sounds may be fifty per cent of the total time taken for the word. This time-interval varies through a wide range for various voices, so that a voice with a high ratio of large amplitude sounds is an easy voice to record, while the converse is also true if the low modulations are lost on account of the poor resolving factor of the film. This experiment has been performed with film having an opaque layer of varying degrees of uniformity, and it is found that the naturalness decreases steadily as the line of demarcation becomes less and less definite. The same corresponding result is arrived at if a print is made from a good negative onto ordinary photographic positive film. This is the factor that determines the minimum recording level, and is evident when a recorded sound is so disturbed by ground-noise that it is annoying for the ear to separate the two. The useful recording range of the system is then the ratio between this minimum sound level and the maximum sound level that the track can accommodate. The perfect recording system would encompass about 125 db., but with the present photographic systems the range varies between 35 and 45 db. and with hill-and-dale acetate records from 50 to 55 db. Therefore, in making measurements of losses at high frequencies, either from recording or printing, it is not sufficient to say that the loss is six or eight db. on a fully modulated track; the recording range and the loss in the last ten db. of the recording range toward the end of minimum recording level must be stated also.

Noise reduction methods reduce the disturbance introduced by irregularities occurring in the transparent part of the track on a dirty film, but have no effect upon limitations caused by irregularities of the materials of the record carrier at the line of demarcation. Eight or ten db. are gained in this manner if the film is bad, but any real extension of the range must be accomplished by improving the material of the carrier itself. That this improvement is accomplished by the mechanographic system is clearly seen in Fig. 7, and it should be possible to have a consistent working range approaching 75 db. by this method. This can be appreciated better by realizing that if the same degree of perfection of the record carrier is arrived at as is reached with an acetate record of the hill-and-dale type, then the advantage gained is of the order of 50 db., which would indicate a possible range of 100 to 105 db. We assume first that all major imperfections are easily removable and that the ones most difficult to remove are of an order of magnitude of 0.0005 inch or less. In a hill-and-dale mechanical record this irregularity produces 100 per cent modulation at

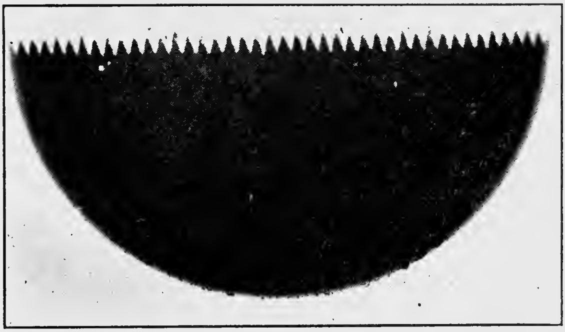


FIG. 9. Mechanographic sound-track showing resolution at 50,000 cps., at a recording level 55 db. below maximum.

6000 cycles, whereas on the mechanographic record it would produce a disturbance 50 db. below full modulation on account of the difference between constant-velocity and constant-amplitude recording.

In other words, when the time arrives for sound to be brought up to the standard that is now being demanded by a large part of the public, it will be necessary to re-record mechanographically on each release print. Of course, in the meantime photographic copies of mechanographic track can be used, thus obtaining a result that lies between the present photographic method and the direct recorded mechanographic (Fig. 8).

In conclusion, in Fig. 9 is seen a sample of resolution at 50,000 cps., 55 db., below maximum, that is better than can be achieved by photographic methods at 5000 cps.

REFERENCE

[1]KELLOGG, E. W.: "The Development of 16-Mm. Sound Motion Pictures," *J. Soc. Mot. Pict. Eng.*, **XXIII** (Jan., 1935), No. 1, p. 65.

DISCUSSION

DR. FRAYNE: Mr. Miller stated that the director should be the director of the sound as well as of the picture. At the present time I believe he does direct both. But to carry Mr. Miller's proposed schedule to its conclusion, the director should be able to view the picture immediately also. I hesitate to make any suggestions as to how that might be done.

PRESIDENT TASKER: How did you make the 50,000-cycle recording?

MR. MILLER: The recording was not done at 50,000 cycles; it was done at 8000, letting the machine slow down. It was done simply to show the resolution on the film at 50,000 cycles. Below that frequency, good wave-form is still maintained, which is very essential.

THE KODACHROME PROCESS FOR AMATEUR CINEMATOGRAPHY IN NATURAL COLORS*

L. D. MANNES AND L. GODOWSKY, JR.**

Summary.—*The new Kodachrome reversal process is a three-color subtractive process, the colors being formed by combining the three complementary or "minus" colors, which absorb the corresponding primary colors from the projection beam. There are three emulsion layers, separated by thin layers of clear gelatin, the first layer being sensitized to blue, the second to green, and the third to red light.*

The film is exposed in the ordinary manner, with the emulsion toward the lens. Processing is done by the reversal process, and the three positive images are their differentially dyed the three corresponding minus colors. The finished Kodachrome film is projected in the usual manner, without filters.

INTRODUCTION

The Kodachrome reversal process recently introduced is the result of an attempt to produce a color process that would involve no problems not incidental to black-and-white photography. While this was by no means achieved in its entirety, the process is, at least from the photographers' and projectionists' points of view, as simple as black-and-white photography. The problems involved are confined to the manufacturing and processing of film, thus placing the burden upon highly organized production facilities rather than upon the sometimes unskilled consumer. Pictures taken by this process are exposed at virtually normal speed in an ordinary 16-mm. camera of any type having a capacity of 100 feet and projected with any 16-mm. projector. No filters are usually necessary in taking or projecting, save in the case of artificial light, where a blue compensating filter is used over the camera lens. Under special daylight conditions involving haze, cold light, or an abundance of reflected ultraviolet light, it is sometimes desirable to expose through a colorless filter which absorbs most of the ultraviolet but does not change the color balance or exposure conditions.

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif. Communication No. 549 from the Kodak Research Laboratories.

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

I. CLASSIFICATION OF THE KODACHROME PROCESS

Color processes are generally divided into two types, the additive and subtractive. With the additive process the actual red, green, and blue colors are either visible in the film itself or are formed by an optical system, as with Kodacolor. These primary colors are projected onto the screen for viewing. Additive methods include Kodacolor, color-screen plates (such as the Autochrome plate), Dufaycolor, and others.

Any possible color upon the screen can be formed by additive combinations of the primary colors, red, green, and blue. Likewise, they can be formed by proper subtractive combinations of the complementary colors. The complement of red is blue-green, of green is magenta, and of blue is yellow. These complements are sometimes referred to as the *minus* colors, thus:

Primary Color	*Complementary Color*	
Red	Blue-green	(Minus red)
Green	Magenta	(Minus green)
Blue	Yellow	(Minus blue)

Subtractive processes, of which Kodachrome and Technicolor are examples, form their colors by combining the three complementary or minus colors. The minus or subtractive colors merely absorb the corresponding primary color from the projection beam of light. Such a light-beam may be considered as white light or as containing a combination of all colors.

If we put a blue-green (which is to say, minus red) filter or dye deposit into such a white light-beam, the red will be absorbed and the screen will appear blue-green. If, however, we add a magenta (minus green) filter to the blue-green filter mentioned above, both the red and the green light will be subtracted from the white light-beam. The only light left to go on through to the screen is blue, and that will be the color of the screen. Similarly, any color may be formed.

Accordingly, the blue-sensitive layer of Kodachrome will in the finished positive contain the complement of blue, which is yellow; the second or green-sensitive layer, the complement of green, namely, magenta; and the bottom or red-sensitive portion will contain the complementary color of red, which is blue-green.

II. FILM

Kodachrome film is panchromatic and bears the ordinary jet backings as used on regular Ciné-Kodak film. The emulsion, however, consists of three layers, each sensitized to one of the primary colors and separated from the adjacent layer by a thin coating of clear gelatin. The top layer of emulsion, upon which the light first falls in exposure, is sensitive only to blue light, but it does transmit green and red light to the layers underneath. While it is sensitive to the blue, it also contains a yellow dye which prevents the blue light from passing through to the silver bromide grains below.

The second or middle layer is sensitive to green and blue light, but as all blue is filtered out by the yellow dye just mentioned, we need to consider only its reaction to the green.

Next to the film support is the bottom or third emulsion, which is sensitive to red and blue; but here again, the blue being stopped in the surface layer, this emulsion reacts to red only.

Briefly, there are three separate emulsions sensitized as follows: the first or top layer to blue, second to green, and the third or bottom to red light. Each coating is exceedingly thin so that the total thickness is about the same as the thickness of black-and-white coatings.

III. EXPOSURE

Kodachrome film is exposed in the normal manner, that is, with the emulsion side toward the lens. It is unnecessary for the light to pass through the support, as it does in Kodacolor or any of the color-screen processes. The speed of the film is somewhat less than that of regular panchromatic Ciné-Kodak films.

IV. PROCESSING

Processing is carried out in continuous machines by a reversal process which converts, by the usual method, the images in all three layers to their corresponding positives. These three positive images are then differentially dyed the three corresponding or minus colors previously described, *i. e.*, blue-green, magenta, and yellow.

All silver is then removed from the film, after which it is washed and dried. The final positive accordingly carries a dye image only.

From the three stages of processing described, we now have the three complementary colors in their respective layers. The amount of each will depend, of course, upon the amount of silver bromide removed in bleaching the original negative. The three colors in turn will combine to form the positive image in natural color.

V. PROJECTION

As the finished Kodachrome film contains the actual colored image, projection is carried out under normal conditions. No filter is used. The light-source, projection distance, and type of screen are the same as for black-and-white film.

DISCUSSION

MR. KELLOGG: Will Kodachrome be available in roll film for ordinary cameras?

MR. CRABTREE: I do not know; it is not available at the present time.

MR. DUBRAY: What would be the effect of under- or over-exposure?

MR. CRABTREE: The effect is relatively the same as with black-and-white 16-mm. film.

MR. HOPPER: How permanent are the colors? Is the dye fairly permanent after projection?

MR. CRABTREE: I see no reason why they should not be satisfactorily permanent. Any dye, of course, is apt to fade under certain adverse conditions.

MISS EVANS: How soon will you be able to develop prints on the Pacific Coast without sending the films back to Rochester?

MR. HUSE: It is contemplated that by late fall we shall have equipment available in Hollywood for processing Kodachrome film, just as we have for black-and-white films. Arrangements are being made at the present moment to that end.

Some persons may have been wondering what is going to happen as regards the 35-mm. film. Up to the present time all our developmental work has had to do with the 16-mm. process. A great deal of work is still to be done in making duplicates or prints from that. Our experimental work on 35-mm. film has not really begun. We shall, no doubt, collaborate with Technicolor on that, for the reason that Dr. Troland's patent indicated that he had done work on a somewhat similar process. What will happen in the future we must wait to find out.

MR. TIMMER: Is it possible to put a sound-track satisfactorily on this film?

DR. SANDVIK: There is one problem that should be considered, and that is the problem of getting dyes that will, in addition to giving satisfactory visual color rendering, also have sufficient absorption in the spectral range to which the photoelectric cell is sensitive.

As most of you know, in the past two years the trend has been to extend the sensitivity of photoelectric cells farther and farther into the infrared, until now some of the cells have the maximum sensitivity at 0.9 mu, which is far beyond the red end of the spectrum. It is a question then of either choosing dyes having a fairly high absorption in the infrared or else sacrifice some of the photoelectric cell sensitivity by using dyes that have a lower absorption throughout the spectral region to which the photoelectric cell is sensitive.

INTRODUCTION TO THE PHOTOGRAPHIC POSSIBILITIES OF POLARIZED LIGHT*

F. TUTTLE AND J. W. McFARLANE**

Summary.—*The introduction of an efficient plane polarizing sheet material in sizes large enough to cover lenses and lights has made simple the use of polarized light in photography. An Eastman Pola-screen, incorporating this material, over the lens, allows unusual sky effects, photographing obliquely through glass and water without reflections, and photographing other surfaces obliquely to show surface detail. When the subject is illuminated through larger Pola-screens, in addition, complete control of gloss results. Faces so photographed can appear unnaturally perspiry, or devoid of all lustre, depending upon the camera Pola-screen position. Reflections from animation cells can be greatly reduced, and photographing any small subject that presents a reflection problem is quite simple. Various trick lightings and color effects are also attainable.*

Our eyes respond naturally to differences in color and in intensity of light, and it is by these differences that we are able to see the world around us. There is another property in which light rays may differ, but our eyes, unaided, can not see those differences. This property is called "polarization," and is concerned, as explained later, with the manner in which the light ray vibrates. Light rays may be polarized by optical devices; they are also partly polarized by reflection from common objects. It also happens that clear skylight is partly polarized. For the last two reasons, much of the light by which we see things is polarized to some extent, a fact we first realize when we look through an Eastman *Pola-screen.*

HOW LIGHT WAVES ARE POLARIZED

While the nature of light is not entirely understood, many phenomena can be explained by assuming that light is a vibratory motion which is propagated through space in the form of electromagnetic waves. Among these phenomena is the polarization of light.

The vibration of a light wave is not along the direction of the ray, as in the case of sound, but is at right angles to the ray and usually

* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

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

in all possible directions, that is, up and down, sidewise, *etc.* (Fig. 1). It is possible by various devices to change the light ray so that it vibrates in only one direction, as shown in Fig. 2. This one vibration is not only composed of the one originally vibrating in this same direction, but is also composed of parts of all the others, except the one vibrating at right angles to it. The result is that almost half the light is allowed through, even though there is only one direction of vibration. It may help to explain this if we draw an analogy:

Imagine a string stretched horizontally, passing through a slit in a card at right angles to it. If the slit is vertical, the string is able to

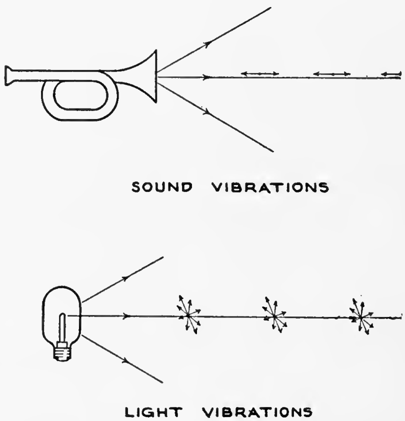

FIG. 1. Sound waves vibrate along the direction of travel; light waves vibrate at right angles to the ray and, ordinarily, in all possible directions.

vibrate in a vertical plane only, and if the slit is horizontal, the vibrations are restricted to a horizontal plane. If the card is rotated, the vibration plane of the string follows the slit. Light behaves in much the same way, except that the vibrations require the optical equivalent of a mechanical slit. A light ray in which only one direction of vibration exists is said to be *plane polarized*, that is to say, polarized in one plane. The vibration plane, that is, the plane parallel to the vibration of the emerging ray, is definitely fixed in the polarizing device, and is rotated when the polarizing device is rotated. A second polarizing device, placed in the path of the ray leaving the first polarizer, may or may not transmit the plane polarized ray, depending upon its angular position. At one angle, practically no light is allowed through, and the polarizers are said to be "crossed." At 90 degrees from this position, all the light from the first polarizer goes through, and the polarizers are said to be "parallel."

A number of polarizing devices, such as prisms made from crystalline Iceland spar, known as Nicol prisms, have been known to scientific workers for many years. Up to now, there has been no polarizing device suitable for ordinary photography. Nicol prisms are very costly, have a very small field, their length being much greater than their free aperture. The desirability of a highly efficient

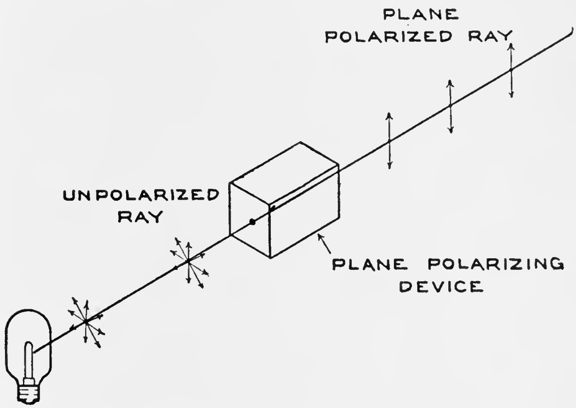

FIG. 2. Any plane polarizing device cuts down the possible directions of vibration to only one; this one is parallel to the vibration plane of the device.

polarizing device in sheet form has been recognized for some time. Such a material is now available, having the necessary optical properties and capable of being produced upon a commercial basis in sufficiently large sheets at a cost low enough to make it practical in photography. The invention is due to Mr. Edwin H. Land, who was the first to prepare a commercially practical sheet containing a polarizing material oriented properly for satisfactory performance. (U. S. Patents 1,918,848, 1,951,664, 1,956,867, 1,989,371.) In this material are countless minute rod-like crystals, which are all parallel to each other. They may be regarded as optical slits, so when the material is rotated, the direction of light vibration is rotated, just as rotating the slit made the string's direction of vibration follow it. The Eastman Pola-screen incorporates this polarizing sheet material, cemented between glass plates. The Eastman Pola-screen is therefore a large polarizing device, free from the limitations of the Nicol prism.

THE IMPORTANCE OF POLARIZED LIGHT IN PHOTOGRAPHY

The importance of polarized light in photography is due to the way in which all natural substances reflect polarized light. When a ray

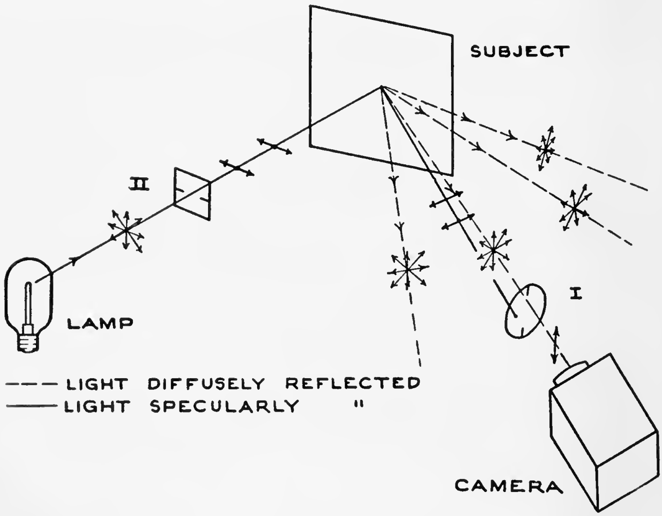

FIG. 3. Photography by diffusely reflected light, using polarizing equipment. Light reflected specularly retains its polarized form; it may therefore be cut out by a Pola-screen at the camera. *I* indicates a Pola-screen, Type I; *II* indicates a large Pola-screen, Type II. The indexes on the two Pola-screens show their planes of vibration.

of light falls upon, for instance, a sheet of paper, the light that is reflected is composed of two parts which are technically known as the specular and diffuse components. The specular component produces what we know as gloss and enables us to see more or less distinctly an image of the source of light. Light reflected from polished metallic articles is almost entirely specular, whereas that reflected from chalk is almost entirely diffuse. The diffuse component is reflected in all directions, and hence does not give rise to an appearance of glossiness.

Now, if the ray of light that is illuminating our subject is plane polarized, the reflected rays that form the specular component are still plane polarized, but the rays reflected diffusely are not. If we look at the subject through a Pola-screen, we can orient the screen so that practically all the specular reflection is stopped, and see the subject by diffusely reflected light. This fact, which is extremely important, permits the many applications described below. The use of Pola-screens in front of the lights illuminates the subject with plane polarized light. Another such device at the camera lens permits photographing by the diffusely reflected light alone, as is shown in Fig. 3. This is desirable in many cases, because the specularly reflected light or glare obscures more or less the detail that it is desired to record. It is obvious from Fig. 3 that if the Pola-screen at the

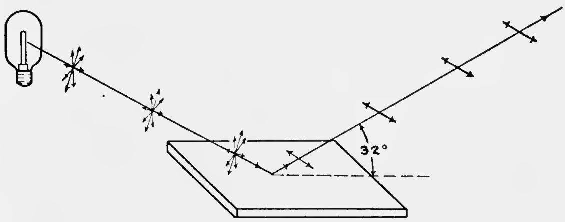

FIG. 4. Ray plane polarized by reflection. A ray of ordinary, unpolarized light is almost completely polarized when specularly reflected at about 32° to any non-metallic surface, such as glass. This permits eliminating oblique reflections from glass and water by a single Pola-screen over the lens.

camera is rotated, some of the specular light will be allowed to pass through, so that the amount of specular reflection is under the control of the photographer. When the camera Pola-screen is rotated so that its polarizing plane is actually parallel to that of the specular ray, this ray is transmitted even more freely than is the diffuse ray, so that the subject appears to have even brighter reflections and more gloss than it actually does have.

Plane polarized light, or light that is partially plane polarized, is very common in nature, so that the photographer who is equipped with a Pola-screen only on his camera lens finds that he has rather considerable control over contrasts in his subject, even though he is unable to change the lighting of his subject. There are two sources of polarized light in nature: (*1*) Light rays from a clear blue sky, arriving at right angles to the sun's rays, are strongly polarized (see

Fig. 5); when this same skylight is specularly reflected from water, *etc.*, these reflected rays are also polarized. (*2*) Ordinary, unpolarized light, specularly reflected from any non-metallic surface at about 32 degrees to the surface, is strongly polarized by the act of reflection (see Fig. 4). There is some effect at other angles, but none at zero or 90 degrees.

These two sources, separately and in combination, polarize much of the light from natural things. Unaided, our eyes do not detect polarized light, and so we have not seen until now that much of the light from our surroundings is polarized. Many natural things, seen through the Pola-screen, assume a new and strange beauty.

These effects can be photographed easily with a Pola-screen over

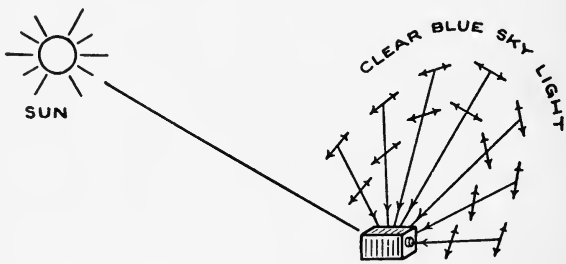

FIG. 5. Clear blue skylight, arriving at right angles to the sun's rays, is polarized. The sky may be darkened by the Pola-screen without affecting the color rendering of foreground objects. The strongest effect is attained with the camera axis roughly at right angles to the sun's rays.

the lens alone. It will pay the photographer to view his subjects. both in the studio and outdoors, through a Pola-screen, while rotating it to see the effects.

PROPERTIES OF THE POLA-SCREENS USEFUL IN MOTION PICTURE WORK

A. Pola-Screen over Lens Alone.—(*1*) Reducing polarized skylight to bring out clouds and other objects: A very dark sky may be obtained in color photography by this means which is impossible to achieve otherwise. The effect is greatest at right angles to the sun's rays. Therefore, at sunrise the region of greatest effect is north—overhead—south; at noon—near the horizon in all directions; and at sunset north—overhead—south again. The arc swings from overhead to the west during the morning, from the east to overhead in the afternoon, passing through every part of the sky.

Ordinary objects, faces, blossoms, trees, mountains, buildings, *etc.*, can be made to stand out against the sky in a very beautiful manner. If desired, the brightness of the sky may be increased relatively to objects photographed against it, by rotating the Pola-screen to the appropriate position. In black-and-white photography, thePola-screen can serve as a filter of variable depth—anything from red filter sky effects (without distortion of tone values) down to no filter effects may be attained by rotating the Pola-screen to the desired position.

(*2*) Changing the contrast of various parts of a subject, without changing the lighting: This effect is very marked in the case of the walls and roofs of buildings, sunlighted water, and pavements from above.

(*3*) Photographing subjects in water, from above: When the angle between lens axis and water surface is about 32 degrees, all reflections from the water surface are eliminated. Reflections may be removed to some extent at other angles, but not at zero or 90 degrees.

Photography through glass or other transparent media: As in the case of water, at 32 degrees from the surface, reflections can be completely removed. This effect can be used to produce double exposures by placing a thin pellicle mirror in front of the camera lens at the required angle, and rotating the Pola-screen at the lens. The image reflected by the pellicle mirror appears or disappears according to the angle of the Pola-screen. Other more obvious applications will suggest themselves, such as photography of aquaria, through windows, and so on.

B. Pola-Screens over Both Lens and Lights.—(*1*) Subduing specular reflections from metallic and other glossy objects: Metallic reflections can not be eliminated entirely, but can be subdued very greatly. Reflections from most other objects can be eliminated if desired. The Pola-screen over the camera lens is crossed with those over the lights for the greatest effect.

(*2*) Increasing specular reflections: Articles may be made to appear unnaturally glossy. The change, while considerable, is not as great as that possible in the opposite direction. The polarizing cells are used parallel.

(*3*) Increasing color saturation: By removing the surface reflection, which is white, the colors of an object increase in their saturation, that is, their purity. The crossed arrangement produces such effects.

(*4*) Effects upon faces: The crossed position produces a strange matte effect, with no luster whatever, and the facial colors are exaggerated. The parallel position has the opposite result—a very perspiry appearance, with the colors subdued.

(*5*) Photographing wet objects: The surface reflections from wet objects, such as clinical specimens, present a severe problem, as they hide detail. These reflections may be subdued as desired, or eliminated at the crossed position.

(*6*) Copying matte prints, pencil sketches, newsprint reproductions, and paintings: Matte prints reflect light specularly in all directions. When this specular component is removed the blacks of the print become much blacker, so that the use of crossed Pola-screens produces a brightness range in the print that is even greater than that of a glossy print viewed in the normal manner. Likewise, the reflections can be removed from pencil graphite and ink particles, producing intense blacks.

(*7*) Animation cells: Reflections from cells used in animation work build up with successive layers so that contrast is seriously affected, limiting the number of cells which may be used. These reflections may be greatly reduced by the crossed arrangement of Pola-screens.

(*8*) Birefringent crystals and fibers: The phenomenon known as birefringence causes any transparent object, possessing the property, to light up, frequently in vivid color, when placed between two crossed Pola-screens. Cellophane, silk, cotton wool, and many natural crystals have this property.

(*9*) Strained glass and celluloid: Any strained transparent medium displays birefringence, and when placed between crossed Pola-screens, shows a strain pattern.

C. Applications in Lighting and Printing.—The variable transmission of two Pola-screens together suggests a number of possibilities. Two Pola-screens used together over the lens constitute a variable neutral density filter, which may be of interest in making fades in some cases. The same arrangement can be used as an intensity control in a printer, and has the merits of simplicity; moreover, it does not cut down the area of the beam.

Two light-source Pola-screens together can be used for controlling spotlight intensity. Cellophane added between these units introduces various color effects.

Various lightings are possible with one Pola-screen over the lens and others at the lights. It is possible to place a back light so covered directly in the camera field. It is also possible to control the light reflected from any light so covered. A control, at the camera, is thus provided. It is therefore possible to photograph the same set with two cameras and obtain quite different lighting effects.

TECHNICAL DATA

The Eastman Pola-screens have a spectral range of polarizing power from 400–700mμ. They absorb in the ultraviolet, and transmit freely, without polarization, in the infrared. They can be damaged by excessive heat, by placing them within a few inches of a lamp bulb, or imaging a lamp filament upon them.

The most suitable negative materials are the panchromatic materials now in general use. While it is possible to use the Pola-screens with orthochromatic or even with non-color-sensitized materials, the exposure increase is very much greater.

The exposure increase, for the Pola-screen over the lens alone, is about four times. For Pola-screens over both lens and lights, the exposure increase is ten times and upwards, depending upon the nature of the subject. When using a photoelectric type of exposure meter, the Pola-screen for the lens may be held over the meter window at the intended angular position of the Pola-screen. The meter should always be used at the same angular position, as some of these meters are slightly polarizing in their sensitive element.

The Pola-screens have a slight scattering power, so that those for lens use must be screened from all extraneous light by a proper lens hood. The Pola-screens supplied for light-source use are not suitable optically for lens use.

If calibrated angular scale is desired for repeating and recording settings used for Lens Pola-screens, the following is suggested:

	Angle	Scale Figure	Effect
Parallel position	0	0	Increased gloss
	45	1	Neutral
	60	2	Decreased gloss
	70	3	"
	76	4	"
	80.5	5	"
	84	6	"
	86.5	7	"
Crossed position	90	8	"

The intervals of this scale will be of equal effectiveness in cutting down the polarized light entering the Pola-screen.

The vibration plane of the Pola-screen meant for lens use is in line with the handle of the mount.

The novelty of this subject makes it difficult to say just what application will be of most value in motion picture work. It is, however, a new tool, by which new effects may be achieved, and its limitations are imposed only by the imagination of the user. We are indebted to Mr. E. H. Land for help and suggestions, and to Dr. L. A. Jones for the demonstration film of polarization phenomenon in crystalline structure.

DISCUSSION

MR. DUNCAN: What is the crystallized material used in the filters?

MR. CRABTREE: I do not know. It is a patented material.

PRESIDENT TASKER: A discussion of the methods and materials is included in the U. S. Patent of E. H. Land, if you care to look that up.

MR. DEPUE: When will the film be available?

MR. CRABTREE: The author advised that a $2^1/_2$-inch disk in a monocle mount will be available in *B* glass later in June, but the price is not yet determined. It will also be available in *A* glass, which should be used with long-focus lenses. The film itself will not be supplied for lens use because it is rippled and prevents good definition. It must be cemented between glass in order to get good definition.

MR. JAMIESON: What is the difference of exposure with and without the filter in the Kodachrome process?

MR. CRABTREE: The factor of one Pola-screen over the lens alone is 4, irrespective of its angular position, for any panchromatic or color-film. When the light-sources are also covered by Pola-screens, the factor is 10 to 50, depending upon the subject.

DR. FRAYNE: Is there a possibility of using these polarizing media in a densitometer?

MR. CRABTREE: It is physically possible, for a limited range.

DR. FRAYNE: What is the cut-off? That is, what is the percentage of light transmitted from the darkest point?

MR. CRABTREE: The optical density of two Pola-screens together, crossed, is 3; the transmission is therefore one-tenth of one per cent.

A DEVICE FOR AUTOMATICALLY CONTROLLING THE BALANCE BETWEEN RECORDED SOUNDS*

W. A. MUELLER**

Summary.—*A re-recording method is described in which the dialog automatically controls the recorded level of the background effects or music, the dialog depressing the level of the effects or music from the normal value. This is accomplished by using the rectified dialog currents to control the grid-bias of a variable-mu tube. Its use results in greater intelligibility and realism in sound pictures.*

In making sound pictures, one of the most difficult problems is to maintain a proper balance between the dialog, music, and sound effects. If the music and effects are too loud, they mask the dialog and tend to make it unintelligible. When the music and effects are held low, so that the dialog will be intelligible, they are no longer lifelike and the picture loses its realism. This difficulty is also noticeable when the effects of large crowds, such as at a prize-fight, are combined with dialog. The two principals in the ring mutter threats to each other in a clinch. Their whispers, for the purpose of story continuity, must be heard and understood by everyone in the audience, even though ten thousand persons are yelling and stamping their feet at the same time.

It has been standard practice to maintain the intelligibility of dialog during such a scene by holding the level of the effects low, or even eliminating them entirely. As a result, the scene lacks realism and much of its dramatic value is lost. If the effects are made loud enough to carry the realism of the scene, the dialog can not be understood, and the thread of the story is lost, while many in the audience turn to their neighbors to inquire what has been said.

These difficulties were overcome some time ago by developing an automatic balance regulator by means of which the volume of the sound effects or music is varied automatically and simultaneously in accordance with the dialog level. The volume of the sound

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** Warner Bros.-First National Studios, Burbank, Calif.

effects is reduced as the dialog occurs, the extent of the reduction being in proportion to the level of the dialog. When the dialog ceases, the sound effects are restored to their normal value.

A scene recorded in this manner gives a most pleasing result, as the sound effects are always real and lifelike, yet the slightest whisper is easily understood. This is possible only because the dialog instantly suppresses the volume of the effects, yet there is no delay between the end of the dialog and the restoration of the effects to normal volume.

A block diagram of the device is shown in Fig. 1. The effects sound-tracks, which are to be combined with the dialog sound-track, are reproduced by machines *3*, *4*, and *5*. The dialog sound-track

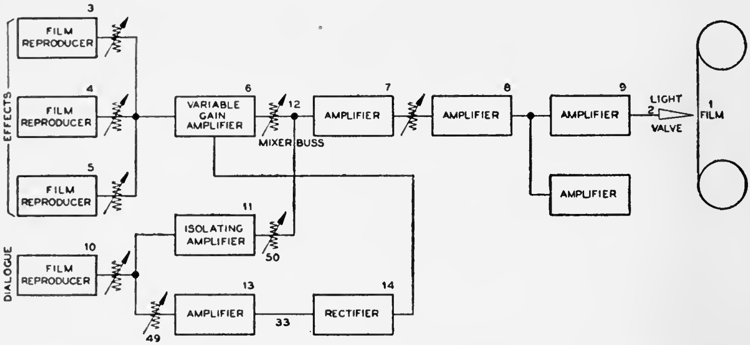

FIG. 1. Schematic diagram of automatic balance regulator.

is reproduced by machine *10*. The outputs of the various effects reproducers pass through the mixer attenuators shown, then into a variable-gain amplifier, *6*, and from there through an attenuator into the common mixer bus, *12*.

The dialog reproduced in machine *10* passes through a mixer attenuator, an isolating amplifier, *11*, another attenuator, and then to the common mixer bus, *12*. Another amplifier, *13*, is bridged across the output of the dialog reproducer for the purpose of supplying dialog to a rectifier, *14*. The direct-current output of this rectifier controls the amplification of the variable-gain amplifier by changing the grid bias of the control grid of a variable-mu tube. As is well known, the effective gain of a variable-mu tube is reduced over a wide range as its grid bias is made more negative. Thus, the arrangement shown in Fig. 1 allows the dialog to control the recorded volume of the effects automatically.

Fig. 2 is a diagram of the variable-gain amplifier and the associated rectifier controlling its gain. The effects or music to be controlled enter the variable-gain amplifier at its input, *15*, and leave at its

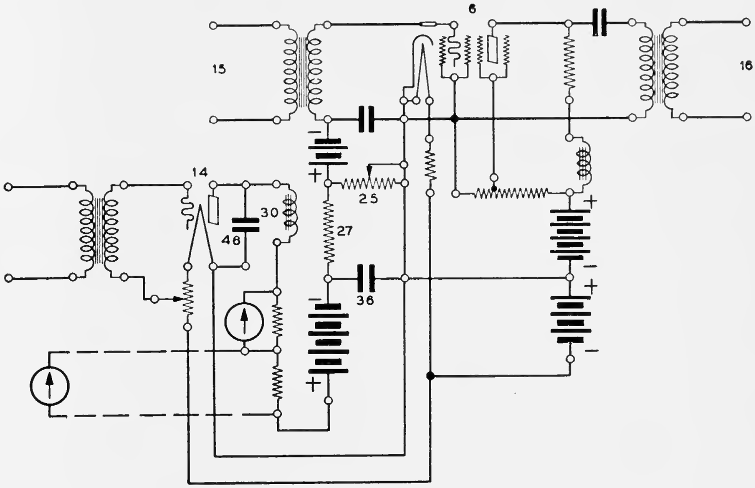

FIG. 2. Variable-gain amplifier and rectifier.

output, *16*. The gain of the amplifier is varied by changing the grid bias on the control grid of the variable-mu tube, *6*. This is accomplished by the direct-current output of the rectifier tube,

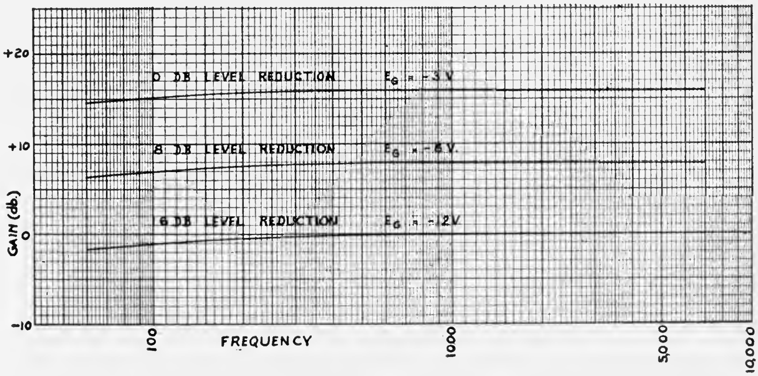

FIG. 3. Frequency characteristic of variable-gain amplifier.

14, flowing through the potentiometer, *25*. Thus, the gain of the variable-gain amplifier and, therefore, the level of the recorded effect are controlled by the level of the dialog impressed upon the input of the rectifier.

It is essential that the variable-gain amplifier introduce no harmonic or frequency distortion and that it does not increase the noise level of the recording system. The frequency characteristic of this amplifier is shown in Fig. 3 for several values of grid bias and over-all gain. It is seen that the amplifier has a flat frequency characteristic which does not vary with changing grid bias. The present variable-mu tubes, with a suppressor grid, do not increase the noise level of the recording circuit by an amount that can be detected.

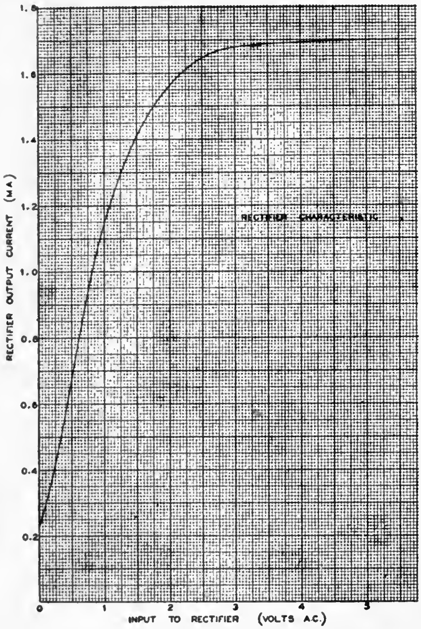

FIG. 4. Rectifier characteristic.

This amplifier with an overload point of a −6 db., is installed in the recording circuit at the point of lowest level, the output that it is required to carry being only −50 db. Consequently, the grid voltage variation on this tube is very small, and the possibility of harmonic distortion minimized. Numerous listening tests as well as harmonic analyses of single tones have conclusively proved that the introduction of this amplifier into the recording circuit does not impair the quality in the slightest degree. The extent to which the variable-gain amplifier reduces the level of the effects or music is controlled by the resistance of the potentiometer, *25*. This control has been calibrated in 2-db. steps with a maximum gain reduction of 20 db., although 8 or 10 db. is all that it has been found necessary to use.

To insure that the variation of the level of the effects will not be noticed even by the most expert listener, a delay circuit consisting of the two condensers, *36* and *48*, and the inductance, *30*, is placed in the output circuit of the rectifier. This delay circuit, which controls the rate at which the effects are varied, has been so adjusted that for normal amounts of background reduction, the variation in level of the effects is undetectable.

It has been found to be important that softly spoken dialog should depress the effects by the desired amount, but as the level of the dialog is increased, the maximum reduction is soon reached, after which there is no change in background level regardless of how loud the dialog becomes. This is accomplished by the resistor, *27* (Fig. 2), in the plate circuit of the rectifier, which limits the maximum value of rectified current as shown in the rectifier characteristic (Fig. 4).

The rectifier characteristic of Fig. 4 results in the relationship between the dialog level and effects level shown in Fig. 5. Study of this curve shows that the reduction of the effects level is proportional

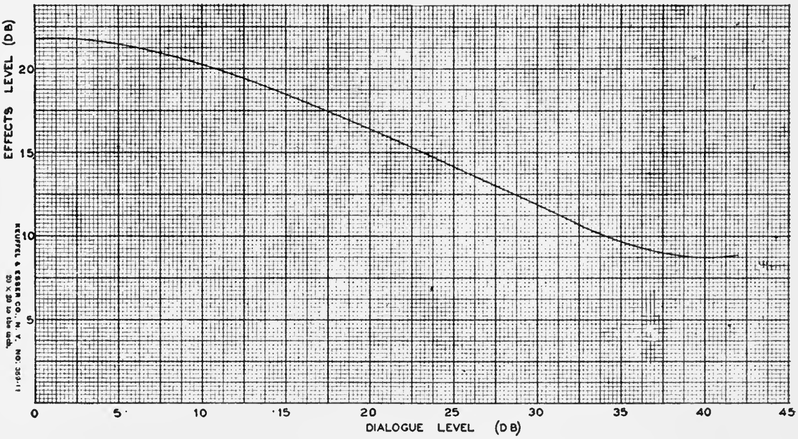

FIG. 5. Level of dialog *vs.* level of effects for 13-db. reduction.

to the dialog up to a certain value, beyond which the effects level does not change regardless of how loud the dialog becomes.

The amplifier *13*, Fig. 1, which is bridged across the dialog circuit and which feeds into the rectifier, is a three-stage amplifier. The gain of this amplifier drops off rapidly at low frequencies. This is necessary in order to prevent door slams, heavy footsteps, and other low-frequency sounds on the dialog track from varying the level of the effects. Consequently, the dialog frequencies have the maximum controlling effect.

The isolating amplifier, *11*, Fig. 1, is a high-quality one-stage amplifier with a flat frequency characteristic. The unilateral conductivity of this amplifier prevents the sound effects from the common mixer bus from being impressed upon the rectifier and interfering with the control of the effects by the dialog channel. This amplifier is followed, as is shown in the block diagram, by an attenuator, *50*. This attenuator properly terminates the amplifier, as well as allows its gain to be made equal to the normal gain of the variable-gain amplifier, which has been previously adjusted to zero by means of an attenuator. Consequently, the insertion of the background regulator into the recording circuit does not change any amplifier or mixer attenuator settings.

The entire equipment is terminated in jacks, so that it can be patched into the circuit when required and removed when it is not needed. It is very flexible, as any number of effects sound-tracks can be controlled by the dialog, music, or any other sound.

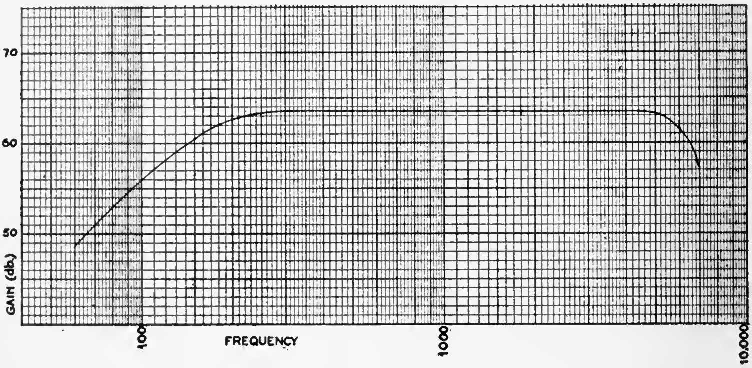

FIG. 6. Frequency characteristic of high-gain amplifier.

The background regulator, as it is used, is very easy to operate and very practical. It gives a greatly improved product with the dialog perfectly understandable at all times, the background music loud and full, and effects that are loud enough to contribute to the realism of the picture.

One of the most striking features of the device has been its ability to give an apparent increase in volume range. When the background effects are automatically reduced by a very loud sound on the dialog track, the effect on an observer is not that the background has been reduced in level, but that the desired sound has been tremendously increased in volume. This is a very desirable feature, as it enables certain sounds to be accentuated and greatly enhances their dramatic value.

It is also very useful in smoothing out sequences in which some angles have background noises and other angles have been photographed without any background effects. Considerable time and money are saved when large crowds are photographed, by dismissing the crowd as soon as the longer shots with the crowd and background effects are finished. The closer shots are made without the expense of the large crowd and with practically no background effects. Such a sequence when originally cut together is very unnatural, because in one cut the crowd will be heard, and in the next, there will be absolute silence.

By using the background regulator to control an effects loop, whenever effects or dialog are present on the dialog track, the background loop is suppressed. Whenever there are no effects or dialog on the dialog track, the background loop is recorded at full level. The result is a scene with a smooth background, resulting in a great improvement in the finished picture and a material saving in the cost of the production.

DISCUSSION

CHAIRMAN HANSEN: Warner Brothers have been working with this device for at least two or three years and probably have done more with it than any other studio.

MR. KELLOGG: Perhaps it may have seemed so because our attention was called to it, but it appeared to me, at least, that the suppression of the background noise was perhaps somewhat excessive. However, Mr. Mueller's statement that it has produced very desirable and pleasing effects is worth more in testimony than one's observations under such limited conditions as these, where we are all primed to expect an effect that is perhaps a little unnatural.

I was interested in the explanation that the system employed here attempts practically to imitate by changes of relative intensity the psychological effect of switching attention from one sound to another. In actual life we can usually take advantage of differences of direction in order to concentrate attention upon a particular sound. The result of concentrating upon one sound is, of course, not to make the sound louder; but with our directive sense to help, we can largely forget the other sounds, which accomplishes the same purpose as making them actually fainter. Since, in the present case, all the sound comes from one direction, and our directive sense can not be brought into play, the suppression of the sounds in which the listener is less interested is accomplished by making them fainter.

MR. MUELLER: In the demonstration reel I purposely over-accentuated the reduction of background effects so it would be very noticeable. The reduction was about twice the normal amount. I can see that we used enough so that everyone could see plainly how the device worked.

CHAIRMAN HANSEN: I was wondering whether when the time arrives that we have binaural recording at a point-source on the screen, we shall be able aurally to reject and keep the background level proper along with the dialog. What is the limiting factor of modulation with a musical background? At what frequency does the modulation effect start to come in? Where does the dialog modulate the music?

MR. MUELLER: We have not made any tests on other than the present monaural recordings, but with the reduction normally used, which is about 8 db., and with proper timing, the device works so well that we had to install the extension meter so that the mixers would know whether the device was in use or not. Under normal conditions, we have made a large number of pictures with it, and have never encountered the difficulty of its being noticed by anyone, even in our own department, nor of the public.

HIGHLIGHTS OF

THE SPRING CONVENTION

HOLLYWOOD, CALIF., MAY 20–24, 1935

HOTEL ROOSEVELT

Throughout the week of the Convention probably as many as 400 or more persons attended from time to time, the attendance at the last session on Friday evening numbering nearly 350 persons. The Convention was probably the most outstanding, both as regards presentations and attendance, that the Society has ever held. The attendance from the East was 120.

The meeting opened Monday morning with the usual Society business and the reports of the Membership and Convention Committees. A recommendation of the Historical Committee, ratified by the Board of Governors on the preceding day, was presented to the Convention, to the effect that Mr. Thomas Armat, pioneer motion picture inventor now living in Washington, D. C., be admitted to Honorary Membership in the Society. With due procedure, the Convention approved the recommendation unanimously, and, accordingly, Mr. Armat will be awarded his Certificate of Honorary Membership at the Fall Convention, to be held at Washington, D. C., next October.

At noon of the opening day, an informal luncheon was held for the members and guests. Short addresses of welcome were made by Mr. G. F. Rackett, on behalf of the Pacific Coast Section, and by Mr. E. Huse, *Executive Vice-President* of the Society, followed by a brief response by President Tasker. Short addresses followed, by Mr. Howard Green, *writer*, Paramount Productions, Inc.; Mr. Kenneth Macgowan, *Associate Producer*, RKO Radio Productions, Inc.; and Mr. George E. Browne, *International President*, I. A. T. S. E. (due to illness, Mr. Browne was unable to attend; his address was read by Mr. Thad Barrows).

The program of papers and presentations, as actually followed at the sessions, was as published on succeeding pages of this issue of the JOURNAL. On Monday evening, Mr. W. Garity, *Production Supervisor* of Walt Disney Studios, entertained approximately 150 of the members with a demonstration of some of the means employed for creating the incidental sounds for the *Mickey Mouse* cartoons and the *Silly Symphonies*, followed by a formal paper on the subject of cartoon technic. The meeting concluded with the projection of several unfinished cartoons by way of explication. It was interesting to learn that the animation is now adapted to the music and not *vice versa*.

On Tuesday, at noon, the members were entertained by the Electrical Department of Warner Bros.-First National at a luncheon in the Studio restaurant, under the direction of Mr. Frank Murphy, *Chief Studio Engineer*. After the luncheon, at which President Tasker briefly addressed the gathering, the party spent the remainder of the afternoon touring the studios.

Tuesday evening, the members of the S. M. P. E. were the guests of the Academy of Motion Picture Arts and Sciences at a meeting of the Technicians Branch, held at the Carthay Circle Theater, in Hollywood. Papers were presented by J. A. Ball, Mrs. N. Kalmus, and R. Mamoulian, on the subject of color in motion pictures (see program on succeeding pages), followed by various examples of recent color motion pictures, including a reel of the currently released feature *Becky Sharp*. Major N. Levinson, *Chairman*, Technicians Branch of the Academy, presided, with Mr. K. Macgowan as guest chairman.

On Wednesday afternoon the members were conducted on a tour through the beautiful Fox Hill Studios of the Fox Film Corp., under the direction of Mr. W. J. Quinlan, *Chief Studio Engineer.*

At the Semi-Annual Banquet and Dance, held in the New Supper Room of the Hotel Roosevelt on Wednesday evening, the members were addressed by Mr. Frank Lloyd, of Metro-Goldwyn-Mayer and President of the Academy of Motion Picture Arts and Sciences, after a brief introduction by President Tasker. Direction of the proceedings was then taken over by Bill Ray of Warner Bros. Radio Station *KFWB*, who acted as master of ceremonies, introducing the various motion picture stars and celebrities who entertained the gathering before the microphone. The proceedings were broadcast through the courtesy of Mr. Jerry King over *KFWB* and associated stations of the Southern California Network.

On Thursday afternoon a trip was arranged to the California Institute of Technology, for those who did not attend the technical session that afternoon. A group of about fifty persons was conducted through the aeronautic, cosmic ray, and high-voltage laboratories under the direction of Dean F. W. Hinrichs, Jr.

THE PAPERS PROGRAM

In spite of the large number of papers on the program, almost without exception these were run strictly according to schedule, thanks to the masterly job of presiding by President Tasker. The standard of quality of the papers was generally of a high order and a number of outstanding papers may be mentioned as follows:

"The Kodachrome Process of Amateur Cinematography in Natural Colors" was described by L. Mannes and L. Godowsky, and a reel of color film projected. This process is epoch-making in so far as the film can be exposed in a motion picture camera without the use of auxiliary devices and, after processing, a three-color image is obtained, the graininess of which is no greater than that of the average silver image.

F. W. Tuttle and J. W. McFarlane, in their paper entitled "Introduction to the Photographic Possibilities of Polarized Light," announced the availability of polarizing filters in sheet form which consist essentially of crystals of certain chemical compounds oriented in a flexible film base. By rotating two such filters into the "crossed" position the incident light is effectually extinguished. It was pointed out that reflected light, in the form of glare, is largely plane polarized, so that by placing a single polarizing filter over the lens of the camera and suitably rotating it, the glare can be effectually eliminated. A demonstration film was shown, illustrating how the glare from automobiles, reflections when photographing store windows, *etc.*, can be eliminated completely in this manner. In color photography, a blue sky can likewise be darkened without affecting the brightness of the foreground. By placing polarizing filters over the lamps and, likewise, over the lens, interesting special effects can be obtained. These filters would appear to be a useful tool for the cameraman.

R. R. Scoville described instruments for measuring flutter, and T. E. Shea, W. A. MacNair, and V. Subrizi explained the effect of flutter on sound quality and gave an enlightening demonstration.

At the symposium on color photography arranged by the Technicians Branch of the Academy of Motion Picture Arts and Sciences the potential importance of color to the motion picture industry was demonstrated forcibly and, from the masterly extemporaneous talk by Mr. Rouben Mamoulian on "Some Problems in Directing Color Motion Pictures," it is apparent that the industry will adopt color almost universally just as soon as a color process is available which is sufficiently cheap, gives correct color rendering and good definition, does not require excessive studio illumination, and can be operated by existing studio personnel.

The largest attendance throughout the convention was during the Sound Session on Friday evening which included three epoch-making demonstrations. The first was that of Douglas Shearer of a push-pull method of recording, involving the use of as many as four light-valve ribbons. The recordings were reproduced through a 60-watt amplifier, using special horns from the Bell Telephone Laboratories. The quality of the reproduced sound was unquestionably the best that has ever been reproduced before our Society, and the resulting sensation simulated very closely that from a large symphonic orchestra.

M. C. Batsel repeated his demonstration of high-quality reproduction first given at the Atlantic City meeting of the Society a year ago.

J. A. Miller described the "Mechanographic Recording of Motion Picture Sound-Tracks." This consists in recording with a *V*-shaped stylus upon a special motion picture film which, apparently, consists of film-base coated with a thick gelatin coating upon which is superimposed a very thin opaque layer. As the stylus vibrates, the opaque layer is removed and a twin variable-width track is produced. In spite of inadequate reproducing equipment, the quality of the reproduced sound was such as to indicate the potential value of this method of recording, especially for play-backs.

THE APPARATUS EXHIBIT

The large attendance indicated appreciation of our members of this feature of the convention. Some of the equipment included in the exhibit was described in the Apparatus Symposium listed in the detailed program on the following pages, and will, of course, be described in the JOURNAL. The following firms exhibited their new equipment.

Ampro, Inc.
Ashcraft Mfg. Co.
Baldor Electric Co.
Cannon Electric Development Co.
Century Electric Co.
O. B. Depue
DeVry Sound System
Dictograph Products Co.
Eastman Kodak Co.
Electrical Research Products, Inc.
Electro-Acoustics Products Co.
General Electric Co.
Goldberg Bros.
Hollywood Camera Exchange
Mole-Richardson, Inc.
Moviola Company

National Carbon Co.
National Theater Supply Co.
Neumade Products Corp.
Newmann Process Projector Co.
RCA Manufacturing Co.
SCK Corporation
Vitachrome, Inc.

ACKNOWLEDGMENT

Credit for the success of the Convention, which may be measured in terms of great increase of interest in the activities of the Society, its Conventions and Local Section meetings, its JOURNAL and technical activities, was largely due to the efforts of Mr. W. C. Kunzmann, *Convention Vice-President;* Mr. J. I. Crabtree, *Editorial Vice-President;* Mr. J. O. Baker, *Chairman* of the Papers Committee; Mr. W. E. Mueller, *Vice-Chairman* of the Papers Committee; Mr. H. Griffin, in charge of projection; Mr. P. Mole, *Chairman*, Local Arrangements Committee; Mr. Ted Lay and his staff, for installing the equipment; Mr. O. F. Neu, in charge of the Apparatus Exhibit; Mrs. E. Huse, *hostess*, in charge of the ladies' activities; and the officers and members of the Los Angeles Local 150 I. A. T. S. E.

The Chairman and Board of Managers of the Pacific Coast Section of the Society especially are to be thanked for their untiring efforts and valuable guidance toward making the Convention a success.

Others to whom credit is due were Mr. W. Garity, Mr. F. Murphy, and Mr. W. J. Quinlan, for arranging the visits to the Walt Disney, Warner Bros.-First National, and Fox Hill Studios, respectively. Thanks are due to the management of Grauman's *Chinese* and *Egyptian* Theaters, Pantages' *Hollywood* Theater, Warner Bros.' *Hollywood* Theater, and Gore Bros.' *Iris* Theater for the passes courteously supplied to the members during the week of the Convention. Mr. Carl Schaefer, of the Warner Bros. Publicity Department, is to be thanked and congratulated for his splendid publicity work.

The sound and projection equipment used at the meetings was supplied and installed by the International Projector Corp., the National Theater Supply Co., Bausch & Lomb Optical Co., National Carbon Co., Raven Screen Co., Electrical Research Products, Inc., RCA Manufacturing Co., Mole-Richardson, Inc.

Acknowledgment is due to the Academy of Motion Picture Arts and Sciences, particularly Mr. Gordon S. Mitchell and Major N. Levinson, for their assistance in arranging various functions and presentations; for the dinner tendered to the Board of Governors on Tuesday, at the Victor Hugo Cafe in Beverley Hills; for the invitation to the Technicians Branch meeting on Tuesday evening; and for the general clerical and other assistance rendered by the Academy.

Kind assistance was also rendered by the J. Slipper Company in connection with the Apparatus Exhibit; and the Royal Typewriter Company, Hollywood Branch, in connection with the registration activities.

Prints of the photograph taken at the banquet on Wednesday evening may be obtained for one dollar each from the Weaver Photo Service, 1041 W. 42nd Place, Los Angeles. Members who were in the photograph taken at the Fox Hill Studio, and who have not yet received their prints, may obtain a print free of charge by writing to the General Office of the Society.

PROGRAM OF THE SPRING CONVENTION AT HOLLYWOOD, CALIF.

MAY 20–24, 1935; HOTEL ROOSEVELT

MONDAY, MAY 20th

10:00 a.m. General Session, Gerald F. Rackett, *Chairman*, Pacific Coast Section of the S. M. P. E. Presiding.

Society Business.

Report of the Membership and Subscription Committee, E. R. Geib, *Chairman*.

Report of the Progress Committee, J. G. Frayne, *Chairman*.

"Television and Motion Pictures"; A. N. Goldsmith, New York, N. Y.

"Theatrical Possibilities of Television"; H. R. Lubcke, Don Lee Broadcasting System, Hollywood, Calif.

Report of the Historical Committee, W. E. Theisen, *Chairman*.

"The Talking Book"; J. O. Kleber and L. Thompson, American Foundation for the Blind, New York, N. Y.

"Use of Films and Motion Picture Equipment in Schools"; Miss M. Evans, San Diego City Schools, San Diego, Calif.

12:30 p.m. Informal Get-Together Luncheon.

Addresses of Welcome: On behalf of the Pacific Coast Section, S. M. P. E., Emery Huse, *Executive Vice-President*, S. M. P. E. On behalf of the Academy of Motion Picture Arts and Sciences, Major N. Levinson, *Chairman*, Technicians Branch and *Vice-Chairman*, Research Council, Academy of Motion Picture Arts and Sciences.

Response: Homer G. Tasker, *President*, Society of Motion Picture Engineers.

Addresses by

Howard Green, *Writer*, Paramount Productions, Inc., Hollywood, Calif.

Kenneth Macgowan, *Associate Producer*, RKO Radio Productions, Hollywood, Calif.

George E. Browne, *International President*, I. A. T. S. E. and M. P. M. O. U., Washington, D. C.

2:00 p.m. General Session. Homer G. Tasker, *President* S. M. P. E. Presiding.

"A Description of the Historical Motion Picture Exhibit in the Los Angeles Museum"; W. E. Theisen, *Honorary Curator*, Motion Picture and Theatrical Arts Section, Los Angeles Museum, Los Angeles, Calif.

"Production Problems of the Writer Related to the Technician"; C. Wilson, Metro-Goldwyn-Mayer Studios, Culver City, Calif.

"The Kodachrome Process of Amateur Cinematography in Natural Color"; L. Mannes and L. Godowsky, Eastman Kodak Company, Rochester, N. Y.

"The Inter-Relation of the Dramatic and Technical Aspects of Motion Pictures"; Prof. B. V. Morkovin, University of Southern California, Los Angeles, Calif.

"Introduction to the Photographic Possibilities of Polarized Light"; F. W. Tuttle and J. W. McFarlane, Eastman Kodak Company, Rochester, N. Y.

"The Problems of a Motion Picture Research Library"; Miss H. G. Percey, Paramount Productions, Inc., Hollywood, Calif.

8:30 p.m. Studio Visit.

Visit to Walt Disney Studio, under the direction of W. Garity, *Production Supervisor.*

TUESDAY, MAY 21st

9:30 a.m. Studio Session. Douglas Shearer, Metro-Goldwyn-Mayer, Presiding.

Report of the Committee on Standards and Nomenclature, E. K. Carver, *Chairman.*

"Flutter in Sound Records"; T. E. Shea, W. A. MacNair, and V. Subrizi, Bell Telephone Laboratories, Inc., New York, N. Y.

"Portable Flutter Measuring Instruments"; R. R. Scoville, Electrical Research Products, Inc., Hollywood, Calif.

"Some Background Considerations of Sound System Service"; J. S. Ward, Electrical Research Products, Inc., New York, N. Y.

"Modern Methods of Servicing Sound Motion Picture Equipment"; C. C. Aiken, RCA Manufacturing Company, Camden, N. J.

"Technic of Present-Day Motion Picture Photography"; V. E. Miller, Paramount Studios, Hollywood, Calif.

"Engineering Technic in Pre-Editing Motion Pictures"; M. J. Abbott, RKO Studios, Hollywood, Calif.

"The Analysis of Harmonic Distortion in a Photographic Sound Record by Means of an Electrical Frequency Analyzer"; O. Sandvik, V. C. Hall, and W. K. Grimwood, Eastman Kodak Company, Rochester, N. Y.

1:30 p.m. Luncheon and Studio Visit.

Luncheon on the lot, and inspection of Warner Bros.-First National Studio; courtesy of the Electrical Department, under the direction of F. Murphy, *Chief Studio Engineer.*

8:30 p.m. Meeting of the Technicians Branch of the Academy of Motion Picture Arts and Sciences; *Carthay Circle Theater, Hollywood.* Major N. Levinson, *Chairman*, Technicians Branch and *Vice-Chairman*, Research Council of the Academy, Presiding. Kenneth Macgowan, Guest Chairman.

"The Technicolor Process"; J. A. Ball, Technicolor Motion Picture Corporation, Hollywood, Calif.

"Psychology of Color"; Natalie Kalmus, Technicolor Motion Picture Corporation, Hollywood, Calif.

"Some Problems in Directing Color Motion Pictures"; Rouben Mamoulian *Director*, Hollywood, Calif.

WEDNESDAY, MAY 22nd

9:30 a.m. Laboratory Session. Emery Huse, *Executive Vice-President*, S. M. P. E., Presiding.

"The Argentometer—an Apparatus for Testing for Silver in a Fixing Bath"; W. Weyerts and K. C. D. Hickman, Eastman Kodak Company, Rochester, N. Y.

"Motion Picture Film Processing Laboratories in Great Britain"; I. D. Wratten, Kodak Limited, London, England.

"Optical Printing and Technic"; Lynn Dunn, RKO Studios, Hollywood, Calif.

"A Continuous Printer for Optically Reducing a Sound Record from 35-Mm. to 16-Mm. Film"; O. Sandvik and J. G. Streiffert, Eastman Kodak Company, Rochester, N. Y.

"Non-Uniformity in Photographic Development"; J. Crabtree, Bell Telephone Laboratories, Inc., New York, N. Y.

"A Dynamic Check on the Processing of Film for Sound Records"; F. G. Albin, United Artists Studios, Hollywood, Calif.

"Emulsions for Special Fields in Motion Picture Photography"; W. Leahy Agfa Ansco Corporation, Hollywood, Calif.

"Sensitometric Studies of Processing Conditions for Motion Picture Film"; H. Meyer, Agfa Ansco Corporation, Hollywood, Calif.

2:30 p.m. Studio Visit.

A Visit to the Fox Hill Studio, under the direction of W. J. Quinlan, *Chief Studio Engineer*.

7:30 p.m. Semi-Annual S. M. P. E. Banquet.

The semi-annual banquet and dance of the Society was held in the New Supper Room of the Hotel. Addresses by Frank Lloyd, *Director*, M-G-M, and *President*, Academy of Motion Picture Arts and Sciences; Rouben Mamoulian, *Director;* star presentations; broadcast through Warner Bros.' Radio Station, KFWB, and associated stations of the Southern California Network.

THURSDAY, MAY 23rd

9:30 a.m. Projection and Studio Lighting Session. Hollis W. Moyse, Dupont Film Mfg. Corp., Presiding.

Report of the Projection Practice Committee, J. O. Baker, *Chairman*.

Report of the Projection Screen Brightness Committee, C. Tuttle, *Chairman*.

Report of Non-Theatrical Equipment Committee, R. F. Mitchell, *Chairman*.

"Non-Theatrical Projection"; R. F. Mitchell, Bell & Howell Company, Chicago, Ill.

"The Relation between Projector Illumination and Screen Size for Non-Theatrical Projection," D. Lyman, Eastman Kodak Company, Rochester, N. Y.

"Sixteen-Mm. Negative-Positive and Grain"; D. Norwood, Lt., U. S. Army Air Corps, Chanute Field, Rantoul, Ill.

"Trends in Sixteen-Mm. Projection with Special Reference to Sound"; A, Shapiro, Ampro Corporation, Chicago, Ill.

Report of the Studio Lighting Committee, R. E. Farnham, *Chairman.*

"The Radiant Energy Delivered on Motion Picture Sets from Carbon Arc Studio Light Sources"; F. T. Bowditch and A. C. Downes, National Carbon Company, Cleveland, Ohio.

"The Photographic Effectiveness of Carbon Arc Studio Light Sources"; F. T. Bowditch and A. C. Downes, National Carbon Company, Cleveland, Ohio.

"Lighting for Technicolor Motion Pictures"; C. W. Handley, National Carbon Company, Los Angeles, Calif.

"A New Wide-Range Spot Lamp"; E. C. Richardson, Mole-Richardson, Inc., Hollywood, Calif.

"Sources of Direct Current for Non-Rotating High-Intensity Reflecting Arc Lamps"; C. C. Dash, Hertner Electric Company, Cleveland, Ohio.

2:00 p.m. Sound and Standardization Session. E. H. Hansen, Fox Film Corp., Presiding.

"The Technical Aspects of Recording Music for Motion Pictures"; R. H. Townsend, Fox Film Company, Hollywood, Calif.

"Pioneering in Motion Pictures"; Dr. Lee deForest, Hollywood, Calif.

"A Device for Automatically Controlling the Balance between Recorded Sounds"; W. A. Mueller, Warner Bros.-First National, Burbank, Calif.

"Improvements in Play-Back Disk Recording"; G. M. Best, Warner Bros.-First National, Burbank, Calif.

"Process Cinematography"; J. A. Norling, Loucks and Norling, New York, N. Y.

2:30 p.m. California Institute of Technology.

A visit to the Institute, under the direction of Dean F. W. Hinrichs, Jr.; inspection of the astronomical, aeronautic, cosmic ray, and high-voltage laboratories.

8:00 p.m. Studio Session, John G. Frayne, Electrical Research Products, Inc., Presiding.

Report of the Sound Committee, P. H. Evans, *Chairman.*

"Improvements in Sound Quality of Newsreels"; J. A. Battle, Electrical Research Products, Inc., New York, N. Y.

"Analysis of the Distortion Resulting from Sprocket-Hole Modulation"; E. W. Kellogg, RCA Manufacturing Company, Camden, N. J.

"Wide-Range Reproduction in Theaters"; J. P. Maxfield and C. Flannagan, Electrical Research Products, Inc., New York, N. Y.

"Characteristics of the Photophone Light-Modulating System"; L. T. Sachtleben, RCA Manufacturing Company, Camden, N. J.

"The Standardization of Make-Up"; M. Factor, Max Factor, Inc., Hollywood, Calif.

FRIDAY, MAY 24th

9:30 a.m. Sound and Acoustics Session. Kenneth F. Morgan, Electrical Research Products, Inc., Presiding.

"Modern Instruments for Acoustical Studies"; E. C. Wente, Bell Telephone Laboratories, New York, N. Y.

"Recent Developments in Architectural Acoustics"; V. O. Knudsen, Professor of Physics and Dean of Graduate Study, University of California at Los Angeles, Calif.

"Principles of Measurements of Room Acoustics"; E. C. Wente, Bell Telephone Laboratories, New York, N. Y.

"Studio Acoustics"; M. Rettinger, Pacific Insulation Company, Los Angeles, Calif.

"The Technical Aspects of the High-Fidelity Reproducer"; E. D. Cook, RCA Manufacturing Company, Camden, N. J.

"Development and Design of the High-Fidelity Reproducer"; F. J. Loomis and E. W. Reynolds, RCA Manufacturing Company, Camden, N. J.

"Calibrated Multi-Frequency Test Film"; F. C. Gilbert, Electrical Research Products, Inc., New York, N. Y.

2:00 p.m. General Session. Joseph A. Dubray, Bell & Howell Co., Presiding.

"Technical Aspects of the Motion Picture"; A. N. Goldsmith, New York, N. Y.

"The History of the Talking Picture"; W. E. Theisen, Hollywood, Calif.

Apparatus Symposium.

"Three New Kodascopes"; N. Green, Eastman Kodak Company, Rochester, N. Y.

"A Continuous Film Camera for High-Speed Photography"; C. T. Burke, General Radio Company, Cambridge, Mass.

"A Professional 16-Mm. Projector with Intermittent Sprocket"; H. A. DeVry, Herman A. DeVry, Inc. Chicago, Ill.

"Arc Supply Generator for Use with Suprex Carbons"; W. K. Hartman, Century Electric Company, Los Angeles, Calif.

"A Sound Reduction Printer"; O. B. Depue, Chicago, Ill.

"A 35-Mm. Automatic Daylight Sound Motion Picture Projector"; A. B. Scott, SCK Corporation, Hollywood, Calif.

"Vitachrome Diffusionlite System and Lamps, Their Uses and Applications"; A. C. Jenking, Vitachrome, Inc., Los Angeles, Calif.

"The Cinemaphone Unit Cabinet for Reproducing 16-Mm. Sound Pictures"; F. J. Hawkins, Los Angeles, Calif.

"The Edmison Film Protective Device for Preventing Ignition of Film during Projection"; F. J. Hawkins, Los Angeles, Calif.

"A New Sound Reader and Frame Viewer"; I. Serrurier, Moviola Co., Hollywood, Calif.

"The New Wall Sound Camera"; H. Griffin, International Projector Corp., New York, N. Y.

"A New Background Projector for Process Cinematography"; H. Griffin, International Projector Corp., New York, N. Y.

"The Use of Cinematography in Aircraft Flight Testing"; F. H. Collbohm, Douglas Aircraft Company, Inc., Santa Monica, Calif.

"The Use of Motion Pictures for Human Power Measurements"; J. M. Albert, Chas. E. Bedaux Company, San Francisco, Calif.

"The Motion Picture in Japan"; Y. Osawa, J. Osawa and Company, Ltd., Kyoto, Japan.

"The Motion Picture Industry in India"; G. D. Lal, Delhi, India.

8:00 p.m. Sound Session. Homer G. Tasker, *President*, S. M. P. E., Presiding.

"A Variable-Density Recording Method to Produce Increased Undistorted Volume Range"; Douglas Shearer, Metro-Goldwyn-Mayer Studios, Culver City, Calif.

"Recording Music for Motion Pictures"; M. C. Batsel, RCA Manufacturing Company, Camden, N. J.

"Mechanographic Recording of Motion Picture Sound-Track"; J. A. Miller, Miller Film, Inc., New York, N. Y.

"A Comparison of Variable-Density and Variable-Width Sound Records"; E. W. Kellogg, RCA Manufacturing Company, Camden, N. J.

"The S. M. P. E. Progress Medal"; H. G. Tasker, *President*, S. M. P. E.

"A Consideration of Some Special Methods of Re-Recording"; E. D. Cook, RCA Manufacturing Company, Camden, N. J.

SOCIETY ANNOUNCEMENTS

FALL, 1935, CONVENTION

The next Convention of the Society will be held at Washington, D. C., October 21–24th, inclusive, headquarters at the Wardman Park Hotel. Members are urged to keep the dates in mind and to plan ahead, so as to assure a good attendance. W. C. Kunzmann, *Convention Vice-President*, is already engaged in arranging the details of the Convention; and the Papers Committee, under the direction of J. I. Crabtree, *Editorial Vice-President*, and J. O. Baker, *Chairman* of the Committee, will soon begin to prepare the technical program of papers and presentations.

SECTIONAL COMMITTEE ON MOTION PICTURES UNDER THE ASA

Following the last meeting of the Committee, letter-ballots were mailed to all the members for voting upon the 16-mm. film and equipment standards contained in the SMPE Standards Booklet and published in the Nov., 1934, issue of the JOURNAL. The approval of the standards as thus published was unanimous; whereupon the project was referred to the SMPE Board of Governors for validation as sponsor and for subsequent transmittal to the ASA for adoption as American national standards.

At the meeting of the Board of Governors at Hollywood on May 19th, the Board ratified the previous action of the SMPE Standards Committee, and adopted all the specifications contained in the Standards Booklet as SMPE Standards. It ratified also the action of the Sectional Committee in respect to the 16-mm. standards, and drafted a letter of transmittal in that regard to the American Standards Association, together with a list of the personnel approved by the Board as sponsor. The list is identical to the list published in the April, 1935, issue of the JOURNAL, p. 378, excepting that D. B. Joy now represents the National Carbon Company; the American Society of Cinematographers is represented by G. A. Mitchell; and the SMPE by A. N. Goldsmith, E. K. Carver, and H. G. Tasker. A. N. Goldsmith is the chairman of the Sectional Committee.

SIXTEEN-MM. SOUND-FILM STANDARDIZATION

At the National Film Congress (Reichsfilmkammer) held at Berlin on April 25th, G. Friedl represented the SMPE and the Sectional Committee in connection with the discussion of 16-mm. sound-film standardization. Unfortunately, the final action of the Congress was to ratify the findings of the previous conference at Stresa, which included, among other things, placing the sound-track at the opposite edge of the film from that specified in the SMPE standards. This means, then, that unless the DIN standards are changed at the forthcoming conference at Paris on July 7th under the auspices of the International Congress of Scientific and Applied Photography and the International Standards Association, there will be two different 16-mm. sound-film standards in Europe, the SMPE and the one proposed by the International Institute of Educational Cinematography (ICE) and ratified at Berlin by the Reichsfilmkammer (DIN = Deutschen Industrie Normen).

A presentation for the Paris conference is now being prepared, which will be published shortly in the JOURNAL. Mr. Friedl will again represent the American interests.

NOMINATIONS FOR OFFICERS AND GOVERNORS FOR 1936

Ballots for nominating officers and governors of the Society for 1936, to take the places of those whose terms expire at the end of this year, were recently mailed to the voting membership of the Society. The ballots, when returned, will form the basis of the nominations made by the Board of Governors at its next meeting at New York on July 19th.

Voting ballots will subsequently be mailed to the Fellow and Active members of the Society, they will be counted at the Fall Convention at Washington, Oct. 21st, and the successful candidates will assume their offices on Jan. 1st. The officers and governors whose terms expire Dec. 31, 1935, are as follows:

H. G. TASKER, *President*	T. E. SHEA, *Treasurer*
E. HUSE, *Executive V-P.*	J. H. KURLANDER, *Secretary*
L. A. JONES, *Engineering V-P.*	A. S. DICKINSON, *Governor*
O. M. GLUNT, *Financial V-P.*	H. GRIFFIN, *Governor*

W. B. RAYTON, *Governor*

Nominations and voting for officers and Boards of Managers of the three Local Sections are likewise being conducted concurrently, the results of which will be announced later.

PROGRESS MEDAL AWARD

Action is being taken by the Committee on the Progress Medal Award to select the recipient of the medal for the year 1934. The recommendation of the Committee will be presented to the Board of Governors on July 19th, and the presentation will be made at the Fall Convention at Washington. Names of persons deemed worthy of the award may be proposed and seconded in writing by any two Fellows or Active members of the Society. A written statement of the accomplishments of the nominee should accompany each proposal.

The Progress Medal was designed by Mr. Alexander Murray of Rochester. In recognition of the excellence of his work, the Board of Governors at its last meeting awarded to Mr. Murray a bronze replica of the medal.

ERRATUM

The following change should be made in the paper entitled "My Part in the Development of the Motion Picture Projector" by Thomas Armat, in the March, 1935, issue of the JOURNAL:

In the second paragraph on p. 243, the patent number 536,539 should read 536,569.

The Society regrets to announce the death of

Eugene Augustin Lauste

Honorary Member of the Society

June 27, 1935

SOCIETY SUPPLIES

Reprints of *Standards of the SMPE and Recommended Practice* may be obtained from the General Office of the Society at the price of twenty-five cents each.

Copies of *Aims and Accomplishments*, an index of the *Transactions* from October, 1916, to June, 1930, containing summaries of all the articles, and author and classified indexes, may be obtained from the General Office at the price of one dollar each. Only a limited number of copies remains.

Certificates of Membership may be obtained from the General Office by all members for the price of one dollar. Lapel buttons of the Society's insignia are also available at the same price.

Black fabrikoid binders, lettered in gold, designed to hold a year's supply of the JOURNAL, may be obtained from the General office for two dollars each. The purchaser's name and the volume number may be lettered in gold upon the backbone of the binder at an additional charge of fifty cents each.

Requests for any of these supplies should be directed to the General Office of the Society at the Hotel Pennsylvania, New York, N. Y., accompanied by the appropriate remittance.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXV **AUGUST, 1935** **Number 2**

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MOTION PICTURE ENGINEERS

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RECORDING MUSIC FOR MOTION PICTURES*

M. C. BATSEL**

Summary.—*The performance standards required for musical reproduction were established in the research laboratories of the General Electric Company early in the period of development of Photophone equipment. Experience has proved the necessity of the refinements found desirable in the research laboratories.*

In this paper several developments are referred to that have reduced distortion. It is pointed out that perfect equipment does not necessarily result in satisfactory musical reproduction. Consideration must be given to the acoustical properties of scoring stages.

The initial ideals in sound motion picture equipment were established in the Research Laboratories of RCA and affiliated companies largely upon the basis of reproduction of music. In the early research work, the necessity for eliminating flutter and other forms of distortion was realized from tests made by recording piano and orchestral music, the quality of which was judged by eminent musicians and others capable of detecting distortions of tone. Thus, there was an early, and there has been a continuous, appreciation by research and development engineers, of the necessity for producing apparatus that would avoid distortion whether arising from mechanical imperfections such as sprocket flutter or from circuit limitations. It is unfortunate for the progress of the industry that, with few exceptions, most studio technicians have been so absorbed in the production problems that they have probably not fully realized the seriousness of distortions present in most recording and reproducing systems.

Through field organizations maintained throughout the world for servicing theater installations and assisting licensees in the operation of recording equipment, the necessary experience for guiding new developments has been gained. That this experience has been extensive is indicated by the fact that although only 300 RCA reproducer installations had been made by January, 1930, approximately

* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

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

5860 were in operation by January, 1935. One hundred and three recording channels have been supplied to RCA licensees. Continued research and experience with commercial equipment have proved that the refinements in equipment demanded by the original ideals are vitally necessary for the more satisfactory reproduction of sound, upon which depends the future progress of the sound picture.

Research has been, and is, constantly directed toward achieving possible improvements through applying the new discoveries in the various branches of physics and engineering. The results of this research and investigation into all methods of recording, which have not been limited to the variable-width system, are today's recording and reproducing devices, which more nearly approximate the engineer's goal of reproduction of the original sound—to arouse in the minds of the audience the illusion of being present at the scenes depicted upon the screen.

Some developments that resulted in a reduction of distortion are:

(1) Film-moving mechanisms for both recording and reproducing equipment that are free from objectionable speed variations. Elimination of flutter caused by film-gate construction and ripples produced by sprocket teeth.

(2) Improvement of the light-modulating system used in photographic recording so that it is now adequate for a frequency range extending to 10,000 cycles.

(3) Improvement of amplifiers, through the development of new types of vacuum-tubes, improved transformers, and resistors.

(4) New laboratory devices for analyzing the causes of distortion, so that they might be eliminated.

(5) New types of microphones. These are of the velocity type, and have a smoother response over a wider frequency range than previous types, and fulfill the requirement for a directional microphone having characteristics independent of frequency. In these microphones not only have the immediately realizable improvements been considered; we have also considered some of the more fundamental factors essential for further improvement in sound recording.

A further explanation of the value of the velocity or ribbon microphone in eliminating distortion is probably warranted. The percentage of reflected or reverberant sound to which a microphone responds in a room having uniformly reflecting boundaries is a function of the distance from the source and the solid angle from which sounds are received. The more limited the angle, the farther the microphone can be used from the source, for the same apparent distance as judged by listening.

The directional characteristics of pressure-operated microphones are such that sensitivity at low frequencies is uniform in all directions and limited to a rather small solid angle at high frequencies. This characteristic results in a different ratio of direct to reflected sound as the frequency changes. The effect is the same as though the microphone were much closer to the source at high frequencies, and produces a distinct "hardening" of the sound. L. E. C. Hughes, lecturer in Electrical Communications, City and Guilds Engineering College, London, has used the term "acoustic distortion" to describe this effect. It is this effect that explains the objectionable sibilants that are largely due to the directional characteristics of microphones and loud speakers. Unless the sibilants become hard and objectionable, tests have shown that speech is more realistic and pleasing when the frequency range is extended.

Velocity microphones, besides eliminating the contribution of the microphone to the hardening effect, possess other desirable characteristics. The directional characteristic can be utilized to differentiate between accompaniments and solo parts in musical recordings. Its use lends a uniform quality to the various instruments in an orchestra, usually located at different angles with respect to the microphone.

Since the human ear is able to hear frequencies above 10,000 cycles per second, it seems logical that reproducing systems should be improved to include a similar range. An extension of the frequency range is practicable with the equipment developed, but without modifications of technic an extension of the frequency range may give results not entirely satisfactory to the ear.

Close observations have been made of the performance of theater reproducing equipment when reproducing from films recorded upon all types of commercial equipment now in use. These observations have led to certain conclusions with respect to the methods employed in the recording studio as well as to the relative merits of the various systems used for recording. Mendoza,[1] in 1933, pointed out some of the defects in musical reproduction that were apparent to him at the time, such as loud speaker arrangement, acoustical characteristics of stages, sprocket hole modulation, limited frequency range, "fuzz," and "edge." With the equipment now available to recording studios, the defects to which he referred that could be attributed to the equipment have been to a great extent overcome.

The lack of resonance or suitable reverberation has not been adequately considered. Theater reproducing equipment must be capable of reproducing the talking portions of a picture satisfactorily. By this is meant that intimate scenes, or scenes in which the observer is apparently very close to the actors, must be reproduced so that the auditors *hear* as though they were correspondingly close. This effect can be attained only when the reproducing system, including the auditorium, is free of resonances and appreciable reverberation. These necessary conditions can be fulfilled with non-directional speakers in small rooms acoustically treated with absorbent materials; or in large auditoriums having sound absorbing materials upon the rear walls, with directional loud speakers that direct the sound sufficiently to permit a high ratio of direct to reflected sound to reach the auditors.

These conditions are not desirable for musical reproduction. The most desirable arrangement would appear to be to use two sound-tracks and two complete reproducing systems so that the dialog might be reproduced over a system similar to that now employed, and the music through a system utilizing an entirely different speaker arrangement, preferably an arrangement that would diffuse the sound and spread the sources over a greater area so as to make effective the reverberation of the auditorium in which the music is heard. For the present time, the best musical results can be attained by adequate reverberation and good tonal characteristics of recording stages.

In support of the necessity for paying greater attention to the tone quality of musical recordings and the effect of the construction of scoring studios, use is made of information contained in *Planning for Good Acoustics*, by Bagenal and Wood, first published in London, in 1931, a book that should be useful to all sound engineers.

> The history of music in relation to buildings shows that tone design has developed not in the open air nor in the laboratory, but in the church, the opera house, and the concert hall. By their longer or shorter reverberations, those buildings have favored this or that type of music, but at all times they have set standards of tones which have been recognized.

These standards should not be less recognized today in our efforts to reproduce music pleasing to the audiences. The famous music halls of the world, it appears, were not accidental in design, nor does it appear that reverberation alone was considered in the design. The authors of this book have designated *tone* to express "an energy condition as will enhance the characteristic of the main groups of musical instruments." This quality, it seems, is difficult to define, yet it is unmistakable to those who are sensitive to it.

If there is present some wood paneling (or some other system in which the internal losses are not very great), it will vibrate whenever a sound is produced having a frequency near its resonance frequency. The effects of these systems may be of considerable importance in recording studios. The resonances should be within the range to build up the fundamentals of the instruments. If the surfacing of the panel is smooth, overtones and harmonics will be reflected, and thus the brightness of the music be improved.

> The effect of the paneling is to increase the apparent loudness, improve the tone of the instruments, and to brighten the musical quality.

It is, therefore, especially useful where the reverberation time is short. The authors of the book state that

> It is controversial whether the brightness secured in this way is a real substitute for the fullness of tone only available with adequate reverberation, but it is greatly superior to the deadness and dullness produced by the lack of both.

It is probable that somewhat less than the optimal reverberation time may be fairly satisfactory when resonances of suitable wooden paneling are effective. This statement is based upon experience with a building that seems to have been famous for its acoustics. It is stated that Mozart, Clementi, Schumann, Mendelssohn, and Wagner have conducted in the old Gewandhaus at Leipzig, and considered it to be very satisfactory. The reverberation time with full audience was only 1.5 seconds. The resonance of the ceiling and of the stressed wooden walls compensated for the short reverberation time. It seems that the large area of wood paneling was quite satisfactory for stringed instruments, but not as effective as reverberation for some of the other instruments, particularly the flute.

Conditions in the scoring studios, however, can undoubtedly be greatly improved by applying some of the principles that have governed the design of the satisfactory music halls of the world. The characteristically thin and unpleasant music usually heard in sound motion picture theaters could be improved during reproduction only by employing reverberation in the theaters. This is not practicable for talking pictures.

The improved scoring stage acoustics would affect the performers equally as well as the auditors in the theaters. The performer hears the sound coming back to him as well as the sound from the instrument. This seems to be important, as it serves to guide the player in voicing the notes played or sung. A good room gives the performer a sense of power which he can control to produce the best effect.

Music is a sequence of tone relationships modified by the player and the room together.

The microphone arrangement used for recording may influence greatly the liveliness of scoring stages without affecting reverberation time, resulting in a full and rounded effect that may be desirable under some conditions. A velocity microphone placed so as to be insensitive to direct sound will respond to the reflected sound, and thus increase the liveness. The effect can be conveniently controlled by the mixer. Recording can be done upon one film or through separate channels, and the mixing done in re-recording.

REFERENCE

[1] MENDOZA, D.: "Practical Problems in the Recording and Reproduction of Music for Motion Pictures," *J. Soc. Mot. Pict. Eng.*, **XX** (Jan., 1933), No. 1, p. 79.

DISCUSSION

MR. LAMBERT: There are two different philosophies, I believe, in recording music for pictures. One is to create the illusion of reality in connection with the picture; the other is to record the music for its own sake. Suppose, for example, you wish an under-score for an intimate scene; if the scoring is reverberant, it tends to draw attention away from the scene that is being portrayed in dialog. The music, instead of adding to the scene, may detract from it. On the other hand, a very reverberant effect may be desired, as in the very effective long shots in the Madame Butterfly scene in *One Night of Love*. This quality was not as effective with the close-ups, however. We must keep in mind the use to which we are going to put the music when deciding how much reverberation is required.

MR. BATSEL: Undoubtedly the perspective must be preserved. It would seem, from observations I have made, that a picture that is primarily musical had better avoid scenes that are too close.

IMPROVEMENTS IN PLAYBACK DISK RECORDING*

G. M. BEST**

Summary.—*A method of recording sound upon cellulose acetate disks for playback purposes in studio production is described. Means of adapting old wax recording equipment to the new recording material are explained, and comparisons with soft wax and shellac pressings are made. Location recording equipment for playback disks is made possible at minimum expense by the use of acetate disks.*

The revival of the screen musical several years ago brought with it an increased use of the system of disk playbacks whereby the music comprising the orchestral arrangements with singing or dancing could be pre-recorded and played back upon the set in synchronism with the camera, while the action was being photographed. It is not intended to discuss the relative merits of various uses of playbacks, but a brief description of the requirements for playbacks is given for those who are not familiar with them.

To handle pre-recorded playbacks upon the set, a $33^1/_3$ rpm. turntable operated by a motor synchronized with the cameras is required, plus a reproducing system consisting of a reproducer, amplifiers, and loud speaker. The disk records are so marked that the needle can be placed in any predetermined groove a few seconds of playing time ahead of the part that is to be used, to avoid waste of film. When the turntable and cameras have reached the standard speed, the actors sing or speak their lines in unison with the sounds coming from the loud speaker, the sound mixer generally watching the lip movement closely to make sure the actors are in step with the pre-recording. Frequently, in order to aid in cutting the picture, a sound-track is recorded simultaneously with the playback, being a composite of the reproduced sounds from the playback, and the voices of the actors. This track is discarded after the picture has been edited. An additional use of playbacks is to photograph and record one camera angle in a scene where several angles are needed, and from a soft wax,

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** Warner Bros.-First National Studios, Burbank, Calif.

to play back the recording in synchronism with the camera while photographing other angles.

Where the pre-recording could be done sufficiently in advance of the time the playbacks were required upon the set, it was customary to record the numbers in soft wax so they could be processed and shellac pressings furnished, or the sound-track was processed and played back through a reproducing dummy, generally from the recording building rather than upon the stage. Use is also made in some studios of a toe-recorded negative which is available for playback within an hour after it is made, provided it is recorded in the studio. If the playbacks were required immediately, it was necessary to cut a number of soft waxes simultaneously, playing them back from the recording room.

These playbacks were expensive because of the additional personnel involved, the short life of each wax, and the fact that the playback disk was not upon the set, thereby slowing up production. Immediate playbacks upon location required at least a two-machine set-up, with a cumbersome and expensive truck and personnel.

In view of these handicaps, the cellulose acetate disk was brought into use about a year ago, and at some studios it has completely supplanted all other methods for obtaining playbacks. It has made possible immediate playbacks on location at a small cost, has cut the cost of playback disks to a small fraction of the former total, and has saved many hours of production time. The acetate disk is not new, having been used for several years in other lines of recording such as air checking for radio stations, so that they are available commercially in several types, the most common consisting of an acetate coating upon both sides of a steel or aluminum disk which usually is furnished in a 12-inch diameter. For motion picture use, an aluminum disk coated with a black acetate has proved the most satisfactory, as it is in appearance much like the shellac pressings previously used and can be marked with white grease pencil so that any section of the recording can be played over and over again from the same start mark. The acetate coating is about 7 mils thick on each side, providing adequate material to cut a groove of standard width and depth. As the disks are double surfaced, the cost per disk is actually less than the cost of shaving two 12-inch waxes.

Cutting acetate surfaces involved certain changes in recording technic. For soft wax recordings, the Western Electric lateral-cut recording head had been in use since the early days of talking pictures, and was designed to cut soft wax at a cutting pressure of approximately 20 grams, or slightly less than one ounce. The mechanical filter components of the recorder were so designed as to function with that cutting pressure, and trial recordings using this cutting head upon acetate verified the conclusion that the greatly increased cutting resistance of the acetate required so much additional cutting pressure as to upset the filter characteristics to such an extent as to lose the intelligibility of speech.

Some idea of the change in frequency characteristic of this recorder when used on acetate can be gained by referring to the curves in Fig. 1. Curve *1* shows the characteristic of the recorder when cutting soft wax, the data for the curve having been obtained by playing back

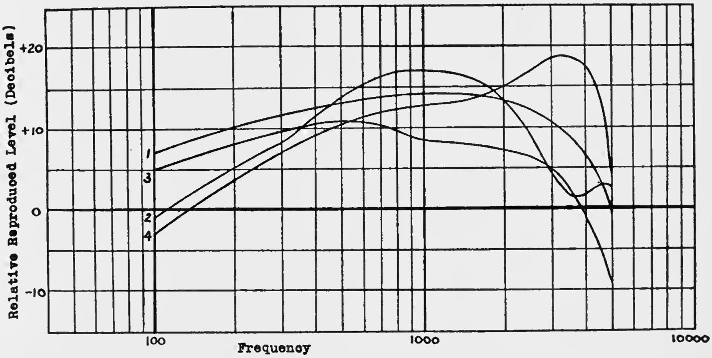

FIG. 1. Characteristics of recorder cutting wax and acetate disks: (*1*) soft wax, standard recorder; (*2*) soft wax, modified recorder; (*3*) acetate disk, standard recorder; (*4*) acetate disk, modified recorder.

a soft wax frequency recording. Curve *3* shows the same recorder used to cut an acetate surface and played back with a *4-A* Western Electric reproducer, using the same amplifier as for the soft wax playbacks. Curve *3* shows the damaging effect of the cutting resistance of the acetate at frequencies above 1000 cycles.

Fortunately, one of the components in the mechanical filter in the recorder consists of a pair of balancing springs which serve to keep the armature in center. By tightening these springs, the characteristic of the recorder was tilted at the high end to such an extent as to give a very satisfactory playback from acetate. The extent of this tilt can be seen in curve *4*, while curve *2* shows the effect that tightening the springs had upon the soft wax characteristic. It is obvious from inspection of both curves *1* and *3* that neither represents what we should regard today as a good frequency characteristic for theater reproduction; but for playback purposes in a production set-up, intelligibility is the prime factor, and a predominance of high frequencies is considered of advantage to the actors in following the dialog or music. Equally obvious is the fact that a recorder adjusted for acetate disks is unfit for soft wax.

The cutting stylus for acetate recordings can be either the sapphire jewel used for soft wax, or a tungsten stylus shaped somewhat like the sapphire. The sapphire wears well provided there are no impurities in the acetate, especially abrasive coloring matter; but,

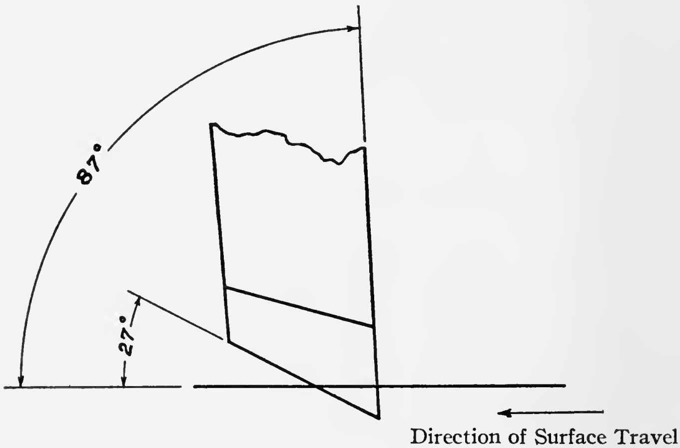

FIG. 2. Angles of cutting stylus with respect to disk.

unfortunately, the commercial acetate supply has occasional bits of foreign matter imbedded in the surface. Also, when the feed screw is stopped at the end of a take, if the stylus is not immediately lifted off the disk, it will cut through the acetate down to the metallic base, and a sapphire jewel is quickly chipped if it comes into contact with the metal. A tungsten stylus will not chip on aluminum, and will cut several acetate disks before it needs resharpening. The cutting pressure required for acetate is approximately 85 grams and, due to the constant and uniform cutting resistance of the acetate, no advance ball is required, the depth of cut being governed by the balance weights upon the end of the recording instrument. The position of the stylus is somewhat different from that used for soft wax recording, for the cutter must scoop the material from the acetate disk in order to avoid chattering. If the stylus cutting face is exactly 90 degrees with respect to the disk surface, a dragging action will ensue, and a high-frequency chatter will be superimposed upon the recording. By placing the cutting face of the stylus between 86 and 87 degrees, with respect to the disk surface, as shown in Fig. 2, a smooth cut can be obtained.

The sliver of material from the disk can be drawn into the vacuum system in the same manner as for soft wax, except that the suction tube is mounted to the rear of the cutting stylus rather than directly in front of it. If no vacuum is available the sliver can be allowed to pile up upon the disk, as it has a tendency to be drawn in toward the center of the disk and does not interfere with the cutting stylus; this phenomenon is particularly useful for location recording, as it obviates the need of a vacuum system. If the cutting stylus becomes dull, the sliver is not uniform, and consists of small particles mixed with dust. Tests made with styli of various forms of steel, especially carboloy, proved that tungsten was superior, the steel causing a feather-edge upon the walls of the groove and a resultant high surface noise. Using the tungsten stylus, the surface noise is approximately that of the best grade of shellac pressings. A tungsten stylus indicates dullness most readily by increased surface noise when the disk is reproduced, and also by narrowing of the groove during recording. Styli can be sharpened in a few minutes' time by placing them in a jig specially made to hold the stylus in position while the edges are honed.

In reproducing acetate disks, the standard shellac disk playback system can be used without change other than to reduce the weight of the reproducer at the needle point to about $2^1/_2$ ounces. This is done by means of a counterbalance weight upon the opposite end of the supporting arm, and with this weight, standard medium-tone steel needles can be used with a life of about 300 playings for the disk. If the weight of the needle exceeds 3 ounces the acetate is quickly cut through. Cutting and reproducing speeds up to 78 rpm. are quite practicable with the acetate disk, although the life of the stylus is considerably reduced by the higher cutting speed.

Location recording for immediate playback is made possible with the acetate disk, as a recording machine can be mounted in a small trailer truck, towed by the film recording truck to the location. Outside of adjusting the position of the truck so that it is approximately level, an operation that is not critical, there is nothing in the operation that is involved or liable in any way to hold up production. Distant locations have been efficiently handled in this manner, sufficient recording heads with sharpened styli being taken along to meet requirements. With immediate playbacks available upon locations, or upon the stages, a resultant speeding up of production, saving in processing costs, transportation, and material has made the acetate disk an important part of the industry.

DISCUSSION

MR. THAYER: What is the angle between the stylus and the disk? If the angle is 87 degrees, does that mean that the stylus leans three degrees forward, or backward?

MR. BEST: The stylus leans backward slightly. The angle is 87 degrees looking from the rear of the recording stylus. The stylus has to scoop the material out slightly.

If it is exactly at right angles, it oscillates at about 5000 cycles; and if it leans slightly forward, it has a tendency to jump out of the material. In other words, if the angle is 85 or 84 degrees, it seems difficult to control the depth of the cut. There is almost an exact setting required, which is usually determined by the recordist when he is setting up the instrument.

He cuts an unmodulated groove and regulates the height of the instrument above the disk, and adjusts the angle very nicely. He listens for the 5000-cycle oscillation; and when it disappears, he knows that he has the right setting. We do not actually measure the angle every time we set up the instrument. The adjustment is almost a matter of instinct with the recordist.

MR. J. CRABTREE: What is the range of frequency that you reproduce?

MR. BEST: About 5000 cycles; not above that. Even at 5000 cycles, it is down about 8 db.

MR. J. CRABTREE: The quality sounds about as good as we hear in the average theater today.

MR. BEST: That is a compliment, because we have not tried to make the quality as good as it might be. So long as the actors upon the set can understand the recordings, particularly in short dialog sequences, that is sufficient. Unless the sibilants are heard the actors have difficulty in following the words that they spoke a few minutes before.

MR. J. I. CRABTREE: It isn't quite clear as to how you utilize the playback. Can the actors synchronize their own lip movements?

MR. BEST: Yes. We make playbacks of dialog as well as of singing and music. It is more or less standard practice in recording a musical to pre-record the number upon a scoring stage with orchestra and voice. The record you have just heard was supposed to simulate a dance band in a hotel, with the usual vocalizing between the orchestral numbers. It was all recorded upon the scoring stage two days before the picture was shot. On the set where the picture was to be made, we installed a turntable operated by a motor synchronized with the cameras, turned over by the same distributor, and the loud speaker was placed in such a position that the singer could hear it very plainly.

In order to aid in the cutting, we have a microphone almost anywhere in the set, outside the picture, and record the playback coming from the horn as well as the actor's voice, to enable the cutter to cut the picture so that it will fit in accurately with the original sound-track, which was recorded at the same time the celluloid disk was made. Afterward, that track is thrown out.

MR. J. I. CRABTREE: How far is the actor usually out of synchronism?

MR. BEST: The sound mixer upon the set stands as close to the actor as he can, and watches the lip motions. Usually a representative of the music department is there also; a take will not be approved until both are satisfied that the synchronism is perfect. I have seen sequences as long as four minutes, in which a song with several verses and a chorus were sung, and at no time during the projection of the picture afterward could one tell that it was made to a playback.

PRESIDENT TASKER: I should like to repeat some thoughts of Mr. P. H. Evans of New York.

Heretofore, photographic take playbacks have been made from soft wax, and hence the wax was normally located in a recording room remote from the stage. This required that when a rehearsal was about to begin a signal be transmitted to the recording room and the recording started. If a breakdown occurred in the rehearsal, a signal to stop went to the recording room. Then the wax had to be reset and restarted when the actors were ready.

When first using this method, Mr. Evans found that the fact that the record could be very quickly made and brought upon the stage, and there placed upon a turntable in full sight of the actors, was of immense facility in speeding rehearsals. It almost entirely eliminated the chain from actor to director to assistant-director to recorder and *vice versa*, to take care of one of these starts and stops.

Suppose that the artist was a dancer. He merely nodded to the boy standing beside the set to start the record at the approved place. If a breakdown occurred, a flick of the hand would stop it, or start it again, or pick it up at any spot. The facility of using the device for rehearsing playbacks was a startling advance in this class of activity. Who originated the method, I don't know. Mr. Best's paper, of course, is concerned mostly with improvements in recording methods.

MR. BEST: It has been in effect, so far as I know, since the Fall of 1928. The first time I ever saw it used was in Warner Brothers' production of the first musical they ever made, *The Desert Song*. They used standard shellac playbacks, processed from soft wax, and they waited until the next day to shoot the picture, which required a twenty-four hour delay. We are now able to play the record back immediately.

On location a few weeks ago in a down town Los Angeles theater, we mounted the location truck alongside the film-recording truck in the alley, and playback records were made while one camera angle was being photographed and the sound-track recorded. The disk was rushed inside and placed upon a turntable, and the other camera angles of the same scene were made to the playback, resulting in no delay whatsoever to the production set-up.

With the former method, if immediate playbacks had been required, we should have had to construct a soft wax recording set-up, with the bulky truck and the difficulties usually encountered in levelling the soft wax machine.

The great advantage of the acetate record is that recordings can be made with the truck leaning at an angle; so long as the recording instrument is rigidly held in its mounting. If the sliver of acetate piles up, the recording stylus plows its way through without jumping or in any way affecting the recording. So, although it is rather a haywire-looking device upon location, it works and saves a lot of time.

Before we started using the method I can recall having the film made upon location, rushed to the laboratory, and the finished print dubbed to soft wax and then sent to the disk-processing plant; six hours later we received the shellac playbacks, which we rushed by motorcycle to the location. If the location was far away, it was the next day before the other camera angles could be shot upon the same set.

MR. HANSEN: What is the volume range?

MR. BEST: The surface noise determines the volume range; the actual surface noise of this disk, as you could hear, was about the same as what would be obtained with a 6- or 8-db. noise reduction on the film. I should say 35 or 40 db. would be the maximum. The low surface noise of the acetate disk is of advantage on location because the same stylus can be used until it is very dull. The only result of using a dull stylus is to increase the surface noise, and with very little surface noise to start with, a considerable increase can be tolerated.

A CONTINUOUS OPTICAL REDUCTION SOUND PRINTER*

O. SANDVIK AND J. G. STREIFFERT**

Summary.—*A continuous optical reduction sound printer is described, which prints by optical means from standard 35-mm. film to standard 16-mm. sound-film. Since the longitudinal reduction of the sound-track is greater than the lateral reduction, an anamorphote optical system is required. In the present case this optical system consists of a combination of spherical and cylindrical lens elements. Data are given which show the change in the frequency characteristic of the 16-mm. sound print as a function of the 35-mm. negative shrinkage.*

The making of 16-mm. prints from 35-mm. picture negatives is now a relatively old and well-established practice. In the more recent problem of transferring sound from 35-mm. film to 16-mm. film, however, the problems are somewhat different and the requirements somewhat more stringent.

Two general procedures for carrying out this operation suggest themselves, namely, by electrical re-recording from 35-mm. film to 16-mm. film, and by reduction printing from 35-mm. film to 16-mm. film.

The relative merits of the two methods have been a subject of much discussion. It is now generally agreed that the printing of the sound is the more practical procedure for making 16-mm. release prints. This can be accomplished either by reducing the sound directly from 35-mm. film to the 16-mm. release print, or by reducing from 35-mm. film to a 16-mm. film from which release prints are made by contact. Making the 16-mm. release print directly from the 35-mm. negative record should lead to somewhat better results. The relative costs of prints made by the two methods would depend somewhat upon the number of prints made and the equipment available in any given laboratory.

Descriptions of several types of continuous reduction printers

* Presented at the Spring, 1935, Meeting at Hollywood, Calif. Communication No. 554 from the Kodak Research Laboratories.

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

have appeared recently in the literature. One type[1] consists basically of a single shaft carrying 35-mm. and 16-mm. sprockets bearing the correct diametrical ratio, these sprockets serving to draw the respective films through stationary gates. Light from the illuminating lamp passes through the 35-mm. gate, and a suitable optical system forms an image of the 35-mm. sound-track upon the 16-mm. raw stock in its gate.

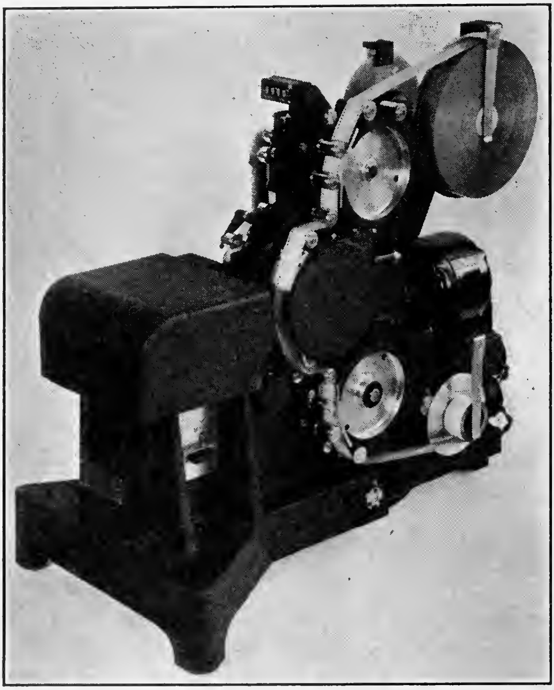

FIG. 1. View showing the 35-mm. side of the reduction printer.

Another paper[2] has described an optical reduction printer which is a modification of a standard 35-mm. to 16-mm. re-recorder. The electrical reproducing and recording elements in this case have been replaced by appropriate optical and illuminating systems. A separate filtered drive is used for each film.

The new Eastman Model *B* reduction printer is a modification of an earlier model which has given very satisfactory performance over a period of four years. The original design necessitated the use of a filtered flywheel drive upon the main shaft carrying the printing sprockets, whereas the new model has been designed for use either with or without such a flywheel. Since the recent settlement of the flywheel patent litigation, the use or disuse of a flywheel is a question only of its technical advantages. Experience with the new model indicates, however, that the flywheel is unnecessary.

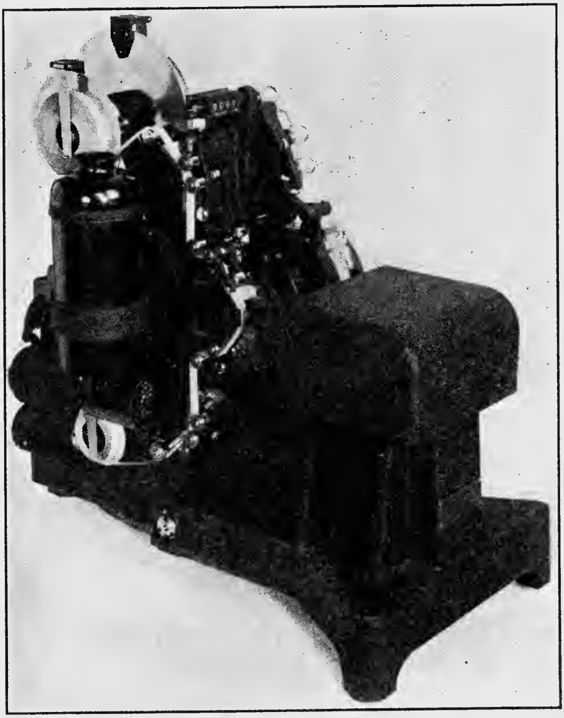

FIG. 2. View showing the 16-mm. side of the reduction printer.

Figs. 1 and 2 illustrate the new printer from the 35-mm. and 16-mm. sides, respectively. It will be noted that there are three pairs of sprockets, serving the purpose of supply sprocket, printing or main sprocket, and take-up sprocket. These sprockets have the correct diametrical ratio to drive the films at the proper relative speeds. Each pair is mounted upon a common shaft, thus assuring uniform relative motion of the films at all points.

A single high-grade worm-reduction couples the constant-speed motor to the shaft carrying the main printing sprockets. A separate worm-reduction drives a vertical shaft which, in turn, drives the supply and take-up sprocket shafts through bevel gears. High-grade chains connect the take-up spindles with the take-up sprocket shaft.

The precision with which the entire machine has been built has resulted in a very light and uniform load upon the over-size motor. This assures constancy of speed, uniformity of exposure, and a minimum of mechanical wear.

Considerable difficulty has been experienced in obtaining sprockets, both 35-mm. and 16-mm., of sufficient accuracy and uniformity in regard to pitch, shape of tooth, and quality of the tooth surface which comes into contact with the film. A new method of cutting sprockets is being developed which, it is believed, will overcome this difficulty. Maximum life of sprockets and film is assured by the use of a minimum of film tension.

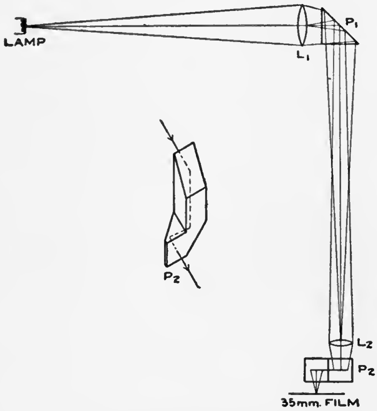

FIG. 3. Schematic diagram of the illuminating system.

The 35-mm. sprockets have been designed to match film having a shrinkage of 0.25 per cent and to accommodate a shrinkage range of about 1.75 per cent. Hence, they will accommodate film having a maximum shrinkage of about 2.0 per cent without interference. The 16-mm. sprockets are cut to match film of zero shrinkage and have a range of about 0.7 per cent. The matter of shrinkage will be discussed more fully later.

In order to eliminate any possibility of distortion or disturbance of the optical system due to vibration, the printer has been built especially rigid and substantial. This, combined with the use of a motor equipped with a floating power type of mounting, has resulted in a machine which is unusually free from vibration.

Although 35-mm. and 16-mm. films run on opposite sides of the machine, both films can be threaded entirely from the front. Film speeds are 70 feet per minute for the 35-mm. film or 28 feet per minute for the 16-mm. film.

The illuminating system is shown diagrammatically in Fig. 3. It consists of a spherical lens, L_1, which images the lamp filament in a second spherical lens, L_2, L_2 forming an image of the uniformly illuminated lens L_1 upon the 35-mm. film. The lamp used during tests was a standard 260-watt, 52-volt prefocus projection lamp.

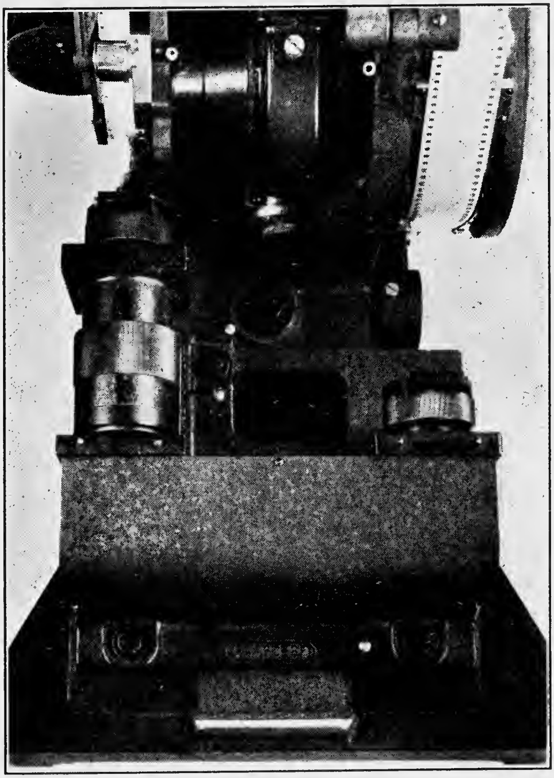

FIG. 4. Top-front view showing the location of the optical system with respect to the printing sprockets.

Although not shown in the figure, a spherical mirror is used behind the lamp, and is located with its center of curvature in the plane of the filament. This increases the light very materially. A lamp of higher wattage, such as a biplanar lamp, can be used if for any reason it were found that more light was required. The present 260-watt lamp, however, gives more than ample light for any printing material now in general use.

Owing to the hub of the 35-mm. main sprocket, it is necessary to bring the light into the sprocket above the hub and deflect it by means of the prism P_2 so that the light is incident normally upon the film within the printing aperture.

The printing aperture measures 101 mils wide and 65 mils high. This height of aperture accounts largely for the high exposure available. At the same time, however, this height of aperture makes it essential that the longitudinal magnification of the imaging system be very accurately adjusted, since the magnification determines the speed at which the image formed upon the 16-mm. film travels. Unless this image travel at the same speed as the 16-mm. film, there will be relative slippage between the image and the film during the period of exposure, with a consequent loss of definition. Both 35-mm. and 16-mm. films are guided at the printing point from the edge of the film nearer the sound-track.

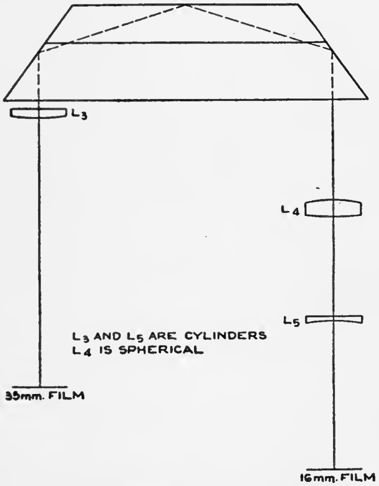

FIG. 5. Schematic diagram of the optical system.

Fig. 4 is a close-up view of the imaging system, with covers removed. The components are shown diagrammatically in Fig. 5. Since the transverse magnification required is 0.845, whereas the longitudinal magnification is 0.400, the image-forming lens must be of the anamorphote type. This is accomplished by means of the cylindrical lenses, L_3 and L_5, which have power along the lateral meridian only and which serve partially to neutralize the power of the spherical objective lens L_4 in the lateral direction. Hence, the lateral magnification is determined by the combined power of L_3, L_4, and L_5, whereas the longitudinal magnification is determined by the spherical element L_4 alone, which is a lens of high quality.

The large roof prism serves to direct the light around to the 16-mm. side and to invert the image in the longitudinal direction so that the image formed upon the 16-mm. film moves in the same direction as the film.

EFFECT OF NEGATIVE SHRINKAGE IN SOUND REDUCTION PRINTING

In order to investigate the effect of shrinkage of the negative film upon definition, reduction prints were made of a series of constant-frequency records. These negatives were identical except that the various samples differed in shrinkage, covering a range from −0.1 per cent, that is, 0.1 per cent above normal pitch, to +1.5 per cent, or 1.5 per cent below normal pitch. This represents a much greater range of shrinkage than that which will be encountered in present 35-mm. motion picture film.

The modulation of these prints was then measured with the micro-densitometer, and the results are shown graphically in Fig. 6.

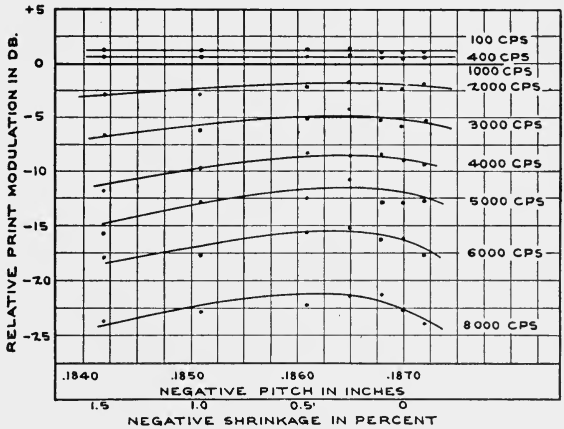

FIG. 6. Microdensitometer readings showing the variations in the definition of the prints with variations in the shrinkage of the negative.

The effective slit width was so small that the scanning loss can be neglected. It is seen that maximum modulation is attained for a negative pitch of 0.1864, corresponding to a shrinkage of 0.32 per cent. This is slightly in excess of the shrinkage for which the 35-mm. sprockets are designed.

It is of particular interest to note that in a print made from a negative whose shrinkage was 1.5 per cent, the loss in modulation in the print resulting from the negative shrinkage was only 2 db. at 4000 cps. and 5 db. at 8000 cps. The loss increases somewhat more rapidly as the shrinkage becomes less than that for which the sprocket is designed, but this is unimportant because in practice the shrinkage will rarely fall below this value. Audition tests on prints made from the above negatives indicated that there was no noticeable increase of sprocket modulation as the negative shrinkage increased. Hence, it is seen that satisfactory reduction prints may be made from negatives covering a wide range of shrinkage.

In this connection it is interesting to compare the relative effects of negative shrinkage upon definition in projection printing and con-

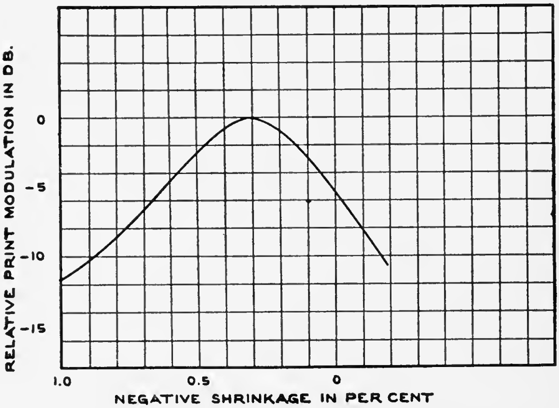

FIG. 7. Relation between negative shrinkage and print modulation in prints made with a standard 35-mm. contact printer. The shrinkage of the printing stock was zero. Modulation was measured on a frequency of 9000 cps.

tact printing. Accordingly, prints on raw stock of zero shrinkage were made with a 35-mm. contact printer from a series of constant-frequency negatives differing only in the amount of film shrinkage. The results are shown graphically in Fig. 7. It is seen that the modulation of the prints is a maximum for a negative shrinkage of about 0.3 per cent and falls off rapidly for values of shrinkage greater or less than this value.

EFFECT OF PRINTING FACTOR IN REDUCTION PRINTING

If a sensitometric strip is printed both by contact and by projection, and the prints are given the same development, the projection print will be found to have a considerably higher gamma than the contact print. This is due to the specular nature of the light forming the image in projection printing as compared to the diffuse nature of the light in contact printing.

For variable-width records this increase in gamma is in general advantageous because of the increase in sharpness of the photographic image along its boundary. In the case of variable-density records, however, the nature of the problem from the photographic standpoint

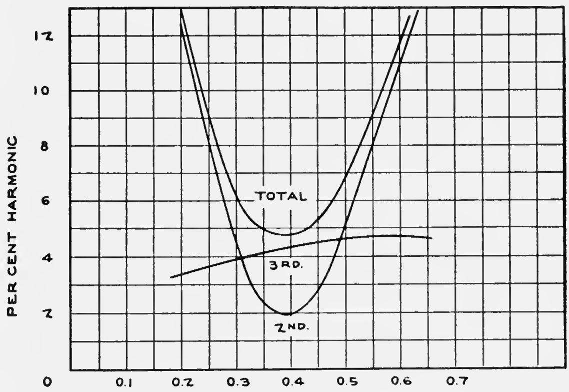

FIG. 8. Relation between harmonic distortion and unmodulated density in variable-density reduction prints: negative density, 0.62; negative gamma, 0.63; print gamma, 2.0.

is somewhat different, being more intimately related to the exposure-transmission characteristic curve of the photographic material.

Since the relation between the exposure of the negative and the transmission of the print is a function of the effective density of the negative in printing, it is evident that the sensitometric conditions of exposure and development which lead to the best wave-form in contact printing are not necessarily the best conditions for projection printing. To illustrate this, a series of reduction prints, that is, projection prints, covering a range of densities made from a constant-frequency, variable-density negative of unmodulated density of 0.62 and gamma of 0.63, was developed under conditions which would obtain for good picture quality, say, gamma, equal to 2.0. It was found upon analyzing these prints that the diffuse print density at which a minimum of harmonic distortion occurs is about 0.4, as shown in the curves of Fig. 8. For a contact print from the same negative and of identical development, the density is normally somewhat higher than this and hence, in general, the sensitometric conditions for projection printing are somewhat different from those for contact printing.

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THE TECHNICOLOR PROCESS OF THREE-COLOR CINEMATOGRAPHY*

J. A. BALL**

Summary.—*The development of the Technicolor process is reviewed historically with particular reference to the guiding motives and technical objectives. This leads up to a brief description of the three-color camera and the three-color imbibition printing process. Following this is a discussion of the photographic principles involved in color photography particularly as they apply to the Technicolor three-color process.*

In the earliest days of the Technicolor development, we recognized that the ultimate goal of workers in the field of color cinematography must be a process that would add a full scale of color reproduction to the existing black-and-white product without subtracting from any of its desirable qualities, without imposing any complications upon theater projection conditions, and with a minimum of added burden in the cost of photography and in the cost of prints. These considerations seemed clearly to indicate a three-color subtractive printing process capable of ultimate low cost of manufacture.

In those days, most other efforts to develop a subtractive printing process made use of double-coated positive stock, invented about 1912 by Hernandez-Mejia. We found a number of objections to the use of this stock; particularly, to the spatial separation of the two components, to the susceptibility to scratching during processing and projection, but most of all, to the impediment imposed upon an ultimate three-color result.

Surveying the field, we chose to work upon the multi-layer, or monopack process, and the imbibition process. In a monopack process the several components are in successive layers, all coated upon the same side of the film strip. In the imbibition process, the several components consist of images formed in water-soluble dyes

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printed on, or rather into, a gelatin-coated film strip, much as colored ink images are printed upon paper in the process of photolithography. A multi-layer, or monopack, process can theoretically be used as a taking process and as a printing process; whereas imbibition, being a photomechanical process, is limited to use as a printing process and requires to be supplemented by a taking method, preferably one providing distinct separation negatives. As printing processes, both monopack and imbibition yield a final product containing all components upon one side of the film strip and with no limitation as to their number. Some fundamental and far-reaching work upon the monopack process by the late Dr. Troland, who at the time of his death was research director of Technicolor, resulted in the issuance in 1932 of Reissue Patent No. 18,680, containing two hundred and thirty-nine claims, broadly covering this field both for taking and printing. The imbibition process seemed to present a less formidable array of processing problems than did the monopack process, so we pushed its development with even greater effort.

We found it necessary to split the problem into two stages. As the first step in an imbibition process it is necessary to prepare a film bearing images consisting of a raised relief of hardened gelatin. This relief image, or matrix, serves the same purpose as the etched copper or zinc plate of photolithography. First, we had to find out how to make a gelatin relief suitable for use as a printing plate. We decided to content ourselves temporarily with two components and to stop short of actual imbibition by making use of an intermediate process wherein two gelatin reliefs, produced upon thin celluloid, were glued together back to back and dyed in complementary colors. Prints of the Technicolor sequence in *The Ten Commandments*, and of Douglas Fairbanks' all-color picture, *The Black Pirate*, were made in this manner.

Then, after having learned how to make gelatin relief matrices of good quality, we tackled the problem of making adequate transfers from those matrices. We had to learn how to prepare the blank film so as to permit imbibition without diffusion. We had to devise a transfer machine capable of handling film in long lengths and in quantities, and in which blank and matrix could be brought into registered contact and held there for several minutes while the dyes transferred.

Simultaneously with work upon these various subtractive printing processes, we devised a camera that gave two-color separation negative images free not only from fringing and parallax but also from the harmful effects of celluloid shrinkage. In this camera the two images were in symmetrical pairs, one being the mirror image of the other. These were arranged upon a single strip of negative stock with both members of the symmetrical pair positioned accurately with respect to symmetrically adjacent pairs of perforations. The perfect geometrical symmetry of this arrangement is shrinkage-proof during the entire life of the negative. The very compact prism system of this camera permitted the use of relatively short focal length lenses. The aberrations of the glass path were taken into account in the computations for these lenses.

Two-color imbibition prints were brought out commercially in 1928, just about the time that sound swept the industry. We were then immediately faced with the necessity of combining color with sound. The only procedure obvious at that time was to make the sound-track identical with one or both of the picture components; but this would give a sound-track in dye, which would have varying absorption throughout the range of wavelengths to which photoelectric cells are sensitive. The response from such a track would then, of course, differ for one type of cell from that for another type and especially so in the case of a variable-density track. We avoided this problem by starting, not with a blank film, but with a strip of positive stock upon which the sound-track could be printed and developed in silver while leaving the picture area blank. Imbibition transfer of the picture components into this blank area could then take place. This method is capable of giving a sound-track absolutely identical to that used in the black-and-white art. Better yet, because of the complete separation of the sound-track technic from the picture technic, the necessity of any compromise between sound and picture quality is eliminated and ideal sound-track processing conditions are possible. Many millions of feet of two-color imbibition prints with a silver sound-track were produced by Technicolor in 1929 and subsequent years.

We were now ready to move on to a three-color process. Since we had planned to do so from the beginning, we encountered no fundamental impediment in our printing process. Mechanically, we had merely to combine the imbibition paths in groups of three instead of in pairs.

The proper choice of dyes presented more of a problem. In a two-color process many colors are compromised, so to speak, and there is considerable choice as to the manner and extent of compromise. In a three-color process, the accuracy of reproduction is greatly increased and the freedom of choice is greatly restricted.

An adequate three-color camera was an exceedingly difficult problem. Three-component taking methods that use only a single aperture (monopack, screen-plates, and lenticulated films) have advantage of economy of light and of mechanism, but they all have other disadvantages, particularly as regards separating or differentiating between the various components; and some of them present difficult raw-stock manufacturing problems.

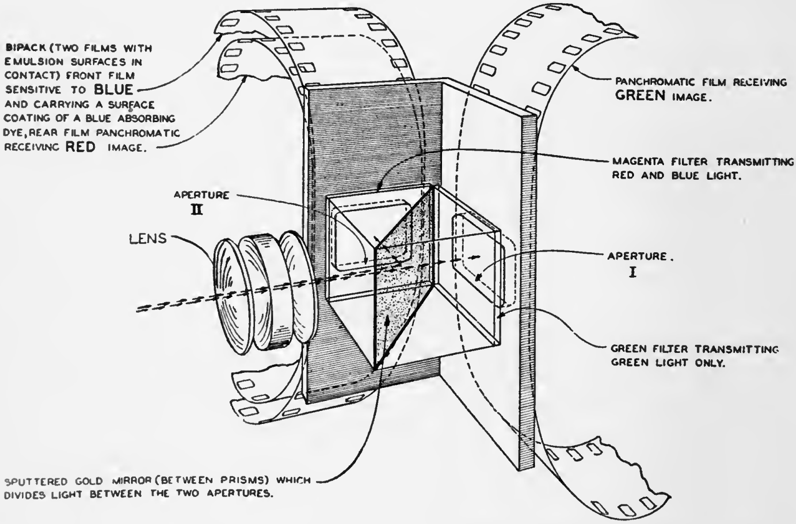

FIG. 1. Arrangement of optical system and films in the three-color camera.

On the other hand, cameras that split the light to three separate apertures, while photographically and optically simple, have the disadvantage of loss of light in the splitting process, long or complicated optical paths, increased size, and mechanical complexity. We chose as a favorable middle-ground solution an intermediate line of attack wherein *three* records are obtained at two *apertures*.

Fig. 1 shows schematically the arrangement of the optical parts and films in this camera. In making use of a bipack at one aperture, we have incorporated means for the practical elimination of halation and also for the elimination of any dependence upon the surface coating of one of the films for the exact determination of our red light filter. Thus, two of the most serious faults of ordinary bipacks have been removed.

To insure that there shall be no differential shrinkage among the three strips of negative, we specify that the celluloid base shall be of the low-shrinkage type, as made by the Eastman Kodak Company. This low-shrinkage celluloid base is of such quality that after processing the negative, including the manufacture of a volume of release prints, the shrinkage is approximately $^1/_8$ of 1 per cent, with differences in shrinkage among the members of a group of about $^1/_8$ of the total shrinkage. This amounts to a small fraction of $^1/_{1000}$ of an inch across the longest dimension of the picture and is therefore entirely negligible.

A group of five lenses ranging in focal length from 35 mm. to 140 mm. have been designed for this camera to our specifications by Messrs. Taylor, Taylor, and Hobson. The chromatic correction of these lenses has been designed to give, in coöperation with our film arrangement, three images of unusually high correction, thus compensating for the loss of definition in the red record of the bipack. The most notable feature of these lenses, however, is the inclusion in the 35-mm. design of what might be called the inverse telephoto principle, whereby the back focal length is considerably longer than the equivalent focal length.

However, it is not the purpose of this paper to go into further detail as to the design and construction of the camera, but to move on to a discussion of the methods of operating the camera. First, however, a brief outline of the complete process as we now work it is perhaps desirable.

The Technicolor three-color camera photographs the three primary aspects of a scene (red, green, and blue) upon three separate film strips, simultaneously, at normal speed, without fringe or parallax, in balance, and in proper register with each other. These separate strips are developed to negatives of equal contrast and must always be considered and handled as a group.

From these color-separation negatives, we print by projection through the celluloid upon a specially prepared stock, which is then developed and processed in such a manner as to produce positive relief images in hardened gelatin. These three hardened gelatin reliefs are then used as printing matrices which absorb dye. This dye is then transferred by imbibition printing to another film strip which, when it has received all three transfers, becomes the final completed print ready for projection. To carry on the process of imbibition, it is necessary merely to press the matrix film into close contact with a properly prepared blank film and hold it there for several minutes. Matrices, of course, can be used over and over again.

The colors of dyes used in the transfer process must be the subtractive primaries, namely, minus-red (or cyan), minus-green (or magenta), and minus-blue (or yellow). The relation of the taking colors to the printing colors is made clear in Fig. 2.

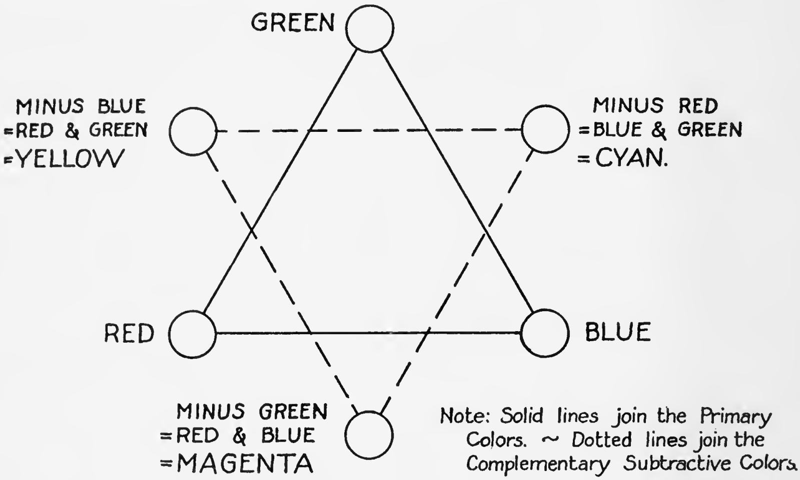

FIG. 2. Diagram showing the relation of the taking colors to the printing colors.

(To show the manner in which the final print is built up, a short demonstration reel was projected. First was shown the sound-track and the yellow dye component, next the cyan component, then the magenta component, and finally the complete image.)

The process just described is designed to reproduce whatever is placed in front of the camera, not only as to color but also as to light and shade. But even the best of reproduction procedures, even that of oil painting upon canvas, is rather severely limited as regards reproducing light and shade. The contrast from whitest white to blackest black in a painting is perhaps 1 to 32. Upon projection from transparencies, as in motion picture work, the range may be slightly greater, about 1 to 64, but in no case is the great range of sensitivity of the eye adequately reproduced. The art of painting and the art of photography then, have this in common: that they seek to suggest a great range of visual contrasts by a skillful use of the more limited contrasts available in the method of reproduction.

In color photography, all very full exposures tend to bleach out to white, and all low exposures tend to drop into black. A highlight upon a face in black-and-white photography can, in the final print, be merely the bare celluloid, and the result will be still entirely satisfactory; but if, in a color print, such a condition exist, the delicate flesh tint will, in that area, be bleached out to white, and the face will look blotchy. All areas of the face should, therefore, be reproduced in such a manner as to yield a good flesh tint. Very light make-ups, and oily make-ups having considerable shine, are apt to be troublesome. In any case, it is necessary to control the light and lighting contrasts accurately and to avoid "hot spots."

The art of the color cinematographer is intermediate between that of the painter and that of the stage artist. The painter has to work with pigments having a limited range of contrast but has great freedom of choice as to composition. The stage artist works with light, and so does not encounter the pigment limitation; but he must select his costumes, backgrounds, *etc.*, to be harmonious in a great variety of arrangements, most of which are more or less out of his control. In color cinematography the difficulties of both are combined; there is the pigment limitation combined with the comparative lack of control of composition. To illustrate this difference let us take, for example, a scene wherein a figure clad in white is to be illuminated by red light, as from a fire which is not visible to the audience. The stage artist, in arranging such an effect, must have a suitable background for the figure when it is viewed from a great many different angles. In arranging his lights, however, he can call for more and more intense beams of red light until he has achieved the desired effect. If a painter is endeavoring to get the same effect in a painting, he can select a favorable pictorial composition, but to depict the red illumination he can use only the brightest red pigment in his palette. If he is dissatisfied with his first effort, he can not heap on more and more of his red pigment. Obviously nothing is to be gained in that manner. He can only improve his result by suppression of, or contrast with, the background. Now in color cinematography, the brightest red that is available is the full value of red pigmentation in the film, and this is obtained by full value of the magenta and yellow dyes without any cyan dye. These conditions result from full exposure of the red negative with no exposure in the green and blue negatives. If the color cinematographer is not satisfied with this full pigmentation and endeavors to get a more intense red by piling on more red light in front of the camera, he merely over-exposes the red negative and begins to get some exposure in the green and blue negatives. The corresponding areas in the print tend to bleach out to white. The significance of the pigment limitation can be summed up in a very few words: if the desired effect can be shown in a painting, it can be photographed, and if it can not be painted, it probably can not be photographed. While no such brief statement is ever strictly true, this one contains such a large percentage of truth that it is worthy of being set up as a guiding principle.

In color photography, it is necessary to operate at rather high levels of illumination. If one is not careful, this may lead to a condition like this: given only relatively weak light-sources, one finds it necessary to use a great many of these sources, in order to attain an adequate level. The widespread distribution of these units then tends to kill all shadows and eliminate modeling on faces. If, then, the attempt is made to provide modeling by superimposing a localized shaft of light, as from a spot-light, the face is burned up, blotchy, and generally unrecognizable. The way out of this dilemma is to recognize that modeling should properly be produced by shadows, and to use fewer and brighter sources or to mass the sources of illumination so that shadows have a chance to exist. In other words, it is just as important for the cameraman to determine directions from which light shall *not* come as it is to determine directions from which light *shall* come.

While color contrasts will occasionally produce a pleasing result when flatly lighted, that is not the way to get sharp photography, nor in general, the most pleasing photography. The Technicolor process is capable of reproducing a full scale of contrasts and those effects of light and shade (*chiaroscuro*), and those directional effects so striking in black-and-white are even more effective in color. These considerations apply not only to the lighting of figures and faces but also to the design and lighting of sets. In the design and painting of sets, the art director should have in mind the cameraman's problem of achieving the necessary light levels with a minimum number of sources of illumination. Under these conditions, it is always much easier to keep parts of a set in low key by keeping light away from them, than it is to paint them dark and then be forced to illuminate them strongly.

This need for fewer and brighter sources is one of the reasons why we choose carbon arcs in preference to incandescent tungsten lamps. Another reason is the fact that only in the white-flame carbon arc and in sunlight do we find the correct balance of blue and red components for the photographic emulsions with which we have to work. If tungsten lamps were to be used, it would be necessary to throw away the excess red light by the use of blue glass bulbs or over-all filters. An additional reason for the use of arcs is that at the high levels of illumination which we require, the heat rays emitted by incandescent lamps are a serious problem. Arcs radiate more light and very much less heat. If incandescent units were properly filtered to correct the color of the light and to absorb heat rays they would undoubtedly be useful on special occasions.

Special arc units have been developed by the National Carbon Company and Mole-Richardson, Inc., for use in connection with the Technicolor three-component process. They have been designed to solve some of the earlier difficulties with arcs, especially noise and flicker. The older types of arc also gave off some smoke which appeared as carbon dust in the air, but it is possible to incorporate absorptive means in the vents to absorb this smoke. The only drawback to the use of arcs is the necessity for "time out" for retrimming, but this can usually be made to coincide with other "time out" activities, particularly if the head electrician works closely with the director.

There is no danger of Kleig eyes when using arcs, provided only that a sheet of ordinary glass is between each arc and the eyes of the people. This is a simple enough requirement and entirely eliminates any danger.

The required level of illumination is not very different from that which was in use by many black-and-white cameramen before the introduction of supersensitive film. We have devised methods of measurement of illumination levels for the guidance of the cameraman.

Exterior photography divides itself into four classifications:

(*A*) Sunlight shots wherein the scenery is of maximum importance. These occur abundantly in travelogues and scenics and quite frequently in dramatic photography, especially in establishing long shots.

(*B*) Sunlight shots wherein faces are of greatest importance.
(*C*) Imitation sunlight exteriors built upon a dark stage and artificially illuminated.
(*D*) Night exteriors.

In group *A* there are pronounced differences between color photography and black-and-white photography because color photography can reproduce those pleasing color contrasts of sky, water, blue haze, foilage, beach, *etc.*, which are almost entirely lost in black-and-white. Furthermore, there is always a strong directional effect to the sunlight with very pronounced shadows. A front cross-light is best in color, whereas a side- or back-cross would generally be preferred in black-and-white.

In class *B* it must be realized that few faces will stand the harsh lighting of the direct sun as in a front cross-lighted setting. So gauzes, diffusers, reflectors, and sometimes "booster" light, must be called into use. Conditions are then most favorable if the sunlight comes from behind the figure. This is true in color or in black-and-white. The skillful cameraman takes advantage of the changing directions of sunlight throughout the day to schedule his shots and angles for best results. Coöperation between director and cameraman in such cases is even more important than in the case of interiors.

It is, of course, perfectly obvious that if artificial light is to be mixed with daylight, as in the case of "booster" light, the color of the "booster" light must approximate sunlight. Here again the use of carbon arcs in preference to incandescent lights is clearly indicated. One might wonder if the change in sunlight quality from morning to late afternoon might not show upon the screen in abrupt changes in color of successive scenes. We have found it generally possible to correct for such differences in the printing. Such correction, however, is not possible where one encounters simultaneously very yellow light from the sun with blue shadows illuminated from a clear sky. Such an effect will, of course, carry through to the screen, and a very beautiful effect it is.

The set-ups of group *C* are very troublesome if the illusion of reality is of importance. This illusion almost always is important in a motion picture so that the artificialities of the usual stage lighting are scarcely acceptable at all. Shadows can perhaps still be painted upon buildings, walls, and backgrounds but of course not upon people. Nor can the shade of a tree be so imitated. What is really needed is a light-source of greater power than any now available. Pending the development of such a source, the sun promises to return to its former importance. In other words, sizeable sunlighted exteriors to be photographed in color had best be real. The difficulties of imitating grass, shrubs, *etc.*, also argue in the same direction.

In the case of night exteriors (class *D*), color has one great advantage over black-and-white in that it is possible to contrast moonlight and lamplight, for example, by the use of blue and amber filters.

Technicolor adds practically no complications to sound recording other than a somewhat noisy camera and the necessity of eliminating "whistle" from the arcs. If the camera is adequately blimped, the problem of camera noise is solved forthwith. The whistle caused by high-frequency ripples in the electric current coming from the commutators of direct-current generators can be practically removed by the combination of an alternating-current filter at the generator and additional choke-coils at the individual arc units.

When we come to the trick department, however, color has its special problems. Fades, lap-dissolves, wipe-offs, *etc.*, can all be made by duping all three negatives and taking pains to preserve the register, exposure, and contrast balance. Those methods of composite photography that depend upon color differences can not be used in Technicolor. The projection background process is, of course, ideal for trick shots in color. However, there is the problem of adequate illumination of the projection screen. So far, projected backgrounds have been used in Technicolor only in relatively small areas, such as through the rear window of a taxi or limousine. Eventually, we hope to be able to work out means for handling projection backgrounds in very much larger sizes, but at present we are rather restricted.

There is a general appreciation of the fact that "color is coming." When sound swept the industry several years ago, it meant the introduction of a new and different technic, and of men of new and different training. The sound engineer was the "big shot." The cameraman was locked in a padded cell with his camera, and the art director was told how he could and could not construct his sets to meet the new acoustic considerations. Conditions will be much more enjoyable for everyone concerned when color sweeps the industry. The sound men will not be affected in any way at all, but the cameraman and the art director will be given new tools to work with, whereby the value and importance of what they can contribute to a picture will be greatly increased. For these reasons it is to be expected that the technicians generally will be enthusiastic and coöperative with the rising tide of color.

It is the policy of the Technicolor Company to organize and maintain a nucleus camera department and color art department for the purpose of accumulating experience and disseminating information and advice as to the skillful and effective use of Technicolor. Beyond this nucleus the policy is to invite coöperation from the studio organizations and especially from those cameramen and art directors who desire to continue to lead in their respective fields. These men will generally be surprised, first, at the extent to which their conscious sense of color has become atrophied through lack of use while working in black-and-white; second, at the speed with which they can regain it; and, third, at the utter inadequacy of black-and-white photography in comparison with good color photography.

When our color was of inferior quality, we used to hear the expression "color interferes with the drama." Since the introduction of the three-component process, the expression has been rapidly fading out of use. Good color assists good drama. Dr. Herbert T. Kalmus, President of Technicolor, has supported a liberal policy of research and development work since the organization of the company. This policy is continuing, and the work involves nearly all departments. We propose to continue to improve our product until the last doubter is swept off his feet.

COLOR CONSCIOUSNESS*

NATALIE M. KALMUS**

Summary.—*Color constitutes another step in the steady advancement of the motion picture toward realism, the same principles of color, tone, and composition applying to the motion picture as to the art of painting. In order fully to appreciate the color picture, a "color consciousness" must be adopted, the lack of which is tantamount in a degree to color blindness.*

Monotony is the enemy of interest, a fact that argues for the color picture; but a superabundance of color is unnatural. Psychologically, colors fall into the "warm" and "cool" groups, and each color and shade has its psychological implications: red—danger, blood, life, heat; green—nature, outdoors, freedom, freshness; etc. To build up personalities and to harmonize emotions and situations, these principles must apply, even to the extent of "color juxtaposition," or the psychological relation of the various colors to each other. For example, of two adjacent or contiguous colors, each tends to "throw" the other toward its complement, considerably affecting the emphasis or import of the color.

On the walls of the cave in Altamira in Spain are found paintings, boldly sketched in three colors by Paleolithic man some fifty thousand years ago. These prehistoric paintings are quite artfully executed, and show that the artist possessed a fine sense of color and a desire to indicate motion as well as form. Various animals are depicted with the use of a red clay, an ochre earth, and a black pigment. One picture shows a wild boar in a standing position. In another picture, nearby, to show the same animal in a gallop, two sets of legs have been used. This ingenious method of showing action indicates the inherent desire of the artist to show motion in color. This ambition has come down through the intervening years to the present day. Now we see the culmination of that idea—motion pictures in color.

From a technical standpoint, motion pictures have been steadily tending toward more complete realism. In the early days, pictures were a mere mechanical process of imprinting light upon film and projecting that result upon a screen. Then came the perfection of

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* *Presented at a meeting of the Technicians Branch of the Academy of Motion Picture Arts and Sciences, Hollywood, Calif., May 21, 1935.*

** *Color Director,* Technicolor Motion Picture Corp., Hollywood, Calif.

detail—more accurate sets and costumes—more perfect photography. The advent of sound brought increased realism through the auditory sense. The last step—color, with the addition of the chromatic sensations, completed the process. Now motion pictures are able to duplicate faithfully all the auditory and visual sensations.

This enhanced realism enables us to portray life and nature as it really is, and in this respect we have made definite strides forward. A motion picture, however, will be merely an accurate record of certain events unless we guide this realism into the realms of art. To accomplish this it becomes necessary to augment the mechanical processes with the inspirational work of the artist. It is not enough that we put a perfect record upon the screen. That record must be molded according to the basic principles of art.

The principles of color, tone, and composition make painting a fine art. The same principles will make a colored motion picture a work of art. The precision and detail of Holbein and Bougereau, the light effects of Rembrandt, the atmosphere and arrangements of Goya, the color of Velasquez, the brilliant sunlight of Sorolla, the mysterious shadows of Innes—all these artistic qualities can eventually be incorporated into motion pictures through the medium of color. The design and colors of sets, costumes, drapes, and furnishings must be planned and selected just as an artist would choose the colors from his pallette and apply them to the proper portions of his painting.

In order to apply the laws of art properly in relation to color, we must first develop a color sense—in other words, we must become "color conscious." We must study color harmony, the appropriateness of color to certain situations, the appeal of color to the emotions. Above all, we must take more interest in the colorful beauties that lie about us—the iridescent brilliance of the butterfly's wing, the subtle tones of a field of grain, the violet shadows of the desert, the sunset's reflection in the ocean. By such observation and study we develop a sense of color appreciation and train our eye to notice an infinite variety of hues.

Serious cases of color blindness are comparatively rare; yet, because the average person is not trained in color appreciation, a decided lack of color consciousness is not at all uncommon. In order to appreciate operatic or classical music, people study music appreciation. Color appreciation, as a study, is almost entirely neglected, although color plays a most important and continuous part in our lives. The average person listens to music for only a short portion of the time, but every moment of the day he looks upon some form of color.

In the study of color appreciation we have two classes of objects. On the one hand, we have Nature, with its flowers, skies, trees, *etc.;* on the other hand, we have man-made objects of all kinds, including art pictures. In the first class the color is already created, and it remains for us only to enjoy and appreciate. In the second class we can exercise a certain amount of selectivity. Because of the general lack of color knowledge, that selectivity is not always tempered with wisdom. If the color schemes of natural objects were used as guides, less flagrant mistakes in color would occur. The use of black and white, however, to the complete exclusion of all color, is decidedly not in keeping with Nature's rules.

Natural colors and lights do not tax the eye nearly as much as man-made colors and artificial lights. Even when Nature indulges in a riot of beautiful colors, there are subtle harmonies which justify those colors. These harmonies are often overlooked by the casual observer. The most brilliant flower has leaves and stem of just the right hue to accompany or complement its gay color.

As we grow in the understanding of color and its uses, we find that our color appreciation develops simultaneously. All the better things in life require a color consciousness for their fullest appreciation and enjoyment.

The eye is the organ of perception. The impulses of light received by the retina are transferred over the optic nerve path to the brain, and we become conscious of light and dark, motion, form, and color. Vision is a sense of ancient lineage and of early development in the individual life. Its characteristic is the clearness and precision of the data it furnishes the mind. Compared to sight, the other senses are dull and groping. It is the sense by which we receive the greatest number of stimuli from the world about us. It is the sense which most frequently affects the nervous system, dominates the attention, and stimulates the mind.

It is a psychological fact that the nervous system experiences a shock when it is forced to adapt itself to any degree of unnaturalness in the reception of external stimuli. The auditory sense would be unpleasantly affected by hearing an actor upon the screen speak his lines in a monotone. The mind would strive to supply the missing inflections. The same is true, but to a greater degree, of the visual sense. A super-abundance of color is unnatural, and has a most unpleasant effect not only upon the eye itself, but upon the mind as well. On the other hand, the complete absence of color is unnatural. The mind strives to supply the missing chromatic sensations, just as it seeks to add the missing inflections to the actor's voice. The monotony of black, gray, and white in comparison with color is an acknowledged fact. It is almost a psychological axiom that *monotony* is the enemy of *interest.* In other words, that which is monotonous will not hold our attention as well as that which shows more variety. Obviously, it is important that the eye be not assailed with glaring color combinations, nor by the indiscriminate use of black and white. Again taking our cue from Nature, we find that colors and neutrals augment each other. The judicious use of neutrals proves an excellent foil for color, and lends power and interest to the touches of color in a scene. The presence of neutrals in our composition adds interest, variety, and charm to our colors. On the other hand, the presence of color in our picture gives added force to the neutrals, emphasizing the severity of black, the gloominess of gray, the purity of white.

From a broader point of view, the psychology of color is of immense value to a director. His prime motive is to direct and control the thoughts and emotions of his audience. The director strives to indicate a fuller significance than is specifically shown by the action and dialog. If he can direct the theatergoer's imagination and interest, he has fulfilled his mission. The psychology of color is all-important in this respect, and we shall now show the manner in which certain colors upon the screen will give rise to certain emotions in the audience.

We have found that by the understanding use of color we can subtly convey dramatic moods and impressions to the audience, making them more receptive to whatever emotional effect the scenes, action, and dialog may convey. Just as every scene has some definite dramatic mood—some definite emotional response which it seeks to arouse within the minds of the audience—so, too, has each scene, each type of action, its definitely indicated color which harmonizes with that emotion.

The usual reaction of a color upon a normal person has been definitely determined. Colors fall into two general groups. The first group is the "warm," and the second the "cool" colors. Red, orange, and yellow are called the warm or advancing colors. They call forth sensations of excitement, activity, and heat. In contrast, green, blue, and violet are the cool or retiring colors. They suggest rest, ease, coolness. Grouping the colors in another manner we find that colors mixed with white indicate youth, gaiety, informality. Colors mixed with gray suggest subtlety, refinement, charm. When mixed with black, colors show strength, seriousness, dignity, but sometimes represent the baser emotions of life.

As to the use of a single color alone, each hue has its particular associations. For example, red recalls to mind a feeling of danger, a warning. It also suggests blood, life, and love. It is materialistic, stimulating. It suffuses the face of anger, it led the Roman soldiers into battle. Different shades of red can suggest various phases of life, such as love, happiness, physical strength, wine, passion, power, excitement, anger, turmoil, tragedy, cruelty, revenge, war, sin, and shame. These are all different, yet in certain respects they are the same. Red may be the color of the revolutionist's flag, and streets may run red with the blood of rioters, yet red may be used in a church ritual for Pentecost as a symbol of sacrifice. Whether blood is spilled upon the battlefield in an approved cause or whether it drips from the assassin's dagger, blood still runs red. The introduction of another color with red can suggest the motive for a crime whether it be jealousy, fanaticism, revenge, patriotism, or religious sacrifice. Love gently warms the blood. The delicacy or strength of the shade of red will suggest the type of love. By introducing the colors of licentiousness, deceit, selfish ambition, or passion, it will be possible to classify the type of love portrayed with considerable accuracy.

Proceeding to the other colors, orange is bright and enlivening; it suggests energy, action.

Yellow and gold symbolize wisdom, light, fruition, harvest, reward, riches, gaiety; but yellow also symbolizes deceit, jealousy, inconstancy in its darker shades, and particularly when it is tinged with green.

Green immediately recalls the garb of Nature, the outdoors, freedom. It also suggests freshness, growth, vigor.

Dark green, blue, violet, and indigo are cooling, quiet colors. They are tranquil and passive. They do not suggest activity, as do the reds and orange. Blue is suggestive of truth ("true blue"), calm, serenity, hope, science, also cold steel, melancholy (we have the expression "blue as indigo").

Purple is a color which does not occur in the spectrum. It is a combination of warm red and cool blue. It will be aggressive and vital if the red predominates, or dignified and quiet if the blue overbalances the red. Purple denotes solemnity, royalty, also pomp and vanity.

Magenta is the combination of purple and red. It is very distinctly materialistic. It is showy, arrogant, and vain.

The neutrals, white, gray, and black, while theoretically not in the category of colors, also stimulate very definite emotional responses. Black is no color, but absorption of all color. It has a distinctly negative and destructive aspect. Black instinctively recalls night, fear, darkness, crime. It suggests funerals, mourning. It is impenetrable, comfortless, secretive. It flies at the masthead of the pirate's ship. Our language is replete with references to this frightful power of black—black art, black despair, black-guard, blackmail, black hand, the black hole of Calcutta, black death (the devastating plague of medieval Europe), black list, black-hearted, *etc.*

Even the poets recognized this symbolism. Shelly, in his dramatic *Alaster* tells how,

> "I have made my bed
> In charnels and on coffins, where black death
> Keeps record of the trophies won—"

The poet Keats, in *The Prisoner of Chillon,* says,

> "I, only, stirred in this black spot,
> I, only, drew the accursed breath of dungeon-dew."

We are speaking a potent language to our audience when we make use of black.

Gray suggests gray skies and rain. It is gloomy, dreary, and represents solemnity and maturity. From its complete neutrality and lack of any color or distinctiveness, it represents mediocrity, indecisiveness, inaction, vagueness.

White reflects the greatest amount of light, it emanates a luminosity which symbolizes spirit. White represents purity, cleanliness, peace, marriage. Its introduction into a color sublimates that color. For example, the red of love becomes more refined and idealistic as white transforms the red to pink. White uplifts and ennobles, while black lowers and renders more base and evil any color. To the degree in which colors are lightened or darkened will the qualities that the color exemplifies be altered.

Thus we see that all the colors in the spectrum speak their particular language. The flush of anger, the vigor of a sun-tanned skin, the richness of gold velvet, the violet mystery of distant mountains, the serenity of blue sky—these colors alone speak with more eloquence than could be described by words.

The modification of a positive color by the introduction of another hue modifies the mental reaction to the degree of the intensity of that hue which is introduced. For example, a positive blue is a cool color, but to the extent in which a red hue is introduced, the coolness of the blue will be altered by the warmth of red. However, these complexities do not alter the basic principles of color or the general reactions which we have outlined.

In the preparation of a picture we read the script and prepare a color chart for the entire production, each scene, sequence, set, and character being considered. This chart may be compared to a musical score, and amplifies the picture in a similar manner. The preparation of this chart calls for careful and judicious work. Subtle effects of beauty and feeling are not attained through haphazard methods, but through application of the rules of art and the physical laws of light and color in relation to literary laws and story values. In the first place, this chart must be in absolute accord with the story action. Again, it must consider the art, principles of unity, color harmony, and contrast. Again, it must consider the practical limitations of motion picture production and photography. The art director, however, in handling a color picture, must be forever mindful that the human eye is many times more sensitive than the photographic emulsion and many times greater in scope than any process of reproduction. Therefore, he must be able to translate his colors in terms of the process.

When we receive the script for a new film, we carefully analyze each sequence and scene to ascertain what dominant mood or emotion is to be expressed. When this is decided, we plan to use the appropriate color or set of colors which will suggest that mood, thus actually fitting the color to the scene and augmenting its dramatic value.

We plan the colors of the actor's costumes with especial care. Whenever possible, we prefer to clothe the actor in colors that build up his or her screen personality. In a picture which we recently completed, two young girls play the parts of sisters. One is vivacious, affectionate, and gay. The other is studious, quiet, and reserved. For the first we planned costumes of pink, red, warm browns, tan, and orange; for the second, blue, green, black, and grey. In this way the colors were kept in unison with their film characters.

One very important phase of making color pictures is the necessity of obtaining distinct color separation. The term "color separation" means that when one color is placed in front of or beside another color, there must be enough difference in their hues to separate one from the other photographically. For example, there must be enough difference in the colors of an actor's face or costume and the walls of the set to make him stand out from the colors back of him; otherwise, he will blend into the background and become indistinguishable, as does a polar bear in the snow. If the colors are properly handled, it is possible to make it appear as though the actors were actually standing there in person, thus creating the illusion of the third dimension. Because of the general warm glow of flesh tints, we usually introduce the cooler tones into the backgrounds; but, if we find it advantageous to use warmer tones in the set, we handle the lighting so that the particular section in back of the actor is left in shadow. This gives a cool contrast to the faces, even though we have a general feeling of warmth in the room. When there are a number of players, all wearing differently colored costumes, it is necessary to disregard those playing relatively unimportant parts, and make the background in contrast to those whose action is most significant to this particular scene.

It is important that the sets have interest and variety. They must not be flat. When the sets have depth it is much easier to introduce interesting shadows and colored lights for special effects. Unless the dramatic aspect dictates to the contrary, it is desirable to have all the colors in any one scene harmonious. Otherwise, we strike an unpleasant, discordant note.

A point to be considered in set dressing depends upon one of the rules of composition in art. The law of emphasis states in part that nothing of relative unimportance in a picture shall be emphasized. If, for example, a bright red ornament were shown behind an actor's head, the bright color would detract from the character and action. Errors of this nature must be carefully avoided.

Color juxtaposition also plays a large part in the selection of colors for the screen. The effect of "color juxtaposition" is an apparent change of hue when different colors are placed one over the other, or side by side. If two cards, one orange, the other blue-green, are placed side by side, the orange will appear more red than it really is, the blue-green more blue. Each color tends "to throw" the other toward its complement. In other words, the complement of orange is blue; therefore, the orange makes the blue-green appear bluer. When any two colors are placed together, the first emphasizes in the second the characteristics which are lacking in the first.

It can readily be seen from this how exceedingly important it is to consider the movement in the scene in determining its color composition because the juxtaposition of colors is constantly changing due to this movement. Quite a different problem from that of an artist, who paints a still scene where the characters remain in their set places, and whose color values, therefore, are not subject to frequently changing contrast.

We must constantly practice color restraint. In the early two-color pictures, producers sometimes thought that because a process could reproduce color, they should flaunt vivid color continually before the eyes of the audience. This often led to unnatural and disastrous results, which experience is now largely eliminating.

The synthesis of all these factors entails many conferences with directors, art directors, writers, cameramen, designers and others. Technicolor color directors, cameramen, and technicians act in a consulting and advisory capacity to the various studio departments during both the preparation and the shooting of the picture.

Music, graphic art, and acting have now been united, and become one expression of more ultimate art. Now for the first time a perfect expression of the combined inspirations of producer, writer, artist, actor, and musician can be adequately presented to an audience. Color has touched the sound picture and it fairly lives.

SOME PROBLEMS IN DIRECTING COLOR PICTURES*

ROUBEN MAMOULIAN**

Summary.—*A brief discussion of whether color in the motion picture is here to stay, pointing out that black-and-white was a convention that had to be accepted because of technical limitations at the beginning of the art. Had color-pictures been invented first, a black-and-white picture would now seem flat and inadequate—although there are beauties in the unreal shadows that can not be denied nor be destroyed. The paper concludes with a few remarks upon the use of color for enhancing and emphasizing the emotional situations of a picture, and the effects to be achieved by carefully selecting the colors of the clothing or uniforms of the actors and of the backgrounds and lighting.*

No art has ever depended so much upon science as the art of motion pictures. In that sense it is truly the most modern of arts. It begins where science ends and it has a hard time, and not always a successful time, in artistically keeping up with the progress of the scientific and technical achievements that are taking place constantly in motion pictures.

Seven years ago motion pictures were revolutionized by the advent of sound. Theretofore silent, the screen acquired the gift of speech. Today, as another result of scientific achievement, color comes to the screen, and to my mind, it is just as much a miracle as sound was. I should like to pay my most respectful tribute to those persons whose names one does not hear but who work in the silence and solitude of their laboratories. I refer to the scientists that compose the body of Technicolor, whose destinies are guided by Dr. Kalmus.

The main question today is, "Will color last or will it not?" I have no doubt that color upon the screen is here to stay. I have also no doubt that there will be as much skepticism for the first few months in regard to color as there was in regard to sound.

They say that what we do not have, we do not miss. No one

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* *Presented at a meeting of the Technicians Branch of the Academy of Motion Picture Arts and Sciences, Hollywood, Calif., May 21, 1935.*

** Director of *Becky Sharp*, the first three-color feature motion picture produced in Technicolor.

ever missed electricity until it came to replace oil and gas. No one missed dialog upon the screen while the screen was silent. However, let a dumb man, after thirty years of life, acquire the gift of speech; would he want to give it up and go back to his silence? Speech came to the screen and stayed—victorious. Now, let a man with ailing eyes wearing black glasses through which the world looks gray, suddenly recover his sight, throw away his glasses, and see the luxury of color of the sky, the earth, and the flowers; would he ever want to go back to his black glasses? We never missed color upon the screen because the very art of the cinema was born black and white. It was a convention that had to be accepted. But once real color comes to the screen, we shall feel its absence as forcefully as we feel the absence of sound when looking at a silent film made some years ago.

I do not mean to say that necessarily all the films will have to be in color, but certainly the great majority of them will be. As in the art of painting, while we admire and love black-and-white drawings and etchings, could we ever do without paintings? So far, the screen has been using a pencil; now it is given a palette with paints.

I do not want to be misunderstood. I do not want to imply that the black-and-white film is not beautiful, nor that the color-film completely displaces the black-and-white. As a matter of fact, the black-and-white has a beauty of its own that could never fade away. The very unreality of those pale shadows moving upon the screen, and that remote quality of a dream, constitute the attraction and the spell of the black-and-white film that could not be destroyed. There will always be room for certain subjects to be treated in terms of these fascinating gray shadows. But color comes to the screen now as a new spring to the earth. It comes as an inspiring and exciting gift, which opens new horizons of creation for the artist and enjoyment for the onlooker.

I am stating this now not merely as a theoretical point, but as a result of an actual experience I went through recently. This experience was directing *Becky Sharp*, the first full-length feature in color. That was a new and wondrous adventure. It had all the thrill and excitement of pioneering in a new field and discovering a theretofore unexplored fairyland.

Color is one of the most powerful and fascinating attributes of nature. Imagine what the world would look like if you took color out of it. What would life be if we were forced to spend it among sky, trees, flowers, and all things black, gray, and white? Having known the living joys of color, we should probably die of melancholia.

Love of color and susceptibility to color are among the strongest instincts in human beings. If you want to discover the most organic, basic elements of the sophisticated human being of today, go to children and to savages. You will find that next to food, they love things of vivid color, which sparkle. That instinct is alive and strong in every one of us.

In relation to motion pictures, our need for color has so far been ungratified. We accepted the situation just as we had accepted the fact of moving upon solid ground, until we learned to fly. But once color comes to the screen, we shall be unhappy without it. It brings a new terrific power to the screen. Our strongest impressions come through vision. So far, visually, we are dealing with light and shade and compositions upon the screen. Now we have an additional element of color. This, not merely superficially to adorn the images in motion, but to increase the dramatic and emotional effectiveness of the story which is being unfolded to the spectator.

Color, like all power, can be harmful and destructive when used badly; life-giving and creative when used well. Animals and human beings have always been and are unconsciously subject to the influence of color. How many times have you walked into a strange house and felt depressed because of the color of the wallpaper? How many times have you found consolation in the rich riot of shades of a gorgeous sunset?

Apart from the pure pictorial beauty and the entertainment value of color, there is also a definite emotional content and meaning in most colors and shades. We have lost sight of that because, as with all important and inevitable phenomena, it has become subconscious with us. It is not an accident that the traffic lights of a city street today are green for safety and red for danger. Colors convey to us subtly different moods, feelings, and impulses. It is not an accident that we use the expressions "to see red," "to feel blue," "to be green with envy," and "to wear a black frown," Is it for nothing that we believe that white is expressive of purity, black of sorrow, red of passion, green of hope, yellow of madness, and so on? The artist should take advantage of the mental and emotional implications of color and use them upon the screen to increase the power and effectiveness of a scene, situation, or character. I have tried to do as much of that in *Becky Sharp* as the story allowed. To quote an example, I would refer to the sequence of the panic that occurs at the Duchess of Richmond's ball when the shots of Napoleon's cannons are heard. You will see how inconspicuously, but with telling effect, the sequence builds to a climax through a series of intercut shots which progress from the coolness and sobriety of colors like gray, blue, green, and pale yellow, to the exciting danger and threat of deep orange and flaming red. The effect is achieved by the selection of dresses and uniforms worn by the characters and the color of backgrounds and lights. There is a little homecoming feeling in this for me, as the use of color and colored lights was one of my main joys and excitement in the theater. Surely, the effectiveness of productions like *Porgy*, *Marco Millions*, and *Congai* which I have done in the theater, would have been sadly decreased if I were forced not to use color in sets, costumes, and lights on the stage.

Of course, in each art different subjects are expressed best through different forms. Undoubtedly, there are some stories that beg for color on the screen more than others do. Off-hand, a story of a historical period, when life and clothing were much more colorful, or stories with the backgrounds of countries like Spain or Italy, even of today, would ask for color more than some stories of our own modern age and civilization. The black-and-white films will still have their place upon the screen, but most assuredly as time goes by there will be less of them and more of the color pictures. For even though our life today is gray (and because of that), we have a great love and longing for color, is it not to be more attractive that women dress their bodies in beautifully shaded gowns and touch their faces with the subtle magic of a discriminating make-up? Is it not the same impulse that drives the gray and tired families of workingmen out to Sunday picnics, where there is a touch of blue sky, a green blade of grass, a tree, or a flower?

Everything that is beautiful to the eye is a great gift to humanity. Color upon the screen is such a gift. The only danger of it that I can see during the first stages of the color picture, would be the danger of excess. Talking pictures did not avoid excess during the first months of their existence. There was too much talk and too much noise coming from the screen. The cinema must not fall into such another trap, and must not go about color as a newly-rich. Color should not mean gaudiness. Restraint and selectiveness are the essence of art.

DISCUSSION

MR. K. MACGOWAN:* I'm going to start by repeating something I said at the Society of Motion Picture Engineers' luncheon yesterday. I'm not repeating it for my own benefit but because I want to say it to the members of the Technicians Branch as well as of the Society. I feel a great deal of envy for you people who work on the technical end. As a producer I'm always running up against questions like these: Is it safe to do this story? Can I do this story as well and as uncompromisingly as it ought to be done?

So often in the producing end we find that we are restricted by the public, or at least by what we think the distributors think the public thinks, and we end by doing a lot of things not nearly as well as they ought to be done.

I noticed, however, in the first three months I was out here that the technicians always seem to do their job just as well as it could be done. They aren't up against the problem of what some picture owner thinks the public wants. Nobody says that what Ray June is doing is over the public's head. Nobody says that the sound in *One Night of Love* is too good for the motion picture audience, nor does anyone say that *Roberta* is too well cut for the masses to understand.

I envy the fact that you are always allowed to take as your motto, "perfection pays."

Probably you are laughing up your sleeves because you find your equipment a little antiquated or you are up against financial difficulties, but you never have that horrible bug-bear—"what the public wants," "the public won't stand for perfection." I know now that two major companies are debating whether or not they can make the greatest play in the English language, and that's a pretty disheartening idea.

I want to tell you roughly the history of RKO's contact with Technicolor. About two years ago Merian Cooper persuaded Jock Whitney to make motion pictures in the new Technicolor process. At that time he was the head of the studio and I was lucky enough to be assigned the first picture in color. Then Mr. Cooper was taken ill. While he was away we determined not to make a long picture but a short. That was *La Cucaracha*. This fall when Mr. Cooper recovered and was ready to go to work again, he had to make two pictures in black and white, and again I had the good luck to be on the job and to do *Becky Sharp*. I'm boring you with this history only to give a bow to Merian Cooper as the father of three-color production on the screen.

Another thing I want to say about technicians is that it seems to me they are wonderful people to deal with. I've found that true in the studio and particularly true at Technicolor. As soon as I went to work on *La Cucaracha* and *Becky Sharp* I came more and more into contact with these people and I found them quite as intelligent, quite as far-seeing as I had found them twenty years ago in Philadelphia when, as a motion picture editor, I first came in contact with Dr. Kalmus and his co-workers. I could name half a dozen men at Technicolor who have done wonderful work, not only in devising this new process but in coöperating with and understanding the rather screwy people connected with production.

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* *Associate Producer*, RKO-Radio Studios. Producer of *Becky Sharp*.

Before you see the reels of film that we have here to show you, I should like to point out one thing that seems quite significant to me. There is some resistance to color due to the fact that we discovered black-and-white photography first.

Suppose there had never been black-and-white photography or black-and-white halftone reproduction. Suppose we had been used to color photographs and colored pictures for the past fifty or seventy-five years. Then if someone invented the black-and-white photography and black-and-white halftones, the result would, I am sure, be frightfully disappointing and definitely puzzling. We should have to translate all the tones almost as we translate a foreign language mentally when we hear someone speaking it. We should have to figure out mentally what actual color was represented by the gray of a face, the black of a tree, *etc.* I found somewhat the same effect after I saw a two-color picture, *The Wax Museum.* When a normal black-and-white picture came upon the screen it gave me a curious psychological shock and the thought, "What is this—a painting in mud?" Experiences like this are going to beat down our instinctive resistance to color.

One thing that is going to push color very far ahead is television. I was in the theater a good many years as a producer, and I saw the road destroyed by the movies. The silent screen was destroyed by the talking picture. Then the talking picture had to meet the competition of the radio. Now they tell us television is coming, and motion picture producers are beginning to worry about it. People can turn a little button and sit at home and be entertained, but they are going to get that entertainment in black-and-white for a good many years. Color television will come undoubtedly, but it will come late, and in the meantime the screen will be able to use color against the competition of television. There will be an added sense of vividness in the theater that will not be apparent upon the home screen.

IMPROVEMENTS IN SOUND QUALITY OF NEWSREELS*

J. A. BATTLE**

Summary.—*The manner in which improvements in newsreel sound quality were effected by coördinating the recording practices of the newsreel producers is described. A theater survey revealed that the projectionists reduced the fader setting for newsreels from one to five steps, or three to fifteen db., below the nominal fader settings for feature pictures to obtain the same volume level in the auditorium. By adherence to accepted recording practices in the studio newsreels are now being reproduced at the same fader settings as feature pictures, with a considerable improvement in sound quality. A brief outline is given of the preparation of the newsreel from news camera to theater.*

A "new deal" in newsreel sound quality was inaugurated on March 4, 1935. Newsreel sound quality, it was generally recognized, was not keeping pace with the improvements in feature picture sound quality, and the increasingly greater contrast became so apparent that it was evident that some measures should be taken to eliminate this contrast. The recordists were cognizant of the reasons for the lack of a commensurate improvement, but as long as one newsreel had to be as loud as or louder than its competitor it was futile to expect any marked improvement. The coördinated policy of recording at reduced levels adopted among the newsreel producers, which became effective with the release of March 4, resulted in a considerable improvement in sound quality; and with this as a nucleus further improvements are bound to follow.

It was the original practice to reproduce the newsreels at slightly higher levels than the feature pictures, the theory being that the interest of the audience should be aroused and that the louder volume would enhance the value of the news. The reason for that seemed to be that the newsreel was apparently a lineal descendant of the town crier whose stentorian voice informed the vicinity at large of the news of the day. At first the louder newsreel volume was accomplished by adjusting the fader settings in the theater in accordance

* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

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

with a cue sheet, but later the increase in sound level was accomplished upon the film itself. Gradually, this slight difference was increased to such an extent that the volume level of the newsreels in the auditorium sometimes became actually uncomfortable; so much so, that projectionists began to acquire the habit of automatically "pulling down" the fader from one to five steps, or three to fifteen db., when showing newsreels.

In order to present to the newsreel producers convincing evidence that the method adopted to achieve loudness was defeating its own purpose, a survey of 150 theaters was made, unknown to the projectionists, by service engineers on their regular visits over a period of two or three weeks. Observations were made of the average fader settings of the feature picture and of the newsreel upon the same program, and the interesting figures shown in Table I were obtained.

TABLE I

Change from Average Feature Fader Setting for Newsreel Projection	Average of 5 Newsreel Companies (Per Cent)
No change	6
Down 1 step (3 db.)	21
2 (6 ")	25
3 (9 ")	30
4 (12 ")	14
5 (15 ")	4
	100

It was evident that the higher recording level was being offset by the lower fader settings for the newsreels in the theaters. In order to obtain the increased volume level the recording equipment was operated beyond its optimal limits, contrary to the better judgment of the recordists, and light prints were released. The obvious solution to improve the quality was to adhere to accepted standards in recording and processing, or, in other words, to strive for feature production quality and return the control of the auditorium volume level to the proper place, *i. e.*, to the projection room fader.

The results of the survey were presented to the newsreel producers, and in subsequent discussions the advisability of correcting the condition was recognized. A conference was arranged at which the current release of each of the five newsreels was compared with a feature and a travelogue, and the comparative volume levels were measured with a volume indicator. The level of the newsreels ranged from +2 db. to +7 db., with reference to the level of the travelogue, which was arbitrarily selected as zero reference. The volume level of the feature measured −4 db. The zero reference level of the travelogue was considered suitable for newsreels, and it was agreed to adopt this level as a "yardstick." Prints of a section of the "yardstick" were distributed among newsreel producers. With the reduced level the projection room fader would remain unchanged for the news and the desired auditorium level would be obtained. The release date for the first news recorded according to the new standards was selected as March 4. This date allowed sufficient time in which to transmit the news of the change to all projectionists by service engineers and by publicity in the trade papers. With this ground work laid, the March 4 release was distributed with the warning notice shown in Fig. 1.

PROJECTIONISTS

BEGINNING WITH FIRST RUN RELEASE

MARCH 4, 1935

NEWSREELS OF ALL COMPANIES WILL BE
ISSUED AT LOWER VOLUME LEVEL

WARNING

RUN THIS AND FUTURE NEWS-
REELS ON NORMAL FADER
STEP USED FOR FEATURE
PICTURES

FIG. 1. Notice distributed with initial release.

After a month's interval it was interesting to observe that the maximum variation in level of all the newsreels measured at a subsequent conference was not more than ± 2 db.; and, of greater importance, there was a decided improvement in quality. Three of the reels were identical, one was 2 db. lower and another 2 db. higher. This close agreement has been verified by the records of the cue sheet of a New York newsreel theater in which all newsreels are shown intercut as a continuous program. The maximum volume adjustment between subjects was reported as 2 db., whereas formerly the variation was as great as 8 db. Now that the benefits of improved recording have been realized there is not likely to be a recession to the old methods. There doubtless will be instances when the feature level is slightly lower than normal, which will necessitate a change in the fader setting for the newsreel, but the quality of reproduction will not be altered. The continued coöperation of the newsreel producers, combined with periodic conferences every six months or so, will tend to assure a continuance of the benefits attained. Further improvements in sound quality will most likely ensue in the footsteps of this first advance.

The men in the field who gather the news are not affected by the change because, not having the same test and maintenance facilities available in the studio, nor the spare equipment, they must of necessity operate within conservative limits. They have to rely upon the home or district office to furnish their supplies, including film. A crew will use on an average of 50,000 feet of film a year, and some crews as much as 100,000 feet. They are constantly in touch with their local office, and receive practically all assignments from that source. In large centers such as New York and Chicago the crews are dispatched upon news assignments from the news desk, which is continually informed of the current events through the medium of the news teletype, telephone, *etc.* In some instances, a contact man accompanies the crew and interviews the "headline" celebrities. In more remote sections where the course of events is less hectic the crews develop their own stories, except in instances of happenings of national interest, such as disaster due to hurricanes, floods, or, for example, the recent dust storms.

When completed, the stories are sent directly to the home office by air-mail; except when the story is not headline news: then the film is shipped by fast train. The cameraman reports the details of the story, including such items as camera angles and the number of feet shot. This report is attached to the film can and a duplicate is mailed at the same time. From it the newsreel editors can have a suitable script prepared for the commentator while the film is being developed. Advantage is taken of every means that will reduce the time interval between taking the story and reproducing it upon the screen in the theater. Each story is assigned an identifying number when reviewed in the negative by the news editors, who select and edit the material for release. A title and a short synopsis of the story are dictated by the editor, and a record is kept of all stories received. About 20 per cent of the stories sent in are used for release. All are catalogued and stored in a vault essentially as they are. The selected stories are edited and cut, and a dupe negative and a lavender print are made. The dupe negative is made as a matter of precaution and, on occasion, is used to double the printing capacity to expedite the release. The lavender "work" print is used for projection in scoring the comments, music, and sound effects if any are required. The commentator reads from a prepared script, and after a rehearsal or two the final sound negative is recorded. The original recorded sound may be used for a final release print or it may be re-recorded as an underlay when adding the comments.

The preparation of the news begins one day prior to the release date, and an entire reel is ready to be printed within 18 or 20 hours. The news subjects are arranged in definite sequence prior to making the reel, and when the first half of the reel is scored prints are run off. The second half follows as quickly as possible, so that the release print is generally made up of two sections spliced together. For checking, a rush print is made from the sound negative and lavender print. The combined print has a negative of the picture, but this is satisfactory for the purpose. The entire process is so thoroughly checked during the assembly of the reel that it is not necessary to await the complete print for a final check. The completed reels are dispatched throughout the country according to a definite schedule, and if necessary delivery is accomplished by airplane to maintain the proper schedule in the event that there is some delay in making up, or in cases of specials or flashes.

Special news stories of national importance are handled as "flashes"; and in such cases, in order to eliminate the delay of awaiting "work" or "scoring" prints, the original negatives are used. In this way the stories are upon the screen within a few hours after the arrival of the negative. It is not at all uncommon in New York to see a newsreel flash of the deciding touchdown of an important football game in the theater the evening of the same day.

The news throughout the world is handled in about the same manner. In the key cities of the globe, London, Paris, Berlin, Rome, and Sydney, news events of world-wide importance are dispatched to the other five distribution centers by the fastest means of transportation. For Canadian and foreign distribution "dupe" negatives of the combined prints are employed. Speed is the essence of news, and the transmission of newsreels by television across seas and continents will probably be a reality in the future.

The work of the sound department is continuous and not finished upon the release of the film. Reports that include the comments of the editor as well as the recording analyses are returned with every story, and by such means a continual check is available to the field crew upon the operation of their equipment. If, for instance, the density of the sound-track indicates a gradual change for two or three consecutive stories, the crew is informed to make the necessary adjustments.

Prosaic facts such as these bear no intimation of the adventure and excitement of gathering news; but the men who travel around the world to record the scenes and sounds know differently. Even in the more densely populated and civilized places they are likely to be on hand when the "fireworks" begin because they shoot anything and everything that will make news; and quite frequently sudden unforeseen happenings such as assassinations are recorded by the news cameras. The newsreel presents news as it actually happens, in a compact form unbiased by prejudices or opinions.

DISCUSSION

CHAIRMAN FRAYNE: How do you take care of the more or less inherent difference of output between variable-density and variable-area films?

MR. HUMPHREY: Each newsreel company was furnished with a portion of a print, so that their prints, run in their own systems, could be checked against the sample.

CHAIRMAN FRAYNE: Was that done by changing the recording level or the transmission of the prints?

MR. HUMPHREY: We left that to the newsreel studios. They do it in their own way, as they see fit. They make the check themselves and, as mentioned, do a pretty good job, because when the prints get to the theaters they seem to be quite uniform.

CHAIRMAN FRAYNE: It is certainly encouraging to learn that the various newsreel companies can get together and bring about such an improvement. I could not help but think, as I listened to Mr. Humphrey, that if the studios of Hollywood could do likewise, the public would be given a lot of relief.

At the present time we go into a theater and hear a feature, or a reel of one, the sound volume of which is very comfortable. We hear and understand perfectly. Then all at once the picture changes to a *Mickey Mouse*, or a newsreel, or to something else. Suddenly there is a tremendous change in the output of the horns, and a great deal of discomfort is caused among the patrons, which must certainly be reflected eventually at the box-office.

If the labors of the Sound Committee can accomplish half as much good as has been done with the newsreels, a great job will have been done.

A DYNAMIC CHECK ON THE PROCESSING OF FILM FOR SOUND RECORDS*

F. G. ALBIN**

Summary.—*The limitations of the sensitometric method of controlling film development as actually affecting the sound recording are reviewed. An auxiliary test designed to check the quality of the development technic is outlined. In this test, the over-all photographic process, including the light-valve circuit which controls the exposure of the negative, and the photoelectric cell which receives the current impulses in accordance with the transmission of the positive film, are considered as an electrical unit. This unit is analogized to a transducer in an electrical transmission circuit and, as such, its fidelity of transmission can be determined by comparing the electrical output with the electrical input. In practice this is accomplished by applying a constant amplitude of electrical input to the light-valve circuit at values of valve spacing selected to allow the peak exposures to extend to the limits of the exposure regions that are to be used in the recording. The resultant projected levels for each value of valve spacing are measured with a volume indicator on the projection amplifier. If the readings obtained are all the same, true reproduction over the exposure range used is indicated.*

In the majority of sound recording and reproducing systems as used today, photography on film is used to attain the required time-delay feature. The technic of the photographic process greatly affects the quality of reproduction and continuous effort is expended to improve the conditions. The control of the photographic process has developed into a science, but the popular control methods when reduced to their simplified practical form are incompetent to provide fundamental data.

Considering the recording and reproducing system as a whole, the photographic portion, including the light-valve circuit which controls the exposures, and the photoelectric-cell circuit which receives the corresponding current impulses as a result of the exposures, may be analogized to an electrical transducer in an electrical circuit. This "transducer" (Fig. 1), as an electrical network, has as its terminations the circuits of the light-valve and the photoelectric cell. It may be characterized by the following features:

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** United Artists Studios, Hollywood, Calif.

(*1*) Time delay (function of system).
(*2*) Ground-noise (inherent noise generated within the "transducer").
(*3*) Limit to input level (usually measured with reference to the ground-noise level).
(*4*) Distortion (not desirable).
  (*a*) Wave-form.
  (*b*) Amplitude distortion as a function of time.
  (*c*) Frequency distortion (principally introduced by the mechanics of the system).
(*5*) Transmission efficiency.
  (*a*) Absolute efficiency, *i. e.*, ratio of output to input power, is relatively unimportant.
  (*b*) Discrimination as to frequency, relatively important.
(*6*) Limit to output level (usually measured with reference to ground-noise level).

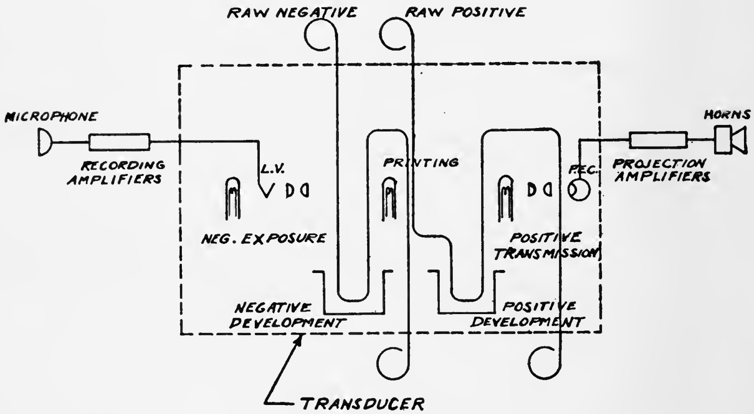

FIG. 1. Analogy of the photographic portion of the recording and reproducing system to an electrical transducer.

These characteristics can be measured electrically at the terminations more easily than by an accumulation of separate tests covering individual steps within the "transducer."

The volume latitude available for reproducing any one frequency is limited by the fidelity of transmission at high output levels and by the ground-noise at low levels. An indefinite number of factors affects the fidelity of transmission through the "transducer," and some of the more important ones are listed in their conventional classification:

(*1*) Light-valve coefficient.
  (*a*) Huyghen's effect upon light passing through a small aperture.

(*b*) Reciprocity law failure due to high intensity and short exposure time.
(*c*) Resolving power variation with density, development time, *etc.*
(*d*) Spectral composition of exposing illumination.

(*2*) Negative gamma.
(*a*) Choice of film emulsion.
(*b*) Negative exposure.
(*c*) Negative development.
(*1*) Type and age of developer.
(*2*) Speed of machine.
(*3*) *Etc.*

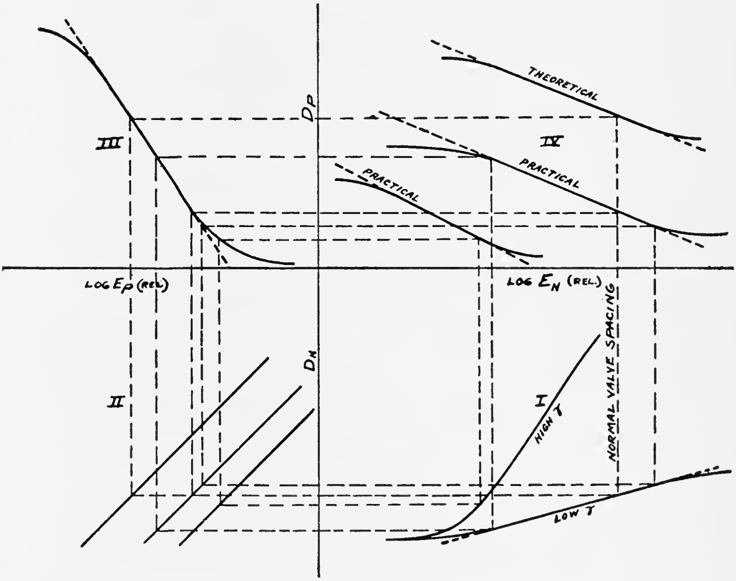

FIG. 2. Over-all graphical construction with H&D curves.

(*3*) Printer coefficient.
(*a*) Spectral composition of exposing illumination.
(*b*) *Etc.*

(*4*) Positive gamma.
(*a*) Choice of film emulsion.
(*b*) Positive exposure (printer point).
(*c*) Positive development.
(*1*) Type and age of developer.
(*2*) Speed of machine.
(*3*) *Etc.*

(*5*) Projection factor.
(*a*) Photoelectric cell type.

(1) Gas.
(2) Window size.
(b) Optical system proportions.

Of all the factors listed, negative and positive development are larger and more important. In practice they are subject to variations which, in turn, greatly affect the others. To control this development the sensitometric method was adopted. The Hurter and Driffield gamma used was defined as the slope of the straight-line portion of the plot of density against the logarithm of relative exposure. The common methods of applying the exposures and mea-

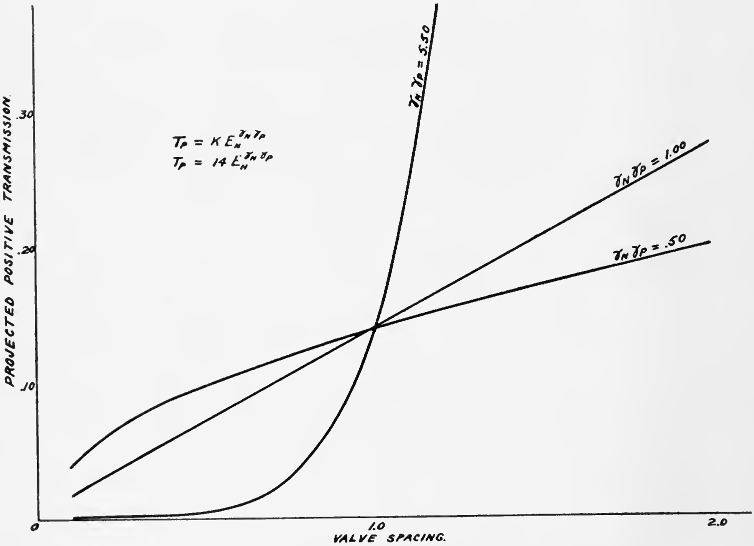

FIG. 3(a). Over-all recording characteristics (theoretical).

suring the densities produce conditions that differ greatly from actual operating conditions. Gamma, to be determined in this manner, must be augmented by the factors and coefficients given above.

If gamma were used in a broader sense to respect exposures as applied by the light-valve and densities as recognized by the photoelectric cell, the various coefficients would be absorbed in the terms negative and positive gamma. With gamma used in this broader sense it holds true that the photographic requirement for true reproduction, where the product of negative and positive gamma is unity, must be met. The requirement for recording is usually expressed as

$$\gamma_n \cdot \gamma_p = 1$$

for

$$T_p = KE_n^{\gamma_n \gamma_p}$$

in which

γ_p = positive gamma.
γ_n = negative gamma.
T_p = positive transmission.
E_n = negative exposure.

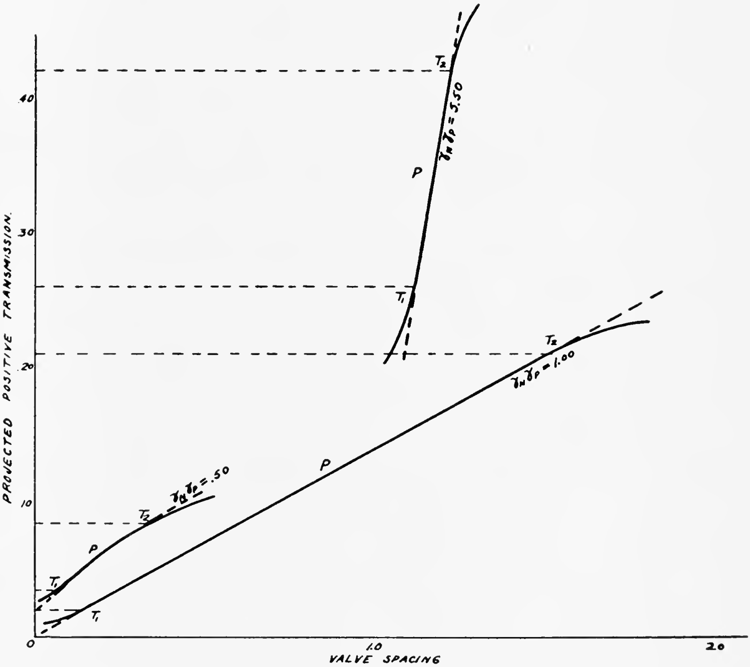

FIG. 3(*b*). Over-all recording characteristics (practical).

Several values of over-all gamma products are shown in Fig. 3(*a*), and it can be seen that for linear reproduction the product must be unity.

In practice, it has been found necessary to allow the exposures of the negative and the positive to extend beyond the straight-line portions of the negative and positive curves. This is shown in the graphical construction using H&D curves (Fig. 2.). In the theoretical plot the logarithmic mean exposures on the positive and negative curves are used as mean exposures. In the practical illustrations, positive mean exposures are determined by the choice of over-all gamma products. The negative exposure is governed by the available illumination, and where possible is usually the logarithmic mean of the straight-line portion.[1] Whenever the exposures are not confined to the straight-line portions, the H&D gamma product loses its significance. It is necessary to consider the term of density gradient instead of H&D gamma. This term, density gradient, as has been defined,[2] is the slope at any point along the curve, and is an instantaneous value. The use of the negative and positive density gradients instead of H&D gamma values in the above equation makes it applicable to types of recording wherein the exposures are allowed to extend beyond the straight-line portions and on to the toes or shoulders of the H&D curves. The equation then becomes

$$T_p = KE_n^{G_n G_p}$$

where G_n and G_p are the negative and positive gradients, respectively.

The curves for various over-all gamma products which were shown involve only the straight-line portions of the H&D curves, and as such are theoretical. When replotted (Fig. 3(*b*)) using gradients, these give actual conditions as obtained in practice, and include all the coefficients involved. The several curves indicate that for any degree of development of negative and positive there is a resulting over-all curve which has a point of inflection about which, for a limited amplitude, the curve is fairly straight. Thus, linear reproduction may result with the development varied over a wide range, provided that for each over-all condition the mean projected positive transmission is adjusted to this point of inflection and the amplitude is restricted to the portion of the curve that is nearly straight. The gradient product over this region is approximately unity. In these curves, however, negative exposure has not been adjusted by the method previously mentioned to permit maximum valve opening. Fig. 4 shows one of the curves replotted to allow the mean valve spacing to produce a projected transmission equal to the optimal point *P*, and permits maximum valve opening with full modulation. Each curve could be similarly treated. The resulting plots would still show that as the over-all gamma product departs from unity the limits of the unity gradient region in terms of T_2 and T_1 would be reduced, and that *P* would be greater with larger values of over-all gamma products. Correspondingly, with smaller values of over-all gamma products T_2 and T_1 would be reduced and *P* would be smaller.

As applied to this over-all curve, the maximum T_2 and minimum T_1 values of projected transmissions that can faithfully be used in a cycle of modulation are determined by the extremes of this unity gradient product region. With maximum allowable amplitude, the peak values of the cycle would correspond to T_2 and T_1, but for lesser values of modulation the peak transmissions of the cycle would not cover the entire range. This allows the mean transmission of the cycle of modulation to be adjusted as desired to increase or decrease the output volume, without introducing distortion, provided the peak

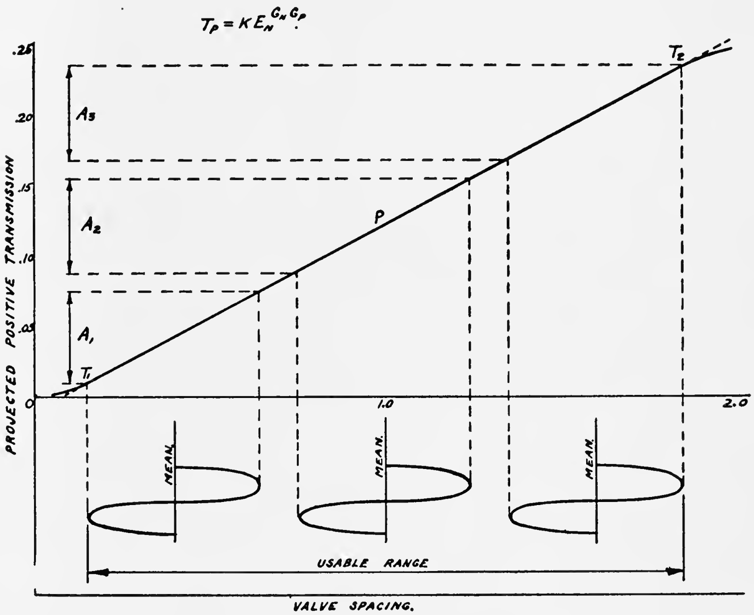

FIG. 4. Over-all recording characteristics (dynamic).

values do not extend beyond T_2 or T_1. This practice is usually referred to as cueing.

The projected level of the positive as measured with the volume indicator is the difference between the maximum and minimum peak values of the cycle being reproduced. The ground-noise for this cycle is determined by its mean transmission. For sine-wave forms the volume latitude, or the modulation of the positive, becomes

$$\frac{T_2 - T_1}{T_2 + T_1}$$

Using the values of volume latitude as obtained from the actual curves (Fig. 4) of transmission *vs.* exposure and plotting them against their corresponding over-all gamma values, an optimal development can be found (Fig. 5). The over-all gamma product is used to identify each development instead of the over-all gradient product, because the latter, as has been shown, is approximately unity for all development conditions throughout the true reproduction range.

In determining these curves so far the shape has been the result of selecting an over-all gamma. Now, if we can determine the shape by some other means, it follows that the over-all gradient can be obtained. The dynamic test is designed to accomplish this determination and provide a simple and practicable means of recognizing a unity gradient product.

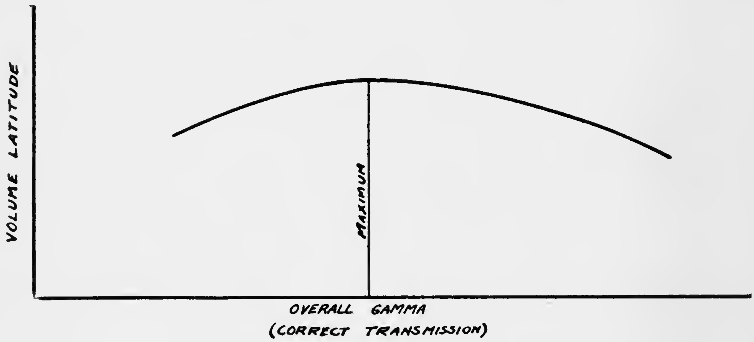

FIG. 5. Curve of optimal development.

THE DYNAMIC TEST

If a very small amplitude of sinusoidal modulation is applied to the light-valve and a predetermined mean spacing is used, a certain projected level with its mean transmission results. By maintaining a constant modulation amplitude and setting the mean spacing at several points, a corresponding projection level for each point can be measured with a volume indicator. The volume indicator readings will be proportional to the slope of the over-all curve at the point of mean valve spacing. By exploring the available exposure range, the complete over-all curve of projection transmission *vs.* light-valve exposure can be constructed. The value of over-all gradient for the portion of the curve between any two mean exposure values, E_{n1} and E_{n2}, is determined by the corresponding volume indicator readings as shown in the following equations:

EQUATION FOR DETERMINING OVER-ALL GRADIENT FROM VOLUME INDICATOR READINGS

Let

γ_n = negative gamma.
γ_p = positive gamma.
G_n = negative gradient.
G_p = positive gradient.
A = projected amplitude.
R = volume indicator readings (db).

For negative and positive exposures on the straight-line portion of the H&D curves

$$T_p = KE_n^{\gamma_n \gamma_p}$$

For any negative and positive exposure on the H&D curves

$$T_p = KE_n^{G_n G_p}$$

Let

$$G_n G_p = G$$

Taking the first derivative

$$\frac{dT_p}{dE_n} = KGE_n^{G-1}$$

Let the ratio of the projected amplitudes for mean exposures E_{n_1} and E_{n_2} be

$$\frac{A_2}{A_1}$$

Then with constant amplitude of negative modulation

$$\frac{A_2}{A_1} = \frac{\dfrac{dT_{p2}}{dE_{n2}}}{\dfrac{dT_{p1}}{dE_{n1}}} = \left(\frac{E_{n2}}{E_{n1}}\right)^{G-1}$$

But volume indicator readings are in decibels, whence

$$R_2 - R_1 = 20 \log \frac{A_2}{A_1}$$

Substituting

$$R_2 - R_1 = 20(G - 1) \log \frac{E_{n2}}{E_{n1}}$$

In the practical daily application of this test method (Fig. 5).

where optimal conditions have been determined from a more complete investigation, only three values of mean valve spacing are chosen, as it is evident that an over-all curve with three points of the same slope must be a straight line. The amplitude is fairly high to give a projected level considerably higher than the ground-noise level. The peak values of these spacings just cover the maximum exposure range used in recording during average conditions. The frequencies usually employed are 1000 and 5000 cps. The projected levels of the three exposures for each frequency when measured with the volume indicator, if flat or equal, show that the recording is not exceeding the straight-line portion of the over-all curve. A comparison of the projected levels of the two frequencies is a measure of the resolving power of the photographic portion. If not flat, the test indicates that adjustments must be made. The nature of the adjustments is determined by the individual conditions. In general, the attenuation of projected levels at low transmissions is caused by (*1*) low negative density, (*2*) low positive transmission, or (*3*) high over-all gamma. Also, the attenuation of the projected levels at high transmissions is caused by (*1*) high negative density, (*2*) high positive transmission, or (*3*) low over-all gamma. In more than 1000 tests, this method of testing has apparently faithfully indicated the film development condition where audible tests verify the indications given by the dynamic test.

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ENGINEERING TECHNIC IN PRE-EDITING MOTION PICTURES*

M. J. ABBOTT**

Summary.—*The use of engineering technic in determining the screen value of each scene in a motion picture before filming is described, and the methods used for control during the process of production are explained.*

Pre-editing motion pictures is nothing more than the application to motion pictures of engineering principles used in other lines of endeavor. In setting out to paint a picture, an artist first determines its size. He then outlines his subject. He does not begin to paint his picture without first knowing the relationship each detail bears to the others. The same is true in constructing a building. The architect first determines the size and type of building desired by his client, and then applies his artistry in designing. After these principal facts have been determined, he applies his technical methods of construction. He uses principles which are based upon past experience to determine the foundation necessary and other technical details that will make the completed building both artistic and practicable.

Motion pictures, being made exclusively for their commercial value, have their limitations as to size and the amount of money that can be derived from renting the prints. As the possible return upon the investment is limited, the cost of the motion picture must of necessity be limited. Although the cost of an article usually has some bearing upon the possible return upon the investment, excessive costs will not lead to excessive returns unless the quality of the article has been enhanced commensurately by the expenditure.

The financial structure of the motion picture industry, established by its competitive industrial standing, is such that it not only determines the possible return upon the investment, but also limits the length of the pictures. To fulfill conditions existing within the indus-

* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** RKO Studios, Hollywood, Calif.

try, exhibitors are compelled to have at least two performances a night in order to operate their theaters profitably. Thus, the playing time for each show is naturally limited. As the exhibitor is compelled to present a balanced program to his patrons, experience having established the newsreels, comedies, educational features, *etc.*, the playing time of a feature picture is limited to approximately one and one-half hours. The studios must construct their pictures to fulfill these requirements.

A general impression exists that making a motion picture is entirely a matter of creative artistry and, as such, must not be hampered by anything of a technical nature. It is not the purpose of this paper to attempt to prove or disprove this theory. We shall grant that it is true in part and that the creator's mind should not be annoyed with technicalities while creating. However, the results of the creator's efforts become purely technical as soon as completed, and their value, technically or commercially, is determinable by comparison with past experience.

The principle of pre-editing is not to curb the creative mind by compelling it to consider the technical points of a picture while working upon a story. It is a means of determining the motion picture value of the creator's efforts. Many question the possibility of computing the value of a story. This impression is not based upon facts, as story values have been measured since the inception of motion pictures. The only difference between pre-editing and the method that has been used in the past is that we do not wait until the story is upon the film and reaches the cutting room to find the errors, and then hope to edit the story by having the cutter remove the surplus or poor scenes and reduce the picture to commercial length. It can, therefore, be seen that the principles used in pre-editing are not new, but are merely the application of these known principles in determining the value of the story before rather than after the picture has been made.

The first principle to be considered in pre-editing is the type of picture to be made. These types are as follows:

(1) Drama
(2) Melodrama
(3) Comedy Drama
(4) Comedy
(5) Farce
(6) Musical Revues
(7) Musicals
(8) Westerns

The determination of the type sets the tempo in which the picture will be made. The story must be timed accordingly.

The first step in determining picture value is to read and study the entire script; after doing which each scene of the script is read and studied individually, as though it were a complete picture. The action as outlined by the writer is studied and allowance made for the footage necessary to place each of the individual scenes upon the screen. The basis used in determining the necessary footage is that of the presently used cutting principles. The dialog of the scene is timed by reading the lines in the tempo of the class of picture to be made, allowance being made for the simultaneous occurrence of dialog and action.

The next step is to determine the value of each scene as a motion picture, namely, what portion of the scene, as outlined, will be given to the audience through the eye, and what portion through the ear. This is arrived at by timing the dialog in the scene which is not covered by action. The scenes are then computed by episode and sequence, and summarized for the entire story. The results are furnished to the writer, producer, and director for their guidance in rewriting the story, to eliminate or correct weak spots due to excessive dialog, and also to visualize the relative value each scene bears to the entire picture, and to regulate the length of the picture to meet the commercial requirements of the exhibitor.

During the shooting of a picture, a production control record is kept, and the actual time of shooting each scene is compared with the estimated value of the scene as conceived by the writer. This control is arrived at by comparing the script notes made by the company script clerk, who times the footage of each scene during the process of shooting. As the various episodes and sequences of the story are completed and placed in "rough cut" by the cutters, they report to the production control the amount of footage of each take made by the director that has been used and placed in "rough cut." Upon receipt of this information, and upon comparing it with the pre-estimate, it can be determined whether or not the picture is being shot in the tempo of the class of picture desired.

Daily Production Reports are furnished to the producers and directors showing the status of their picture, as to the shooting schedule, the quantity of film used, and the tempo in which the director is actually shooting the picture. As the story value of the picture in the pre-ëstimate is based upon the correct tempo of the type of picture to be made, by comparing the actual shooting with the estimated time the producer is informed as to the tempo of each scene and sequence, and as to whether or not it is shot too slow or too fast, so that when the picture is completed it will not be slow in spots and fast in others.

When the picture is finally completed and ready for release, the actual takes used in the picture are compared with those shot by the director and the cost of those not used (the out-takes) is determined by the time spent in making them. Some of the benefits to be derived from pre-editing are as follows:

(1) Eliminates waste due to over-shooting.
(2) Shortens shooting schedules.
(3) Saves time of company and executives in projection room checking film which never reaches the finished picture.
(4) Prevents distorting the story by endeavors to cure defects after shooting.
(5) Allows the story as written to reach the finished picture without mutilation.
(6) Allows the judicious and profitable spending of money.
(7) Hence the improvement in quality of product.
(8) Finally, cleans up the cutting room floor.

CHARACTERISTICS OF THE PHOTOPHONE LIGHT-MODULATING SYSTEM*

L. T. SACHTLEBEN**

Summary.—*Some of the requirements of the ideal light-modulating system for recording sound upon film are discussed, together with features of design and certain operating characteristics which should be incorporated into and exhibited by such a system. The Photophone light-modulating system is outlined, its general adaptability to the production of a wide variety of sound-track types reviewed, and its practical conformity to the ideal requirements pointed out.*

Any practicable light-modulating system used in recording sound upon film, by either the variable-width or variable-density method, should be designed with certain ideal requirements in mind, and should be made to fulfill those ideal requirements as closely as possible. Although the variable-width and variable-density sound-tracks are quite different in character, the apparatus used in making them is essentially the same, in that both employ long, narrow, illuminated slits focused upon the moving film by optical means.

In variable-width recording this slit image is modulated by varying the length of its illuminated portion so as to produce upon the finished film a strip of constant density and varying width, constituting a wave geometrically perceptible to the eye, whose contour is a graphic picture of the pressure or velocity component of the sound-wave at the microphone diaphragm. The variable-width sound-track is essentially an oscillogram (Fig. 1*a*).

Modulation of the slit image in variable-density recording is such as to vary the exposure from point to point along the length of the sound-track, keeping the slit image at all times uniformly illuminated along its length. The resulting sound-track varies in density from point to point along its length, its transmission varying, ideally, in linear relation to the pressure or velocity component of the sound-wave at the microphone diaphragm. Although the variations of density are apparent to the eye, the transmission of the track, or

* Presented at the Spring, 1935, Meeting at Hollywood, Calif.
** RCA Manufacturing Co., Camden, N. J.

its power to transmit light, is not geometrically apparent to the eye as in the variable-width sound-track (Fig. 1*b*). Since exposure is proportional to the product of image illumination and the time during which the emulsion is submitted to the action of the light, variable-density records may be made by varying the exposure time and keeping the illumination constant, or by varying the illumination and keeping the exposure time constant.

In so far as the character of the slit and optical system are concerned, departure of the sound record from ideal perfection, through attenuation of the high frequencies, introduction of harmonic distortion, and so forth, is largely due to departure of the system from the following ideal conditions:

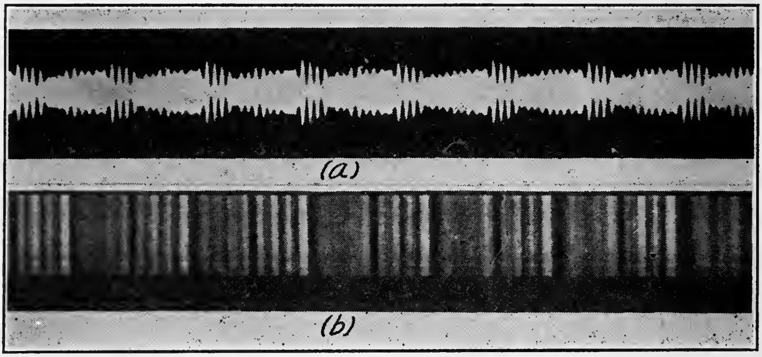

FIG. 1. (*a*) Double-edged or bilateral variable-width sound-track; (*b*) variable-density sound-track.

(*1*) The slit image should be of infinitesimal width.

(*2*) The slit image should be fixed in width.

(*3*) The illumination should be perfectly uniform along the length of the slit image.

(*4*) The exposure should be adequate to produce the densities required by the type of sound-track used.

(*5*) The stray light ratio should be zero.

In practice, recorder slit images are of finite width, and give rise to the slit effect, the magnitude of which can be kept small only by keeping the width of the slit image very small. The slit effect in variable-width recording has been analyzed by Cook[1] and Foster,[2] the former having determined the ideal superior limit of the effect, and the latter having analyzed its extent under the conditions of practice. Briefly, it is the introduction of harmonic distortion into a recording and the attenuation of the fundamental, due to the fact that the width of the recording slit image is an appreciable fraction of the wavelength (upon the film) of the recorded frequencies. In variable-density, the slit effect introduces only attentuation, and does not give rise to harmonic distortion.

The recorder slit image is fixed in width in variable-width work, and in variable-density work where the image illumination is varied, as in glow-lamp recording. The image varies in width in variable-density work where the illumination is constant and the exposure time is varied.

Any very great departure from uniform illumination along the length of the slit image will cause distortion in either variable-width or variable-density work. In variable-width, departure from uniform density across the sound-track will cause the transmission to be no longer linearly related to the amplitude of the impressed signal; and in variable-density, non-uniformity in this respect may cause longitudinal portions of the sound-track to depart seriously from linearity. These distortions will arise in variable-width work if the density of one edge of the negative drops sufficiently to allow appreciable printing through, with attendant change of wave-shape; and in variable-density work if non-uniformity of slit image illumination is such as to cause a portion of the track to be recorded off the linear portion of the over-all curve.

The fourth point, calling for adequate exposure, is more or less obvious. In variable-density recording by means of a glow-lamp, the classical straight-line recording scheme is abandoned in favor of toe recording, on account of limited illumination, and the light-valve has been adopted for straight-line recording where large exposures and large variations of exposure are required.

A low ratio of stray light to useful light is important in variable-width work, in which the exposed portion of the track varies in width and the unexposed portion must receive no exposure, in order to assure good output at high densities and to keep down attenuation at high frequencies due to irradiation.

Aside from approaching these ideal requirements, a practical light-modulating system should fulfill additional requirements of great practical importance. A practicable system should be simple to adjust and operate, and should be stable in adjustment even when subjected to serious overloads. It should be rugged in construction, protected against dust, and readily cleaned and kept in condition. The system should be capable of being checked in a simple manner as to condition and performance, or monitored, continuously during recording. Optical efficiency and the quality of optical correction should be high, and the system should incorporate a ground-noise reduction feature, to keep the ground-noise to signal ratio low at low recorded amplitudes. Power requirements should be reasonable, and the frequency response sufficiently wide to allow music and speech to be recorded with natural fidelity or life-like quality.

THE PHOTOPHONE LIGHT-MODULATING SYSTEM

Before discussing the features of the Photophone light-modulating system in detail, the more important ones will be presented in outline:

(*1*) High illumination of the slit image makes it possible to use slow, fine-grained emulsions of high resolving power.

(*2*) The slit image is fixed in width.

(*3*) The slit image is 0.00025 inch wide, practically eliminating the slit effect.

(*4*) The movements of the recording beam are sufficiently apparent to the eye to constitute an effective monitoring system.

(*5*) All parts are rugged, thoroughly protected, capable of recording amplitudes well beyond the limit set by the width of the sound-track before overloading, and will withstand large overloads without injury.

(*6*) A ground-noise reduction circuit is built into the Photophone recording galvanometer.

(*7*) The frequency response is essentially flat from 0 to 9000 cycles.

(*8*) The system is capable of recording three distinct types of sound-tracks, including the variable-density.

(*9*) The images of the recording aperture and of the slit are both formed by special achromatic lenses.

Construction and Operation (General).—In its essential form the new Photophone light-modulating system does not differ from the earliest variable-width recording systems, closely adhering to the arrangement described by Hardy in 1928.[3] Fig. 2 is a schematic diagram, in the horizontal plane, of the Photophone system, the operation of which may be briefly described as follows: the condenser lens *b* and the achromatic lens *d* image the lamp filament *a* upon the vibrating mirror *e*. Aperture *c* lies close to the condenser *b*, and is imaged sharply upon the slit *g* by the achromatic lens *d*. The condenser lens *f* images the mirror *e* upon the special corrected achromatic objective *h*, which images the slit *g* sharply upon the film. In operation,[4] the mirror *e* vibrates about an axis in the plane of the figure and intersecting both optical axes in their common intersection point. This moves the image of the aperture *c* up and down in the plane of the slit *g*.

By making the aperture *c* in the form of an isosceles triangle with its base horizontal (parallel to the slit), its image will appear upon the slit *g* as shown in Fig. 3. As the aperture image moves up and down, the length of the illuminated portion of the slit will be in linear relation to the angular displacement of the mirror *e*. The variable-width sound-track thus produced will, in the print, have the general appearance indicated. It will readily be appreciated that in the

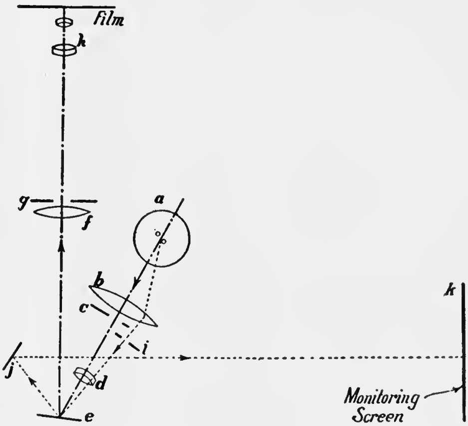

FIG. 2. Diagram of the Photophone light-modulating system.

variable-width track the recorded wave is geometrically perceptible to the eye, its contour being a graphic picture of the pressure or velocity component of the sound-wave at the diaphragm or ribbon of the microphone. In fact, with the variable-width type of record, "faithfulness of reproduction is primarily a matter of reproducing a geometric form."[5]

If recordings are made in the manner just illustrated, the average transmission of the resulting sound-track will be constant and equal to 50 per cent, whether the modulation be high or low. When modulation is low it is desirable that the average print transmission be low also, in the interest of a low ground-noise to signal ratio. This end is attained[6] in the Photophone optical system by electrically biasing the position of the mirror *e* (Fig. 2) until only the tip of the triangular image falls upon the center of the slit (Fig. 4). When no signal is impressed upon the amplifier an extremely narrow transparent line occurs down the center of the printed sound-track. When a signal is impressed upon the amplifier, a special ground-noise reduction circuit causes the image of the triangle to rise proportionately to the envelope of the impressed signal until the average transmission of the track is 50 per cent, thereby increasing the average transmission of the print to just the extent necessary to

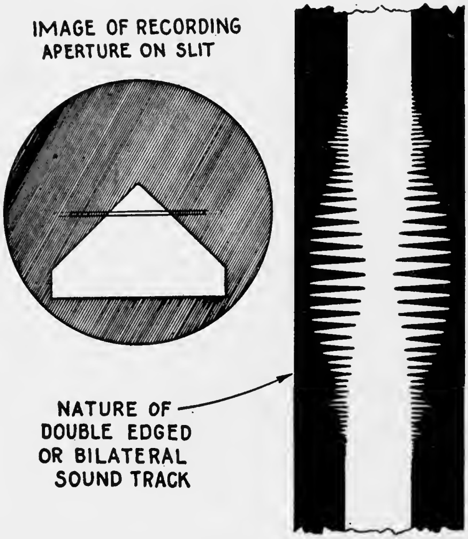

FIG. 3. The variable-width sound-track without ground-noise reduction.

accommodate the wave without overshooting. In this manner, the ratio of ground-noise to signal is kept low at all times. The operation of the ground-noise reduction system will be described in more detail later.

The adjustments of the high-fidelity recording optical system are relatively simple and uncritical (Fig. 5). The mechanical slit, which is 0.0015 inch wide by 0.420 inch long, is fixed in permanent adjustment at the factory and presents no adjustment problems whatever in the field. It is so located in the optical system as to be entirely dust-proof, and with ordinary use and care will never be liable to injury or require cleaning.

The exposure lamp is set in a universal mounting, and can be simply and quickly adjusted so that the image of the filament falls centrally upon the galvanometer mirror, which, incidentally, is covered with a plane glass window, tilted to introduce no stray light and designed to protect the galvanometer from dust and mechanical injury.

Like the slit, the triangular recording aperture, which is imaged upon the slit, is set in a dust-proof mounting. It is fully adjusted at the factory and sharply focused upon the slit, and requires no

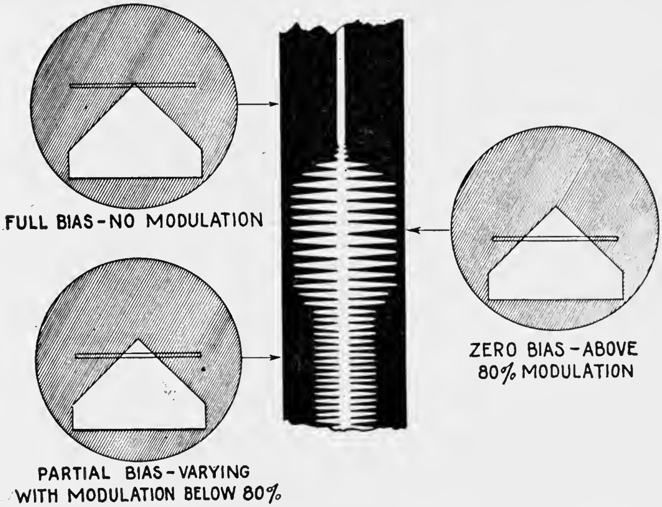

FIG. 4. Ground-noise reduction as applied to variable-width recording.

subsequent adjustment although, should occasion ever arise, it could be adjusted in the field. Likewise the location of the optical system upon the recorder is determined at the factory, and permanent adjustment of the sound-track location assured by means of dowel pins. Removal of the optical system from the recorder, therefore, does not disturb this adjustment. Optical systems can be interchanged between recorders by removing the dowel pins.

Adjustment of the System.—In practice the recordist is concerned with only four mechanical adjustments of the optical system. These are (*1*) lamp filament centering, which has already been discussed, (*2*) focusing the slit upon the film, (*3*) adjusting the galvanometer about the horizontal axis, and (*4*) about the vertical axis. The focusing adjustment of the slit upon the film is ordinarily fixed, but is easily changed and checked. The adjustment is accomplished by inserting a special microscope into the end of the hollow recording drum, and viewing the spot of light upon the film through a hole in the drum while moving the objective and slit assembly axially by means of a knurled adjusting nut. When the slit image appears sharp the adjustment is fixed by tightening a set-screw which clamps the barrel without disturbing the adjustment.

Adjustment of the galvanometer about the vertical axis is like-

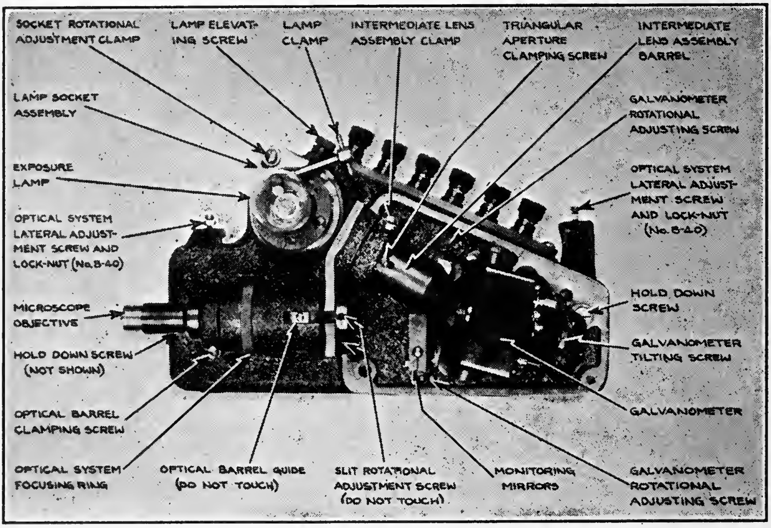

FIG. 5. The Photophone high-fidelity, light-modulating system.

wise made while viewing the image through the focusing microscope. It is turned about the vertical axis until its rotation about the horizontal axis causes the two edges of the triangle of light to reach the two ends of the slit simultaneously. The adjustment is then locked by tightening two adjusting screws which work in opposition. Adjustment about the horizontal axis is associated with the adjustment of the ground-noise reduction system, to be described later. It is accomplished by turning a finely threaded screw at the rear of the galvanometer which, after adjustment, is secured by a knurled lock-nut.

Inasmuch as the system is sealed by optical surfaces at all points, dust does not enter, and it is necessary only to clean these readily accessible surfaces regularly with lens paper to keep the system in good working condition.

The One-Fourth Mil Slit Image.—The analyses of slit effect previously mentioned show that the aperture effect diminishes rapidly as the slit image width decreases. Steady progress has been made in the direction of eliminating it. In the early days of recording, slit images one mil wide were considered satisfactory. Galvanometer mirrors were then too small to illuminate very much narrower images properly, and the limited frequency ranges then employed made the aperture effect not serious. A little later, three-quarter mil slit images came to be employed, and the way was made clear for further reductions by the increased efficiency of the larger mirror of a new galvanometer,[7] which at the same time extended the frequency range of sound-film recordings. The frequency range[4] was then extended still further by the design of a new galvanometer mechanism; and certain increases in optical efficiency, made possible by the adoption of the double-edged variable-width track, were used to reduce the slit image width further, to one-half mil. Finally, the one-quarter mil recording slit image was adopted, the necessary increase in optical efficiency being conveniently attained by replacing the 5-volt, 6-ampere recorder lamp with the 10-volt, 7.5-ampere reproducer lamp, which more completely filled the galvanometer mirror with light. Improvements in the sensitivity of photographic materials for sound recording have also contributed to the successful reduction of the size of recording slit images.

The new Photophone light-modulating system records with a one-quarter mil slit image, which effectively reduces the aperture effect to negligible proportions. Although further improvements in this direction may eventuate, it appears that an additional reduction of about 30 per cent will cause the optical system to reach the limit of its optical resolving power. This limit is reached when the primary diffraction images of the source, whose distance from the axis increases with diminished slit width, spread out so far as not to enter the lens by which the slit is imaged upon the film. An image can not be formed when only the central diffraction image of the light-source enters the lens.

The Front Surface Galvanometer Mirror.—An important improvement is the adoption of a new front-surface galvanometer mirror. Previously, a high-quality, back-silvered mirror was used with very good results, except for the unavoidable secondary images characteristic of this kind of mirror. The new optical system employs an identical glass mirror except that the front surface is the reflecting surface, being coated with a film of aluminum alloy by the evaporation process. Treatment subsequent to deposition renders the surface resistant to corrosion and thoroughly cleanable without danger of mechanical injury or scratching. An additional advantage, attending the elimination of the secondary images by the front-surface mirror, is the elimination of the stray light that formerly arose from irregular reflection at the edges of the mirror. The total effective reflectivity of the new aluminum mirror is practically the same as that of the silvered mirror.

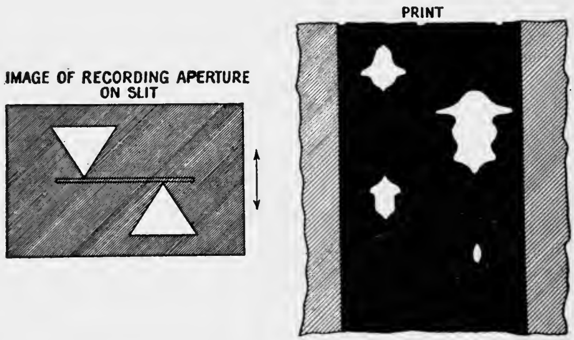

FIG. 6. The variable-width, push-pull sound-track.

Instant Convertibility from Conventional to Push-Pull Recording.—Within recent months, the RCA engineers have developed an improved system for noiseless recording known as the push-pull system.[8] Briefly, the central feature of the new system is a new type of sound-track, which is opaque except where modulation has been impressed upon it. This sound-track is effectively a double track, occupying the same portion of the film as the standard variable-width tracks, with one of the double tracks carrying the positive portion of the impressed wave, and the other alongside it and carrying the negative portion of the wave. In reproduction, these positive and negative impulses are electrically recombined so as to recreate the original sound.

The essential design of the optical system undergoes no change when converted for the production of this new push-pull sound-track.

The triangular recording aperture used in recording the conventional variable-width sound-track is replaced by an aperture with two triangular openings (Fig. 6) so arranged that when modulation swings the galvanometer in one direction from the zero position the portion of the sound-track carrying the positive portion of the wave is exposed to a varying width, and when it swings it in the opposite direction the negat ve portion of the sound-track is exposed in the same manner. When there is no modulation the sound-track receives no exposure, and the corresponding portions of the print are opaque.

The new Photophone light-modulating system is available with

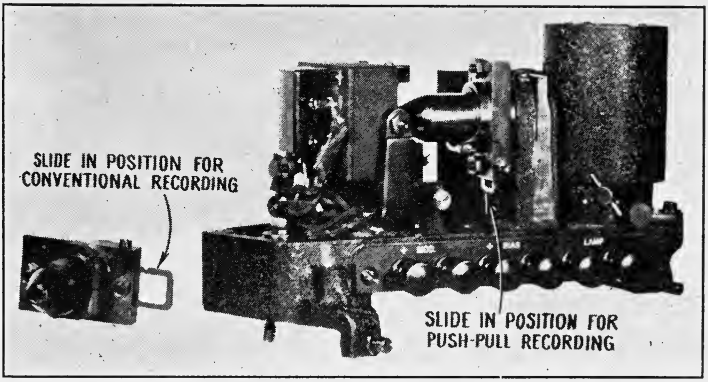

FIG. 7. The Photophone light-modulating system equipped with slide for changing from conventional to push-pull variable-width recording.

both the conventional and push-pull recording apertures mounted upon a single slide (Fig. 7) in such manner that simply by pushing the slide in or pulling it out with the fingers the optical system is instantly made ready to record either conventional or push-pull sound-tracks. When recording in conventional fashion, the ground-noise reduction equipment is, of course, employed and associated adjustments of the optical system must be made. No ground-noise reduction equipment is used when recording push-pull, as the push-pull track is inherently noiseless.

Recording Variable-Density.—Although the Photophone light-modulating system is designed primarily for variable-width recording, it lends itself very readily to variable-density work. Since the coiled tungsten filament of the 10-volt, 7.5-ampere lamp is set with its axis in the horizontal plane, a horizontal edge placed between the lamp and the first condenser lens will cast a straight shadow upon the recording aperture, displaying the well-known penumbra characteristic of shadows produced by extended sources (Fig. 8). The shadow is, in turn, imaged upon the slit by the same lens that images the recording aperture for variable-width work. The illumination in this penumbra will at any point be proportional to the distance of the point from the edge of the umbra, up to the limit of full illumination. While Fig. 8 illustrates schematically the formation

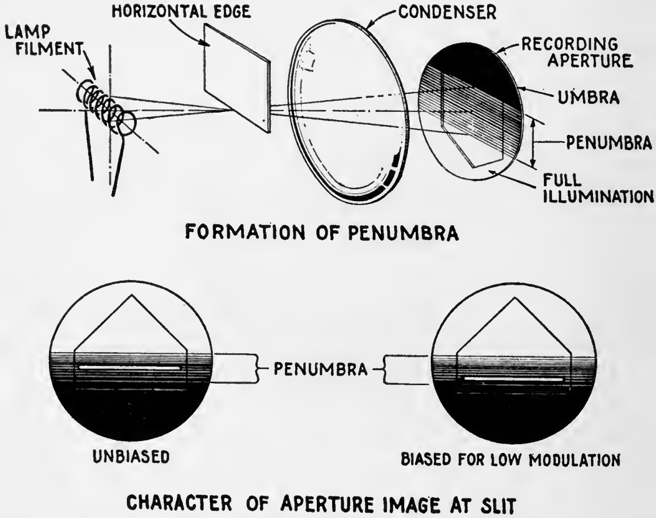

Fig. 8. Formation of penumbra for variable-density recording with the Photophone light-modulating system.

of the penumbra, actually the top and the bottom of the filament are masked off at the filament image on the galvanometer mirror. This is done to attain a linear distribution of light in the penumbra. Variable-density recordings are made by modulating the galvanometer in the same way as in variable-width recording, and causing the penumbra of the shadow to pass up and down across the slit to vary the exposure of the film within the permissible limits. This method of producing variable-density recordings combines two desirable features, namely: sufficient illumination to expose the slower, finer-grained emulsions of high resolving power; and a recording slit image width which is fixed and equal to 0.00025 inch. The ground-noise reduction system operates as in variable-width work, and biases down the average exposure[9] of the negative for low modulation values by causing the darker portions of the penumbra to be cast upon the slit.

The Direct Visual Monitoring System.—An outstanding feature of the Photophone light-modulating system is direct visual monitoring by observing the vibrating image of the recording aperture. What is observed is not the image of the recording aperture itself, but the image of another aperture (*i* in Fig. 2) which moves through the same angle, being formed by the same lens that images the recording

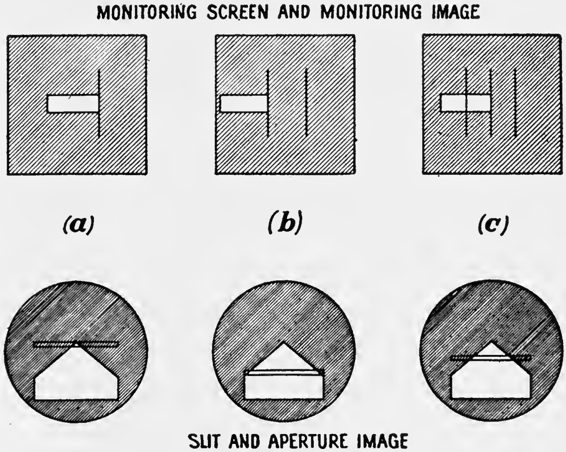

FIG. 9. Adjustment of the Photophone monitoring system.

aperture and being deflected by the same mirror. This image is reflected to a white screen (*k*, Fig. 2) farther from the galvanometer mirror than the slit and vibrates at a greater linear amplitude than the image of the recording aperture, making it somewhat easier to observe than the latter. Adjustment is simple in that it is required only to mark upon the card the position of one end of the monitoring image when the tip of the triangular recording image just crosses the slit (*a*, Fig. 9), and again when the galvanometer is in such position as just to illuminate the full length of the slit (*b*, Fig. 9). These points are easily determined visually and marked upon the monitoring card, and locate the limits beyond which the sound-track will be overloaded or "overshot." It is necessary to draw accurately an additional line midway between the two, and it is by this line that the galvanometer is set at the mid-position about which vibration must take place when the track is fully modulated (*c*, Fig. 9).

With the indexed monitoring card as a guide, the routine adjustments consist of mechanically setting the monitoring image to the central line (*c*), increasing the d-c. biasing current of the ground-noise reduction system until the mirror is deflected to the point where the tip of the triangle just extends across the slit (*a*), and, by

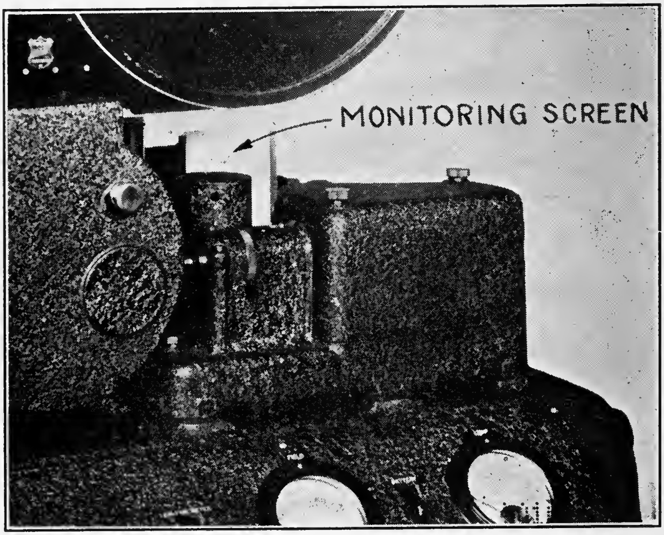

Fig. 10. Light-modulating system and monitoring screen in position on a Photophone recorder.

means of the 1000-cycle oscillator, adjusting the gain of the ground-noise reduction amplifier until the current that biases the mirror cuts off at a predetermined value of modulation, usually about 80 per cent. These adjustments make the system ready to operate. During recording, the amplifier gain is kept such that the edge of the monitoring image does not pass beyond the limit lines on the monitoring card. Fig. 10 shows the appearance of the light-modulating system and monitoring screen in position on a Photophone recorder.

This visual monitoring of film recordings parallels the visual examination of lateral-cut disk records in that overshooting is at once apparent to the recordist when the take is made, and retakes can be made at once without the necessity of first processing the record to learn if overshooting has occurred.

The Recording Galvanometer.—The recording galvanometer or vibrator is both simple and rugged in construction, and is so designed that its operating characteristics are stable and not dependent upon any field adjustments. All parts are of substantial dimensions and the nature of the operating characteristics of the instrument depends more upon the physical properties of the materials used and their physical dimensions than upon delicate mechanical adjustments subsequent to assembly. This was not true of the Duddell type of oscillograph vibrator originally used, in which critical adjustment of

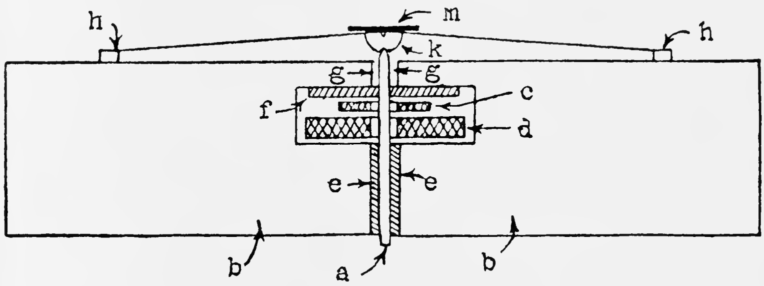

FIG. 11. Diagram of Photophone galvanometer or vibrator.

the tension of a pair of delicate vibrating ribbon conductors was necessary.

The construction of the galvanometer has been previously described, and has undergone little modification, except that tungsten loaded rubber damping is used, and its method of application is modified and improved. Fig. 11[4] shows the construction: A silicon steel armature, *a*, is clamped between two laminated silicon steel pole-pieces, *b*, being separated from the pole-pieces by two non-magnetic spacers, *e*. The free end of the armature is ground to form a knife-edge, which fits into a groove in the semicylindrical mirror plate, *k*. A phosphor bronze ribbon is fastened to two prongs, *h*, and passes over the mirror plate. The two prongs press against the pole pieces and tend to spring apart, providing a small tension in the ribbon. The slight angle between the ribbon and the face of the pole piece results in a component of force tending to hold the mirror plate against the armature. An aluminum alloy coated front-surface mirror, 0.125 inch long by 0.100 inch wide, is cemented to the mirror plate, the cement also preventing relative motion between the mirror plate and the ribbon. A force applied near the end of the armature deflects it in a manner similar to a cantilever beam. Since the phosphor bronze ribbon prevents lateral displacement of the mirror plate, the latter is free to vibrate only rotationally about a center through the ribbon. A major part of the controlling stiffness is due to the armature itself, the remainder being in the ribbon. A portion of the flux from two cobalt steel magnets passes through the two air gaps, *g*. Two coils, *c* and *d*, surround the armature, but are not in contact with it. Coil *c* carries the voice current from the recording amplifier while coil *d*, wound with many turns of fine wire, carries the biasing current required in eliminating ground-noise. A rubber pad, *f*, provides the desired damping at resonance, which occurs at 9000 cycles.

The impedance of the galvanometer is 2 ohms and its power consumption is less than 175 milliwatts when working at full modulation. Inasmuch as magnetic saturation occurs at 100 per cent overload, the instrument is self-protected against mechanical injury, because beyond saturation practically no increase of deflecting force occurs with increased current.

Adequate Exposures with Low Lamp Currents.—In the Photophone light-modulating system, the illumination of the slit image is high and also very uniform. Negatives developed to high gammas show no measurable variation of density across the sound-track. Generally speaking, the finer-grained emulsions of high resolving power are most desirable for sound recording, and this system provides sufficient light to expose such emulsions properly. At the present time, variable-width negatives are being recorded on Eastman emulsion *No. 1359* and Du Pont emulsion *No. 201*, both of which are faster emulsions than the Eastman *No. 1301* used in the early days of sound-film recording. With these emulsions and the one-quarter mil slit image, suitable negative densities result from operating the 7.5-ampere lamp at 7.0 amperes. The resulting extension of lamp life, uniform lamp performance, and freedom from untimely burn-outs and frequent lamp replacements are obvious.

Special acknowledgment is due Mr. G. L. Dimmick who, for the past five years, has been immediately responsible for the development and continuous improvement of the Photophone light-modulating system.

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DISCUSSION

MR. KELLOGG: Several improvements have been mentioned that have resulted in increased light intensity. Advantage has been taken of this to narrow the recording slit and thereby improve the resolution. The most important factor in increasing the light intensity was undoubtedly the development by Dimmick of a galvanometer having a much larger mirror than the oscillograph type of galvanometer previously employed. Next in importance was the feature of placing the mirror axis horizontal and using an acute angle of intersection between the slit and the edge of the aperture image, thereby making it possible to cover the complete range of slit illumination with smaller movements and with the galvanometer brought closer to the slit. A third major factor in making it feasible to reduce the slit to the present quarter-mil width was the availability of faster recording films. This contribution through the coöperation of film manufacturers deserves special acknowledgment. The problem was evidently by no means a simple one. Motion picture positive which was used at first is a fine-grained, high-resolution film. Increased speed, although desirable, has not been extremely urgent. At first it seemed as if any increase in speed was at the cost of resolution; and high contrast, which is desirable for variable-width recording, was always accompanied by a higher toe. But films were finally made available which had the increased speed with little, if any, sacrifice of the other desirable properties.

REPORT OF THE STANDARDS COMMITTEE*

With the publication of the new motion picture standards in the November, 1934, issue of the JOURNAL, and of the Standards Booklet, the Standards Committee, under the Chairmanship of M. C. Batsel, completed many of the problems in which it had been engaged.

At the beginning of 1935, L. A. Jones, *Engineering Vice-President*, appointed a new Standards Committee, composed of many of the old members and some new members. One special feature of this new Committee is that there is a Vice-Chairman on the Pacific Coast whose duties are to help correlate the opinions of the West Coast members with those of the East Coast members. J. A. Dubray was appointed to this Vice-Chairmanship. Before each meeting of the Standards Committee, an agenda is mailed to all the members, and those on the West Coast meet together at about the same time as those on the East Coast, and discuss the same problems. The minutes of both groups are sent to all the members.

The main items under consideration by the Committee at the present time are as follows:

(*1*) *Sprockets.*—The standards published in the Standards Booklet for 35-mm. sprockets apply only to projectors. We have no standards for cameras, sound apparatus, or printers. There is considerable doubt in the minds of most members of the Committee as to whether or not we are ready to standardize any of these items, or even whether it will ever be desirable to do so. The subject is being taken up with the manufacturers of these products to see what, if anything, should be done at the present time.

(*2*) *Guiding Methods in Cameras, Printers, Etc.*—The Standards Committee has already committed itself to edge guiding in the projector, but as yet no agreement has been reached as to the desirability of edge guiding in the camera or printer.

(*3*) *Screen Brightness.*—The Standards Committee is awaiting the report of the Committee on Projection Screen Brightness before taking any action upon the subject of standard screen brightness.

(*4*) *Reel Dimensions.*—The question of standardizing sizes and di-

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

mensions of reels was ably discussed in the report of the Sub-Committee on Exchange Practice at the Spring Meeting in 1934, and is now under consideration by the Standards Committee.

(5) *Photoelectric Cells.*—A set of standard specifications for photoelectric cells adopted by the British Standards Institution and published in January, 1935, is under consideration and is awaiting criticism by the Sound Committee.

Two of the standards that have already been officially adopted by the Society are still of great interest. One of these relates to the use of a single type of perforation for both negative and positive, and it is the hope of the Committee that the old type of perforation will be discarded for negative film as it has been for positive film. The other item, the standards for 16-mm. sound-film, is the source of considerable anxiety to those interested in the future of 16-mm. projection.

Through a misinterpretation of the drawing published in the JOURNAL of the Society of Motion Picture Engineers, the Committee of the Deutsche Kinotechnische Gesellschaft recommended a film which they thought was a duplicate of ours but which actually had the sound-track upon the opposite side of the film from that of the American standard. Through a misinterpretation of their drawing, upon our part, this error was not noticed until some time had passed, with the result that two different camps have arisen, each favoring a different standard.

Last summer, at a conference called by the International Educational Cinematographic Institute (I. C. E.) of the League of Nations, the German proposal was adopted. All the above was explained in more detail by Mr. Batsel in the report of the Standards Committee for last Fall. Since then, a Sectional Committee on Motion Pictures, organized according to the procedure of the American Standards Association, has been formed. This Committee will undoubtedly approve the S. M. P. E. standards, and it is hoped that the American Standards Association, through the International Standards Association, can succeed this next summer in achieving international adoption of a single standard, through regular channels.

During the last week in April, 1935, an International Film Congress was held in Berlin and a sub-committee of this Congress was formed for further consideration of the 16-mm. sound-film standard. Al though the Standards Committee has not yet seen the full report of this meeting, it apparently was in favor of upholding the decision of the Stresa Conference. The subject will again be discussed at a conference of the International Standards Association to be held at Paris in July in conjunction with the International Photographic Congress, and the results of this conference will be of great interest to the industry.

Aside from these items, there are a few items upon which the Committee has not yet had a chance to act. These are:

(1) A proposal for 8-mm. sound-film.

(2) The possibility of supplying sets of densities of sputtered glass or other material for use as reference standards with densitometers.

(3) The production of a 16-mm. test-film for use in testing 16-mm. sound projectors.

The general policy of the Standards Committee remains unchanged except that we shall endeavor to keep in closer touch with the European standardization groups and to promote a closer coöperation between the East Coast and West Coast members.

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FALL, 1935, CONVENTION

WASHINGTON, D. C.
WARDMAN PARK HOTEL
OCTOBER 21–24, INCLUSIVE

Officers and Committees in Charge

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Headquarters

The headquarters of the Convention will be the Wardman Park Hotel, where excellent accommodations and Convention facilities are assured. Registration will begin at 9 A.M., Monday, October 21st. A special suite will be provided for the ladies. Rates for S. M. P. E. delegates, European plan, will be as follows:

One person, room and bath	$3.00
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	5.00
Rates for connecting parlors	5.00

A modern fire-proof garage is located on the Hotel property, and a special 75 cents per day rate has been arranged for.

Technical Sessions

An attractive program of technical papers and presentations is being arranged by the Papers Committee. Sessions will be held in the *Little Theater* of the Hotel, off the west lobby, as follows: Monday to Thursday mornings, inclusive; and Monday, Tuesday, and Thursday afternoons.

Film Programs

Exhibitions of newly released motion picture features and short subjects will be held in the *Little Theater* on Monday and Tuesday evenings.

Apparatus Exhibit

An exhibit of newly developed motion picture apparatus will be held in the east lobby of the Hotel, to which all manufacturers of equipment are invited to contribute. The apparatus to be exhibited must either be new or contain new features of interest from a technical point of view. Information concerning the exhibit and reservations for space should be made in writing to the Chairman of the Exhibits Committee, Mr. O. F. Neu, addressed to the General Office of the Society at the Hotel Pennsylvania, New York, N. Y. No charge will be made for space.

Semi-Annual Banquet

The semi-annual banquet and dance of the Society will be held in the *Continental Room* of the Hotel on Wednesday, October 23rd. Addresses will be delivered by eminent members of the industry, followed by dancing and entertainment. Tables reserved at the registration desk.

Recreation

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

PROGRAM

Monday, Oct. 21st

9:30 A.M.	Registration
10:00 A.M.	Society business
	Technical papers program
12:30 P.M.	Informal get-together luncheon
2:00 P.M.	Technical papers program
8:00 P.M.	Exhibition of newly released motion pictures

Tuesday, Oct. 22nd

10:00 A.M.	Technical papers program
2:00 P.M.	Technical papers program
8:00 P.M.	Exhibition of newly released motion pictures

Wednesday, Oct. 23rd

10:00 A.M.	Technical papers program
12:30 P.M.	Free afternoon, for recreation or special trips and visits
7:30 P.M.	Semi-annual banquet

Thursday, Oct. 24th

10:00 A.M.	Technical papers program
2:00 P.M.	Technical papers program
6:00 P.M.	Adjournment of the Convention

SOCIETY ANNOUNCEMENTS

BOARD OF GOVERNORS

At a meeting held at the Hotel Pennsylvania, New York, N. Y., October 19th, further plans were made for the approaching Convention at Washington, D. C., October 21st–24th, inclusive. The general arrangements for the Convention are described in the preceding pages of this issue of the JOURNAL, and preliminary programs and Hotel reservation cards will be mailed to the membership in the near future.

Nominations were held for officers and governors of the Society for 1936. Voting ballots will be mailed shortly to the Fellow and Active membership of the Society, the ballots will be counted and the results announced at the Washington Convention, and the successful candidates will assume their offices on January 1, 1936.

SECTIONAL COMMITTEE

Following the *Reichsfilmkammer* (National Film Conference) held at Berlin last April, at which the differences existing between the DIN (Deutschen Industrie Normen) standards and the SMPE standards for 16-mm. sound-film were discussed, arrangements were made to confer upon the subject further at Paris during the week of July 7th, under the auspices of the International Standards Association and the International Congress of Scientific and Applied Photography. An extensive presentation of the American arguments was drawn up, and Mr. George Friedl, who represented the Sectional Committee at the Berlin conference, was appointed American delegate to the Paris Congress. Mr. W. J. McNair, assistant to Dr. P. G. Agnew, Secretary of the American Standards Association, also attended the Congress in the interests of the Sectional Committee. Dr. Walter Clark, Secretary of the American Committee of the International Congress, attended in his official capacity. A report of the proceedings of the Congress will be published in the JOURNAL as soon as available.

HOLLYWOOD CONVENTION PHOTOGRAPHS

Those who were in the photograph taken at the Fox Hill Studio on June 25th and who have not yet received a copy, may do so by writing to the General Office of the Society, enclosing six cents in stamps as return postage. No charge will be made for the photograph.

At the Warner Bros.-First National Studios, on June 26th, two photographs were taken, the first in two halves, which may be matched and glued together. Although the match is not exact, the picture is quite good. Copies may be obtained from the General Office at the price of fifty cents for the two sections, including postage. The other photograph is identical to the larger one, but of half the width. The smaller picture measures 8 by 10 inches, and the larger 8 by 20.

ACADEMY OF MOTION PICTURE ARTS AND SCIENCES

Ralph Townsend, Assistant Director of Sound Recording for Fox studios, was elected Chairman of the Research Council Acoustic Subcommittee recently at the first meeting of the group.

In addition to the acoustic tests now being planned, the Subcommittee also decided to make a questionnaire survey to determine the type of wall coverings, floor coverings, and set materials used in each studio, and to include a correlation of this information in their report, which will be submitted to the Research Council for distribution to the studio sound, art, and construction departments.

SOCIETY SUPPLIES

Reprints of *Standards of the SMPE and Recommended Practice* may be obtained from the General Office of the Society at the price of twenty-five cents each.

Copies of *Aims and Accomplishments*, an index of the *Transactions* from October, 1916, to June, 1930, containing summaries of all the articles, and author and classified indexes, may be obtained from the General Office at the price of one dollar each. Only a limited number of copies remains.

Certificates of Membership may be obtained from the General Office by all members for the price of one dollar. Lapel buttons of the Society's insignia are also available at the same price.

Black fabrikoid binders, lettered in gold, designed to hold a year's supply of the JOURNAL, may be obtained from the General office for two dollars each. The purchaser's name and the volume number may be lettered in gold upon the backbone of the binder at an additional charge of fifty cents each.

Requests for any of these supplies should be directed to the General Office of the Society at the Hotel Pennsylvania, New York, N. Y., accompanied by the appropriate remittance.

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OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

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SYLVAN HARRIS, EDITOR

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A COMPARISON OF VARIABLE-DENSITY AND VARIABLE-WIDTH SYSTEMS*

E. W. KELLOGG**

Summary.—*In the earlier stages of the development of the sound recording system of RCA Photophone, the balance seemed to swing at times in favor of variable-density and at times in favor of variable-width recording. The close tolerances for exposure and development which the variable-density system requires made the variable-width system seem preferable. Difficulties in obtaining, with narrow recording slits, sufficient exposure for variable-width recording on high-resolution films were overcome by various improvements in the optical recording system and galvanometers. A slit image 0.00025 inch wide is standard for the newest recording equipment.*

While for variable-density recording a number of combinations of exposure and development of both negative and positive have been worked out which give a linear relation between exposing light and print transmission, practical considerations, especially that of obtaining reasonably high outputs, have led to departures from the ideal conditions. Measurements have been published which show the wave-form distortion found in actual recordings of both types, made under representative conditions. The measurements indicate considerably greater distortion in the variable-density records for amplitudes in excess of 50 per cent modulation. For smaller modulations the distortion in both systems is of the order of 5 per cent or less. Variable-width records are subject to a wave-shape distortion which becomes appreciable at very high frequencies. Printing to a suitable density largely neutralizes this type of distortion.

The output from variable-width records is higher by 3 to 8 db. With respect to ground-noise due to scratches and dirt on the positive, the variable-density system may be expected to show a better ratio; while the hiss due to film graininess, and noise due to imperfections of the negative, is less in variable-width records. The fact that extension of the frequency range makes the latter type of noise a more serious factor, plus the fact that the prints will be relatively new, puts the variable-width system at advantage for first-run theaters and for master records for re-recording.

The system of monitoring by observing the moving light spot in variable-width recorders and the ability to judge a recording by inspection of the negative are of considerable practical importance. The full benefits of the recently developed "push-pull" sound-track are obtained only with variable-width recordings.

HISTORICAL BACKGROUND

Development of the system of recording sound on film as now employed by RCA Photophone began with the early work of C. A.

* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

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

Hoxie at Schenectady. As with many such developments, the early experiments were primarily concerned with the general problem of recording the sound, and immediate concern was not given to specific applications. Although employing motion picture film, Hoxie used as much of the film as seemed desirable at the time, and did not try to leave room on the same film for the picture. Many of his records utilized the entire one inch of clear space between the perforations. In view of the increasing difficulty of obtaining sufficient exposure as the sound-track is widened, it is somewhat difficult to explain how Mr. Hoxie got sufficient exposure, except that he used negative stock, a fairly wide recording slit, moderately low film speed (60 feet per minute), and probably an extra large mirror on the galvanometer. Extreme care of slit alignment was, of course, necessary. With many of these records Hoxie obtained a very creditable quality of sound reproduction. The recording of speech was the primary interest. The work was done in the same laboratory where the General Electric oscillographs were developed and built, and oscillograph tradition naturally exercised some influence on point of view, so that it was natural to think of a sound-track in terms of the rather large dimensions of conventional oscillograms. The recording optical system was, in principle, essentially the same as that employed in an oscillograph and produced a variable-width track. All who have worked with oscillographs are aware of the fact that it is not too easy to obtain a sharp spot. In the recording arrangement the edge of the light-spot was not sharply defined. In fact the light intensity tapered off for a considerable distance. We debated the pros and cons of the "fuzzy edge." If no overshooting is permitted, the space across the sound-track which the tapering light intensity occupies is track width thrown away, so far as possible light modulation is concerned. On the other hand, if overshooting does occur the distortion is less noticeable and less objectionable with the soft-edged light spot. The more orthodox members of the group maintained that overshooting must be strictly avoided; but Mr. Hoxie, who was of a very practical turn of mind, was not convinced that that was important. To prove his point he masked off the ends of his reproducing slit and played one of his records using various fractions of the total width. To his surprise and to the surprise of the other listeners no sudden ruin of quality occurred, and the record still sounded good as the scanning slit was shortened, down to $^1/_{16}$ inch. The realization that such a narrow track was entirely practicable led to the happy conclusion that picture and sound could just as well as not be put on one film, and from then on only narrow tracks were employed.

Obviously, the narrow strip of track used in Hoxie's test could reproduce sound only by its variations in density; and, as he shortened his scanning slit, he had gone by steps from a variable-width to a variable-density track. For a while the variable-density track reigned supreme at Schenectady. These variable-density tracks were made by providing graded light intensity in the direction of slit length and sweeping the light-spot back and forth through amplitudes several times the slit length. The method was clumsy, and expensive of power for vibrator input, but was nevertheless effective.

The revival of interest in the variable-width system is probably due to A. C. Hardy, who called our attention to the much greater danger of distortion in the variable-density system due to lack of linearity in the film characteristics,[1] unless exposures and developments were held within very close tolerances. To make a true variable-width track only $^1/_{10}$ inch wide or less called for a new optical system capable of producing at the film a light-spot whose edge was much sharper than an optical system such as those used in oscillographs was capable of giving. The desired result was obtained by the simple expedient of forming on the film a reduced image of a comparatively long slit over which the light-spot played as before. In this small image, the edge of the light-spot was sharpened in the same ratio that the slit was shortened. Although there have been a number of modifications of the optical system, this general feature has been retained.

A desire for achieving the best possible results in sound quality led to experiments with various film emulsions and different recording systems. Many engineers concerned with sound recording and reproduction have a feeling that devices without moving parts are likely to be inherently superior, especially because adequate reproduction of the high frequencies has always been a problem, and avoidance of limitations due to inertia seemed like a step in the right direction. This idea led to studies of the possibilities of glow-lamp recording and particularly to experiments with Kerr cells, both at the General Electric Company and the Westinghouse Company.[2] These, of course, could make only variable-density tracks. While there is something to be said for the avoidance of moving mechanical parts, the oscillograph galvanometers were, as subsequent experience has proved, one of the least of the sources of trouble and distortion.

The spread of exposure in the film was early appreciated as one of the major causes of distortion and loss of high-frequency response. How much of these losses to attribute to the film and how much to imperfections in the optical systems was difficult to decide, and still is; but the obvious and proper procedure was to improve both as much as possible. Films of higher resolving power called for greater exposure, and this factor for a while turned the balance in favor of variable-density. Those who have analyzed and calculated light intensity in optical systems are familiar with the fact that high light intensities are easier to obtain in a variable-density system. The Kerr cell was certainly not a help in that direction, owing to the necessity of passing the light between closely spaced plates through a considerable thickness of the yellow nitrobenzol. On the other hand, a single-string light-valve[3] was built and recordings made with it which were regarded as quite satisfactory. At Prof. Hardy's suggestion, considerable work was done with yellow-dyed duplicating film, which showed especially fine grain and high resolution. This film was readily given adequate exposure with the light-valve, but meantime progress was being made with systems of the oscillographic type adapted to variable-width records. Mr. L. E. Clark suggested the use of a cylindrical lens close to the slit, and this, although reducing the depth of focus, gave a marked increase in light intensity, so that an exposure entirely adequate for Eastman positive stock was obtained with a slit image about $^3/_4$ mil wide at the film. The optical system in this form was employed in Photophone recording equipments until 1932.

A modification of the optical system which gave a large increase in light intensity without sacrificing depth of focus consisted in placing the galvanometer with its axis horizontal so that the light spot moved up and down across the slit instead of parallel with it.[4] The light-spot was given a slanting edge, intersecting the slit at an acute angle. This made it possible to illuminate varying fractions of the slit length with much smaller movements of the light-spot than had previously been necessary when the motion of the spot was parallel to the slit. With a smaller required light-spot movement, it became feasible to bring the galvanometer closer to the slit. Other factors being kept the same, the light intensity depends on the solid angle subtended by the mirror as viewed from the slit, and this solid angle increases with the inverse square of the distance between the mirror and the slit. With this "scissors type" optical system it was possible to get adequate exposures for variable-width tracks on yellow-dyed film. The argument for variable-density tracks on the score of greater ease of obtaining plenty of exposure thereafter had little weight. More recently the development of the magnetic vane galvanometer described by G. L. Dimmick,[5] with its large mirror, has made possible a several-fold increase in light intensity. Advantage has been taken of this, and of the increased speed of the newer recording films, to reduce the width of the recording slit, and a slit image $^1/_4$ mil wide at the film is standard with the newest Photophone equipment. The large mirror also results in utilizing enough of the aperture of the objective lens to avoid diffraction losses,* while at the same time maintaining a desirable depth of focus, so that focusing is not too critical. With a recording slit of the size and quality now obtainable, such spreading of exposures as occurs is due almost entirely to scattering of light within the film emulsion itself.

Two arguments for variable-density tracks which for a time carried some weight in the minds of the development engineers were, first, that the variable-width system would call for a higher degree of light uniformity across the reproducing slit; and, second, that scratches in the film (of which we are today happily getting far fewer than in the early days of talking pictures) would cut minute pieces out of the wave-form and thereby produce distortion. With a variable-density system, on the other hand, a streak parallel to the track merely narrows the track by that much. Satisfactorily uniform slit images were obtained with the reproducing optical system adopted, and there appeared to be no reason to anticipate difficulty on this score, especially since it can be shown that fairly large departures from uniformity of slit illumination result in surprisingly little wave-shape distortion.** To ascertain whether the

* In the recording optical system, an image of the mirror is formed approximately in the plane of the objective lens. Since the image does not completely fill the lens aperture, only the central part of the lens is used. The resolving power of a well corrected lens increases with its numerical aperture. Utilizing a larger part of the available lens area results in an increase in the effective numerical aperture.

** The curve which shows the relation between galvanometer deflection and photo-cell illumination (and which should be a straight line for zero distortion) wave-form distortion which was feared from parallel streaks on the film would be serious, tests were made by sandpapering the sound-track in such a direction as to make parallel scratches. In running the film repeatedly with more and more scratches, the only change which was detected was the inevitable increase in ground-noise, which would also be true of a variable-density track. The results of these tests removed the last argument in the minds of the engineers at Schenectady against adoption of the variable-width system. Continued improvements in equipment, and the experiences of the past few years, have in our estimation vindicated the choice.

COMPARISON OF VARIABLE-DENSITY AND VARIABLE-WIDTH SYSTEMS

The fact that engineers not associated with RCA chose and are still using the variable-density system makes it appropriate to examine the arguments on both sides as they appear today. It would, of course, require a very clear case of superiority of one type over the other to induce any large organization to change the system which it has been employing. It is of interest, however, that the latest equipment offered by RCA Photophone happens to lend itself, with an extremely simple modification, to the making of variable-density as well as variable-width tracks. This is an almost accidental feature of the optical system in the form in which it has been developed, and although we are firmly convinced of the practical superiority of the variable-width system, this feature of our equipment is advantageous in that those who have a preference for variable-density tracks (due perhaps to greater familiarity with their requirements), or those who wish to be on the right side and feel that the

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is the integral of the curve which shows the light intensity from point to point along the slit. If various, somewhat irregular, or non-uniform curves of distribution are assumed and the corresponding total light or integral curves calculated, the latter will be found to deviate only slightly from straight lines. As an example of what would be a particularly bad departure from uniformity, it was assumed that the light intensity is down 25 per cent at each end of the slit, the distribution being represented by a curve of parabolic form. Calculation of the distortion of a sine wave showed that a third harmonic (no others) would be produced, having an amplitude equal to 2 per cent of the fundamental. If, instead of a simple sine wave track, we assume a symmetrical or double-edged track, such as is now employed, the same irregularity of illumination results in the production of a 3 per cent second harmonic and a negligible third. If the irregularities are of the same magnitude but more numerous, such, for example, as might be produced by imaging a coil filament in the slit, the harmonics are of higher order but are still smaller in magnitude.

question of relative merits is still in the balance, would with this equipment be able to make records of either type by a simple change.[6]

WAVE-SHAPE DISTORTION IN VARIABLE-DENSITY RECORDS

The primary and generally recognized argument for the variable-width sound-track is that virtual freedom from distortion is not dependent on observation of close tolerances in respect to exposure and development of both negatives and prints. The edge of the light-spot moves back and forth along the length of the slit and traces a microscopic oscillogram on the film, whose outline is a picture of the wave-shape. So long as the film on one side of this edge is of uniform darkness and the film on the other side uniformly clear, we have a practically perfect trace of the sound wave, for it has been possible to develop a galvanometer having a response range up to 9000 cycles and in which distortion is negligible, so far as we can ascertain. Only in so far as the recording slit must have a finite width, and as the film fails to resolve the high-frequency waves, does wave-shape distortion enter in the recording. Distortion, therefore, becomes appreciable only when this spreading of exposure covers a substantial fraction of a wavelength, or, in other words, at high frequency.

On the other hand, as pointed out by Hardy[1] and others,[7] a truly linear relation between negative illumination and print transmission, such as is required for faithful reproduction, is obtained in variable-density tracks only when the exposures of both negative and print are within the limits of the straight parts of the H&D curves, and the product of the negative and print gammas is equal to unity. In this the gammas to be considered are not those obtained with sensitometers and densitometers of the forms in general use, but the exposures; and methods of measuring density should conform to the conditions of recording, printing, and reproducing in order that departures from photographic reciprocity and differences in diffusion of transmitted light may not introduce errors. Routine measurements may be made with standard apparatus and suitable correction factors applied, the correction factors depending on the recording, printing, and reproducing systems employed. Thus, in laboratories where accurate sensitometric control is attempted, it is general practice to check development and to measure and specify densities in the usual manner, but to call for diffuse densities that correspond to the desired semi-specular densities and to work for a gamma product (in terms of diffuse densities) other than unity, the necessary correction factors having been taken into account. The problem of sound-track density and gamma determinations has been treated by Tuttle and McFarlane[8] and by MacKenzie.[9] For the relation between the ordinarily measured diffuse density, and the semi-specular density which is appropriate in rating sound prints in average reproducing optical systems, the authors just mentioned give factors of the order ot 1.25 to 1.3.

If the only difficulty were that of laboratory control, in holding the gamma product within reasonable limits (assuming the proper product to have been correctly ascertained), the problem would not be serious, for calculation shows that only about 5 per cent harmonics would be produced by departures of 0.2 in either direction from the unity product, provided the exposures are confined to the straight parts of the characteristics. It appears, however, that the difficulties are not with maintaining the gamma product within these limits, but rather that it is practically necessary to utilize ranges of exposure much below the straight-line portion of the H&D characteristic. For example, positive film developed to a gamma of approximately 2 is practically standard for the final print of the sound-track, for the reason that the picture requires this treatment. The H&D curve for positive film developed to a gamma of 2 does not become straight until the diffuse density exceeds 0.6 or more, although the curvature is slight if the density does not fall below 0.5. The semi-specular density which corresponds to a diffuse density of 0.5, would be about 0.63, or the transmission to the photo-cell 23 per cent. If the minimum transmission can be as small as 2 per cent, this leaves only a 21 per cent range from minimum to maximum transmission, which would result in very small photo-cell output. The average or unmodulated transmission would have to be as low as about 12.5 per cent. In order to obtain more output, higher average transmissions are used, ranging from 15 to 30 per cent. At full modulation the maximum transmission would be nearly twice the average, and this would mean minimum diffuse densities of 0.42 to 0.18, which would be well down on the toe of the H&D curve.

There appears to be no theoretical reason why the negative might not be given sufficient exposure to avoid using the toe of its H&D characteristic, but there is no object in confining the negative exposure to the straight part of the curve unless the prints also are to be so confined. In fact, the negative toe can be used partly to offset the distortion resulting from the print toe. There is, moreover, for variable-density recordings, as will be presently explained, an objection on the score of ground-noise to the use of a negative any darker than necessary. Instead of adhering to the classical means of obtaining distortionless reproduction, therefore, it has become general practice to utilize part of the toe of the positive and, in some cases, that of the negative as well, and to attempt to work out a combination which gives acceptably low distortion.

A very thorough analysis of toe recording, and a comparison of toe recording with classical recording and with composite recording, was published in 1932 by MacKenzie,[9] who shows that it is possible to obtain an over-all characteristic having a usable linear range by proper combinations of toe recording, toe printing, and development. The toe recording, while having relatively high output, is of very limited range, and does not give good ground-noise ratio nor permit much benefit from biasing the light-valve. Strict adherence to the classical conditions for freedom from distortion is shown to result in good ground-noise ratios but extremely low output. A more practical solution is a composite system in which the part of the negative characteristic that is utilized is for the most part above the toe; and in which, in view of the reduced average slope of the part of the positive H&D characteristic which is used, comprising part of the toe, an effective gamma product of about 1.4 is used. The permissible limits of negative exposure are different for different printer settings.

In his recent review of sound recording Mees[10] assumes a 25 per cent print transmission for the unmodulated track without light-valve bias as fairly representative of practice in variable-density tracks. This is near the upper end of the toe of Eastman positive film developed to a gamma of 2, so that the modulation is partly on the toe and partly on the straight part of the H&D curve. Mees presents a number of over-all characteristics for various conditions, from which an idea can be formed of the effects of changing various factors.

Since the avoidance of distortion in variable-density systems is largely on an empirical basis and involves certain compromises, no fundamental rules can be laid down to define correct procedure, and opinions and practices vary. The lack of universality of rules and specifications, of course, makes the observance and enforcement of reasonable tolerances the more difficult. The large amount of literature on the subject bears testimony to the complexity of the problems.

Experimental determinations of wave-shape distortion are of especial interest, and are undoubtedly a safer guide as to what may be expected than pure calculation. For such experimental results we may refer to the work of Messrs. Sandvik and Hall.[11] Of the numerous tests tabulated by these writers, a few of the best have been selected and are listed below. These may probably be safely taken as fairly representative of what may be expected with good processing control. The prints having a density of 0.60 made from negatives of density 0.75 correspond most nearly to what the authors refer to as normal conditions.

TABLE I

Tests of Variable-Density Recordings

Freq. (Cps.)	Light-Valve Mod. (Per Cent)	Negative Gamma	Negative Density	Print Gamma	Print Density	Output (Db. below 100%)	R.M.S. Harmonics (Per Cent of Fundamental)
100	90	0.5	0.55	2	0.40	7.1	8
100	90	0.5	0.55	2	0.60	9.7	11.5
100	90	0.5	0.75	2	0.40	6.1	9
100	90	0.5	0.75	2	0.60	9.5	13
100	50	0.5	0.55	2	0.40	12.8	5.6
100	50	0.5	0.55	2	0.60	15.8	5.6
100	50	0.5	0.75	2	0.40	9.9	6.25
100	50	0.5	0.75	2	0.60	13.4	6.0

WAVE-SHAPE DISTORTION IN VARIABLE-WIDTH RECORDS

Such distortion as takes place in variable-width records is of a different nature, and is due almost entirely to the spread of the exposure outside the boundaries of the exposed region and to the finite width of the recording slit. These two factors are similar in their effect. The ideal variable-width record would be one made with a slit of negligible width, and would have an infinitely sharp border between the exposed and unexposed areas. Actually, owing to the finite slit width, and to image spread, there is a gradation of exposure over a minute distance, and when recording such high frequencies that this distance becomes a considerable fraction of the wavelength, distortion becomes appreciable. With the exposures and developments used, the blackened areas are in general slightly oversized. Since both films are developed to fairly high contrast, the edge of the image is, in general, sharper than that of the actual exposure. The spreading of the image in the negative is in a large measure compensated by similar spreading of the image in the print, and it has been found possible practically to neutralize distortion by proper choice of printing exposure.

The effect of image spread has been analyzed by Cook,[12] the image spread being assumed for simplicity's sake to be due entirely to finite slit width. Cook's calculations show what may be taken as an upper limit or pessimistic estimate of the loss of fundamental, production of harmonics, and rectification or change in average transmission, as functions of the ratio of slit width to wavelength. The change in average transmission is, without doubt, the most serious of the three effects mentioned, because it results in difference tones which are well within the important audio range, whereas the loss of fundamental can within reason be compensated, and the harmonics generated are for the most part above the frequency range over which the reproducing system is sensitive. The justification for the last statement is that in the variable-width system the wave-shape distortion or generation of overtones is largely confined to the high-frequency waves for which the slit width is a considerable fraction of a wavelength. On the other hand, overtones produced in a variable-density system by non-linear film characteristics would be distributed throughout the audible range. The change in average transmission accompanies practically all non-linear distortion, and its magnitude closely follows that of the second harmonic produced. It is therefore a factor which may impair quality in either the variable-width or the variable-density system. Distortion which appears at high amplitudes, and at low as well as at high frequencies, is more likely to be injurious to musical reproduction where the peak powers are in the lower- and middle-frequency range than distortion which occurs only at high frequency where the waves to be recorded are of small amplitude.

A further analysis of the effect of finite slit width in variable-width recording has been made by Foster,[13] who takes the gradations of exposure and the film characteristic into account. This, as would be expected, gives lower values for harmonics than Cook's assumptions. Foster points out that the same conditions which give freedom from distortion in the variable-density system, also eliminate the wave-shape distortion due to slit width in variable-width recordings, namely, a gamma product of unity and no exposures below the straight parts of the H&D curves. This is not, however, the only way practically to eliminate this form of distortion. As has already been stated, suitable exposures of negative and print, without the requirement of unity gamma product, will accomplish the same purpose. High contrast and the lowest possible density in the clear areas are desirable in variable-width records, and neither of these is compatible with the conditions called for by the first method. Minimizing the distortion of high-frequency waves due to slit width and image spread is therefore accomplished by removing the causes, so far as possible, by the best of optical conditions and a very narrow recording slit, and then by proper printing. In the negative the dark areas are slightly oversize, but in the printing the exposure spreads slightly under the edge of the black parts of the negative, and by printing to a suitable density, the edge of the blackened area of the print can be brought back to where it would be had there been no spreading in either negative or print.

TABLE II

Variable-Width Records

Freq. (Cps.)	Negative Gamma	Negative Density	Print Density, 1.2: Fundamental, Db. below 100%	Print Density, 1.2: Harmonics Per Cent of Fund.	Print Density, 1.5: Fundamental, Db. below 100%	Print Density, 1.5: Harmonics
100	2	1.3	3.5	3	4.2	4
100	2	1.5	3.2	5	3.4	4.6
100	2	2.1	3.1	7	3.2	6
4000	2	1.25	7.4	3	8.3	5
4000	2	1.46	7.3	4	7.0	2
4000	2	2.1	9.1	7	8.4	5

For an estimate of the magnitude of the distortion to be expected in a variable-width recording we may again refer to the valuable contributions of Sandvik, Hall, and Streiffert.[14] The values in Table II are taken from the Table II and the curves of Figs. 2 and 3 of their paper on wave-form analysis of variable-width records.[14] The output of fundamental frequency is expressed in decibels below 100 per cent modulation of the incident light, and since the outputs of variable-density records have been given in the same terms, the figures are directly comparable. The modulation in the recording was 90 per cent. The harmonics are given in terms of the rms. amplitude of total harmonic content, in per cent of the amplitude of the fundamental.

General recommendations for variable-width films call for a negative density of 1.4 to 1.5 and a print density of 1.3 to 1.4, and the figures given above show what may be expected in these ranges. The 2.1 density negatives are outside the range of ordinary use, but prints from these have been included in the list since some negatives may be denser than the next lighter ones listed.

Comparing the harmonic distortion figures for the two systems (if we exclude the variable-width prints made from the 2.1 density negatives) we find that the variable-width records showed harmonic contents less than half of those of the 90 per cent modulated variable-density records, and materially less (relative to fundamental) than the variable-density records which were made with 50 per cent light-

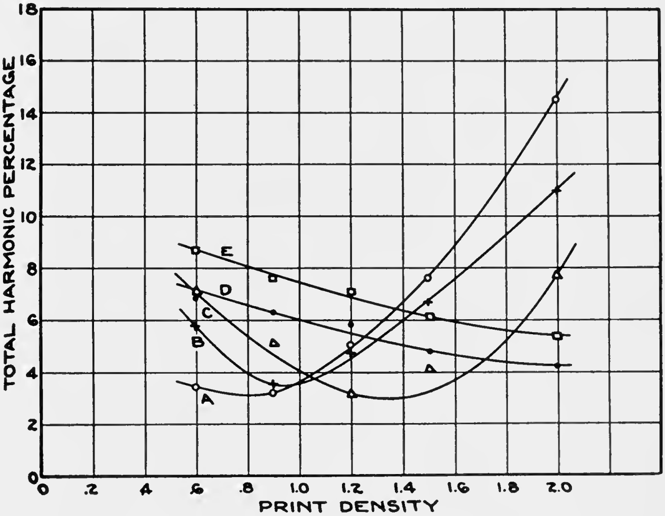

FIG. 1. Harmonic distortion in variable-width records at 100 cycles per second as a function of print density for various negative densities. Negative densities 0.8, 1.0, 1.25, 1.5, and 2.1 for curves *A*, *B*, *C*, *D*, and *E*, respectively. Negative gamma, 2.0.

valve modulation. Since in the variable-density system distortion decreases at low amplitudes, while in the variable-width system amplitude is not a material factor, the superiority of the variable-width system on the score of wave-form distortion applies only to amplitudes in excess of 30 to 40 per cent. With amplitudes smaller than this neither system would produce sufficient distortion to be detected.

The expectation of increasing distortion at high frequency in the variable-width system is not shown in the measurements cited here, but comparison of the curves of Figs. 1 and 2 which are reproduced through the courtesy of the authors of the paper cited,[14] shows that the range of negative and print densities which gives good results is less at 4000 cycles than at 100 cycles. Other factors than image spread must account for harmonics of the order of 3 or 4 per cent, since image spread could hardly have played an appreciable part at 100 cycles. The printing operation was effective in neutralizing a large part of the image spread distortion, as evidenced by the fact that measurements by the same authors on the 4000-cycle negatives showed considerably larger harmonic ratios than those of the prints. At 100 cycles there was little difference between negatives and prints.

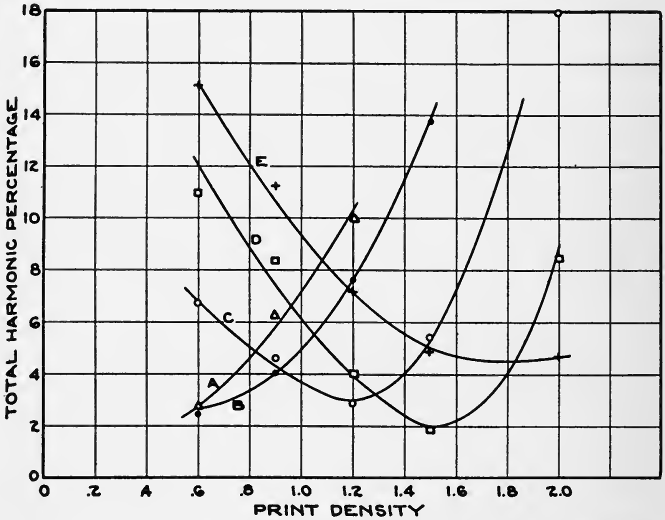

FIG. 2. Harmonic distortion in variable-width records at 4000 cycles per second as a function of print density for various negative densities. Negative densities 0.85, 1.0, 1.3, 1.5, and 2.1 for curves *A*, *B*, *C*, *D*, and *E*, respectively. Negative gamma 2.0.

In the experience in the Photophone laboratory at Camden, N. J., trouble from fogging-in of the waves does not begin until frequencies considerably above 4000 cycles are reached, and the measurements of harmonic distortion given above lead to a similar conclusion.

COMPARISON OF OUTPUTS

With respect to output, the 100-cycle, variable-width records are seen to give about 6 db. more output than the normal variable-density record, or from 2.5 to 3 db. more than the lighter print, which had a density of 0.4 for the unmodulated track.

A comparison of outputs at higher frequency can not be made, since the only measurements of variable-density records published were those at 100 cycles. Both systems are subject to loss of output with increasing frequency, and if the full potentialities of both systems are attained, the high-frequency losses are at least of the same order of magnitude.

GROUND-NOISE RATIOS

In making any comparison of the two systems with respect to ground-noise we find it necessary to consider separately the ground-noise which arises from emulsion graininess in either film and from imperfections or specks on the negative, and that which is produced by dirt and abrasions on the positive film. It will be convenient to designate the former as type *A* and the latter as type *B* ground-noise.

Little has been published in the way of actual measurements of type *B* ground-noise (dirt and scratches on the positive) and such noise, being more irregular than that due to graininess and depending as it does on accidental causes, is difficult to measure or estimate with sufficient accuracy to be significant. Theoretical considerations indicate that with respect to this kind of noise the variable-density records have an advantage.

In order to illustrate the difference by a simple case, let us compare two films, both of which reduce the transmitted light to 50 per cent, one by making half the track black, and the other by interposing a uniform gray across the whole track. If the light could be modulated 100 per cent in both films, the useful outputs would be the same and the same amplification would be required. Since the light-beam issuing from the transparent half of the variable-width track is twice as intense as that which has passed through the variable-density track (the same total light in a beam of half the cross-section) obstructions on that side of the track produce twice the light modulation, and therefore four times the energy in photo-cell output, that would be produced by identical obstruction which may be assumed to be found within the corresponding half of the variable-density track. But in the latter, the other half of the track makes an equal contribution to the noise. The noise generated on the two sides is, of course, in random relation, and under such conditions the total power is twice that produced by either half alone. This makes the total energy or power in type *B* ground-noise twice as great for the variable-width track as for the variable-density track, or a difference of 3 db. If the average transmission is decreased by a uniform additional density, but the *per cent* modulation of such light as is transmitted is kept the same, the ratio of useful output to ground noise (of the type under discussion) is unaltered. The 3-db. advantage in type *B* ground-noise ratio of the variable-density record, is, therefore, not altered by the fact that average transmissions much below 50 per cent are employed. Neither is the type *B* ground-noise ratio for a variable-width record altered by a uniform fog or density over the transparent area, for, although this reduces the per cent modulation of the incident light, it does not reduce the per cent modulation of light reaching the photo-cell. The amplification would be turned up to compensate for the reduced illumination, and the useful sound and ground-noise would both be brought back to the original value.

Whether the difference in type *B* ground-noise will be as great as the above-calculated 3 db., or something less, will depend on such questions as:

(*1*) Can both systems provide equally high percentage modulation of the photo-cell light without excessive distortion?

(*2*) Will the slightly rough or matte surface of a film having a density of 0.5 or more tend to pick up or hold dirt more than the more glossy surface of clear film?

(*3*) Is the gray film more or less easily scratched?

(*4*) Will oil or wax tend to fill up and obliterate scratches more if they are in clear film than in gray film?

Ground-noise reduction has been applied to both variable-density and variable-width records, the object being accomplished in both cases by reducing the average transmitted light during passages with low modulation. The variable-density records are made darker, while the width of clear track is reduced in the variable-width records. The same reasoning which we have already used shows that reducing the average transmission by darkening the track causes the ground-noise to fall off faster than an equal transmission reduction accomplished by narrowing the track. But in practice it has been found feasible to go further in the way of light reduction in the variable-width system, and a noise reduction of about 10 db. has been attained in both cases. There is a limit to how far it is desirable to go in any ground-noise reduction system of the variable-bias type. Fluctuating ground-noise is more conspicuous than steady ground-noise, and the best degree of reduction is a compromise between the attainment of low ground-noise during soft passages and the avoidance of conspicuous fluctuations. This consideration is in part responsible for the practical limitation to 10 db.

With respect to type *A* ground-noise, or that due to emulsion graininess in both films, and to imperfections in the negative, the advantage is on the side of the variable-width system. The reason for this lies in the inherent difference between a system which depends

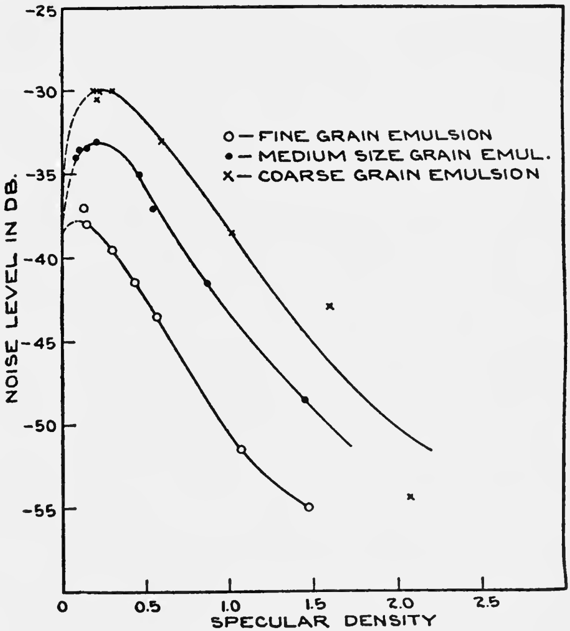

FIG. 3. The relation between ground-noise and density.

on blacks and whites, and one which depends on transmission through various shades of gray. The gray of the film is not uniform, especially when we are referring to microscopic areas such as fall within the reproducing light-beam. Despite the high degree of excellence of film emulsions, it could not be expected that the light which passes through a dense film would be as uniformly distributed as that which passes through a less dense film. This decreasing uniformity with increased density would be expected from considerations of probability, but is borne out by experimental evidence. Were the per cent variation in light from point to point the same for a dense film as for a lighter film, ground-noise due to film graininess or grain clumpings would go down at the rate of 20 db. per unit increase in specular density. Curves published by Sandvik, Hall, and Grimwood[15] and reproduced in Fig. 3 show that, starting with fresh unexposed film, the ground-noise increases with density up to a specular density of about 0.25; after which it falls, but not as rapidly as it would if the increased density merely cut down the light without affecting its uniformity. The maximum rate of decrease is about 15 db. per unit increase in specular density, and the difference between this and the 20 db. mentioned above is a measure of the increasing irregularity of light distribution at high densities. Since the purpose of a variable-density print is to reproduce all fluctuations in negative density, the graininess of the negative is necessarily printed through on the positive; and the positive, which is also a dark gray, adds its own graininess. Any scratches or specks which may be on the negative must likewise appear on the print.

In the case of the black-and-white, variable-width records, the clear part of the positive is so far down on the toe of the film characteristic that its photographic sensitivity is practically zero, and it fails to register the irregularities of what little light reaches it through the dense part of the negative. Thus, negative graininess and specks* in the dark half of the negative do not show on the print or produce appreciable ground-noise; nor does the positive itself cause appreciable noise from graininess on the clear side, for where there are few grains there can not be graininess.**

There remains to be considered the ground-noise which may be contributed by the black side of the print, whether resulting from its own graininess or from imperfections in the corresponding clear part of the negative. Here the total light transmitted is so feeble that even though it should be considerably modulated by imperfect distribution of the silver, the resulting noise is negligible. With a diffuse density of 1.4, for example, which is about normal, the semi-

* Scratches which leave actual holes in the negative emulsion would, of course, show as black spots in the print, but such injuries to films are rare. Nearly all scratches appear as dark lines.

** Noise from graininess is not primarily the result of disturbances produced by individual grains, but of irregular distribution of the silver. Only when the number of grains becomes sufficient to produce material reduction of the transmitted light does graininess become appreciable.

specular density would be about 1.75 and the transmission to the photo-cell less than 2 per cent.

Specks and scratches on the clear part of the negative would, of course, show as minute holes or clear spots in the otherwise black part of the print, but with the high exposure which this part of the print receives, these light spots tend to become fogged in—because the specks and scratches are, for the most part, of very small dimensions. In this case, advantage is gained from the spread of exposure in the emulsion of the positive. Printing to a low density, as required for variable-density records, tends less to obliterate such marks.

The essential difference between variable-width and variable-density records with respect to type *A* ground-noise may be better appreciated if we bear in mind that a variable-width track is made up of clear film, which has inherently low ground-noise, and of very dark film which for a given amplifier setting also causes small ground-noise (under the conditions of its use in a variable-width track, in which the amplification required is dependent not on the transmission through the dark but through the clear side of the film). In the case of a variable-density track, on the other hand, clear film is not permissible on account of distortion, and whenever a high density is employed in the variable-density system, either the illumination (in a printer) or the amplification (in a reproducer) must be increased correspondingly, and the full effect of the graininess of the dense film is registered.

From the foregoing it appears that the relative advantage of one system or the other with respect to ground-noise will depend on the condition of the print and on which type of ground-noise is the more objectionable. If prints are in good condition, the variable-width records may be expected to have less ground-noise, especially the hiss type of noise characteristic of the film emulsion; whereas, as the print gets older the ground-noise due to scratches and dirt will probably increase more rapidly in films of the variable-width type.

The hiss type of ground-noise has become a more serious problem since the introduction of reproducing equipment responsive to higher frequencies, and theaters which have the new equipment (presumably, for the most part, first-run theaters) are benefited by the system which minimizes this type of ground-noise. The prints which they receive, being relatively fresh, should have comparatively little of the type *B* noise.

The advantage of the variable-width record in its relative freedom from ground-noise due to film grain commends it especially for the increasingly important application of master records to be used in re-recording. For this service the very minimum of ground-noise of all kinds would be sought, and ground-noise due to dirt and scratches is hardly a factor, because no print which had been in the least damaged would be employed.

VISUAL MONITORING AND TRACK INSPECTION

Factors which are of considerable practical importance are (*1*) the visual indication which the variable-width recording system provides of the amplitudes of the waves being recorded, and (*2*) the immediate judgment of a record which can be formed as soon as the negative can be examined.

The relatively large amplitudes of movement of the light-spot as it plays across the slit enable the operator to judge how close it is coming to the overshooting limit, and thereby control his amplitudes with the maximum of nicety. Viewing screens are provided on which the proper limits of movement are marked, and as the screen is placed farther from the galvanometer than the slit, the movement is magnified. Alternative methods of observing amplitude, as, for example, by meter, do not reveal whether the modulating device is functioning, and may cause errors because of difference in the frequency characteristics of modulator and meter, failure of the meter to respond to peaks of short duration, or to the greater possibility of wrong adjustment when a separate indicating device is used.

Inspection of a variable-width negative will reveal, almost without fail, whether the recording has been properly done, because the distinctive appearance of the waves enables a practiced eye to tell much about the characteristics of the entire recording system, and such factors as proper density, freedom from fogging, overshooting, and the maintenance of suitable levels are at once apparent. It would be interesting to know just how far an expert can go in interpreting the appearance of a variable-density record, but certainly it is far more difficult than in the case of the variable-width recording, and rendered still more difficult by the fact that there are so many combinations of negative characteristics with various printing exposures and developments which give usable prints. Since playing a variable-density negative gives such high distortion that no fair judgment could be formed by a listening test, final evidence that a recording has been satisfactorily made can not be had until a print has been made and played; whereas a variable-width negative may be played, and would in general be indistinguishable from a good print.

Another factor which ought not to be a factor, but which unfortunately is occasionally, is the effect of printer speed fluctuations. The output of a variable-width record is little affected by considerable variations in recording light or printing exposure. There is, therefore, less modulation of the useful sound by recording or printing lamp fluctuations or by printer speed variations (due to gears or sprocket action) than would be the case with a variable-density recording.

PUSH-PULL SOUND-TRACK

The recently developed "push-pull" sound-track system which was described by G. L. Dimmick and H. Belar,[16] and first demonstrated before the Society at the Atlantic City Convention in April, 1934, offers possibilities of a new standard in high-quality sound reproduction. Although its general introduction into theaters will necessarily require time, it is available now for master records. The outstanding advantage of the push-pull system is on the score of ground-noise, but it has another feature which deserves mention. We have discussed the wave-shape distortion and change in average transmission which occurs in recording high-frequency waves. The effect may be practically eliminated by proper printing, but in the push-pull system the change in average transmission and all the even harmonics are completely balanced out, thus removing from the variable-width system about the only photographic factor which is at all critical, and also carrying the already small distortion to a still lower point.

But the really important feature of the push-pull track is that the track is black when there is no modulation, and the amount of clear film within the scanning beam at any time is proportional only to the instantaneous useful voltage being developed, instead of to the instantaneous value plus an average equal to the highest near-by peaks plus a substantial margin for safety, as is required in all present noise-reducing systems depending on bias. There is no margin needed to prevent overshooting or to enable the galvanometer or light-valve to open up in case of a sudden burst of sound, no sluggish closing down (as at present necessary to prevent a "pumping" sound), and no rise and fall of the ground-noise imperfectly following the increase and decrease in modulation which is often noticeable in all systems depending on shifting bias. In the push-pull system the moment the output voltage drops the track is black again.

These advantages of the new sound recording system were pointed out by Dimmick and Belar, but are restated here for the reason that the availability of this system is a factor to be weighed in comparing variable-density with variable-width. Although variable-density recordings may benefit in some measure from application of the push-pull principle,[17] the full advantages are realizable only if the print transmission can be brought practically to zero whenever the galvanometer current is zero (or the sound-pressure zero). For this, definite and reproducible linear relationship between galvanometer current and print transmission is essential, and it is in such linear relationship that the variable-width system has its great advantage.

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DISCUSSION

DR. J. G. FRAYNE: It is true that the lowest density of the straight-line portion of the characteristic is about 0.6, which would indicate that that would be the lowest density that would be practicable if we want to adhere to the straight-line portion of the positive film. We have found that a density of 0.7 in the unbiased portion, corresponding to about 20 per cent visual transmission, represents a fair value of print density from the standpoint of low harmonic content and faithfulness of wave-shape. The practice in Hollywood varies considerably from studio to studio. The darkest prints made are about 0.8 in visual density, and vary all the way to 0.5, with the average probably around 0.65, or 22 per cent.

Now, if we take a variable-density film of an average transmission of 22 per cent, we shall find the output from that film to be approximately 7 or 8 db. below the average of variable-width films. However, those of us who belong to the variable-density school do not regard that as any particular disadvantage. It simply means a change in the fader setting, and since films are mixed at such vastly different levels, the fader correction has to be made anyhow, in order to obtain uniform reproduction of sound in the theater. However, certain studio executives whose ears are not the very best insist upon a certain sound volume from some fixed fader setting. Thus, certain sound directors, against their wishes, are forced to make prints lighter just to satisfy their immediate executives. However, the studios that make lighter prints make them not on the basis of data from sensitometric studies, but on the basis that they sound better than the darker prints. I have been sceptical of this for a long time, but recently have begun to change my mind somewhat. A series of exposures made very close together and developed in machines in which there are pronounced directional affects, may give widely different results from a scheme in which the densities are scattered over a long band of film, as in a sound-track. That is borne out by the test known as the delta db., discussed by Mr. Albin before this Convention the other day. Very often the Eastman *2B* data will tell us that we should make a variable-density print at 0.7 for the best results, and yet the dynamic test will indicate that the density should be 0.5 or 0.6, and in every case this conclusion appears to be borne out by listening tests. So, until we know more about how to measure densities, or until we get a sensitometer that will really tell us the physical facts, our ears will have to give us the final verdict. Based upon the ear, the optimal print may vary from 15 to 30 per cent.

Despite the fact that the harmonics may appear to increase rapidly with change of density, it is customary practice in several studios to make use of a fairly wide portion of print transmission to secure volume control. It is generally recognized that a density range from 0.8 up to possibly 0.5 can be used without any serious deterioration of sound. That gives a 6-db. volume range. I do not believe such control by print density in the variable-width system is practicable without introducing other difficulties. The ability to control print volume in the variable-density system by printer light control is an outstanding advantage.

MR. KELLOGG: Dr. Frayne has raised the question of the possibility of controlling output levels by changing the print exposure. If certain passages have been recorded at higher levels than desired there are two methods by which they may be reduced: (*1*) re-recording and (*2*) dark printing. In the case of re-recording, the light-valve would be given small modulation and bias. This results in a light negative and a dark print. The method of increasing the printer light, using the original negative, likewise gives a dark print. I have pointed out in the paper that if a given print density is obtained by high printing light through a dense negative, the resulting graininess in the print is greater than would be the case with less printer light and a thinner negative. It should be possible to obtain about the same percentage modulation of the light reaching the photo-cell whichever way the print is made. The re-recording system, therefore, offers the possibility of the same volume of useful sound with less hiss due to film grain. The ground-noise due to dirt and scratches upon the print is the same for the two types of printing, since both are assumed to have equal average density.

Since re-recording offers a preferable means of obtaining the reduced-level print, it would appear that the application of the heavy-print method should be limited to cases in which the number of prints to be made is not sufficient to justify a re-recording operation. If re-recording is to be employed we are brought back to the question whether variable-density or variable-width recording will give the best results (*1*) for the original and (*2*) for the reduced-level recording.

If the number of prints to be made is small, and re-recording therefore not justified, both the variable-density and the variable-width systems permit reducing the level of certain passages by a printer operation. In the variable-density system the printing light is increased and the result is a dark print. In the variable-width system the objective can be attained by flashing the print, or, in other words, by giving the entire sound-track an exposure in addition to that which prints the sound. This will result in a uniform gray in the transparent areas, while the density in the dark areas should be kept about the same as for a standard print. Tests have been made which show that a reduction of the order of 6 to 8 db. can be made by the flashing operation, without appreciable impairment of the relative high-frequency output or other distortion. The additional exposure may be attained by running the film through the printer a second time if only a few prints are wanted. For a larger number an auxiliary lamp can be readily arranged.

Assuming for comparison that the standard prints would give equal ground-noise, the reduced-level print would have less hiss in the variable-width system. The reason for this is that in the case of a variable-density print, the darkening of the print is attained by a strong light through a comparatively dense negative, the graininess of which is added to that of the positive; whereas in the variable-width system only the inherent graininess of the positive enters.

RELATION BETWEEN ILLUMINATION AND SCREEN SIZE FOR NON-THEATRICAL PROJECTION*

D. F. LYMAN**

Summary.—*Methods of measuring the illumination output of 8-mm. and 16-mm. projectors are discussed, with particular reference to some of the many variables that affect the results. This output value, expressed in screen lumens, permits determining the screen size for any desired foot-candle level. But because screen brightness depends also upon the reflection characteristics of the screen material, there is presented a classification of various types of screen material. For each class of screen, maximum and minimum illumination values are suggested, with the object of keeping the screen brightness within the limits necessary for good picture quality. Charts illustrate the relation between these factors and between the screen size and projection distance.*

During the development of 8- and 16-mm. projectors, the screen illumination has been increased steadily by the adoption of more and more efficient optical systems and lamps of higher wattage. This increase has introduced another projection problem, a tendency toward excesssive screen brightness, which may be nearly as objectionable as under-illumination. It is the purpose of this paper to suggest flexible limits for screen brightness, taking into consideration the light flux from the projector and the size and reflection characteristics of the screen.

LIGHT FLUX FROM THE PROJECTOR

The luminous flux from a projector is expressed in terms of screen lumens. One method of determining its value is as follows: The projector is run at about normal speed without film, and the light beam is projected to a wall or screen upon which can be measured the magnified image of the gate aperture. For this purpose the lens is focused so that the image is sharply defined, and the aperture is framed properly. Since the illumination varies slightly with the position of the lens, the image is made about average screen size, at least three or four feet wide. Then, by means of an illuminometer,

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

readings in foot-candles are taken at nine or more points in the field. If the points are well distributed over the field, including the corners, the readings at once show the degree of uniformity of the illumination. Their average multiplied by the area of the field in square feet gives the flux, F, in screen lumens,

$$F = 0.75\ W^2E$$

where E is the average illumination in foot-candles and W is the width of the screen in feet. The 0.75 factor is the ratio of aperture height to width.

Corrections must be applied in order to attain consistent results, one of which is for the variation of area of the lamp filaments. Source areas of a number of lamps of the same type are measured, and the dimensions are checked against the specified size. Then illumination tests made with the same lamps reveal the variation that may be expected with various filament spreads.

Another reason for including several lamps is the slight variation in the location of filaments with respect to the optical axis. Prefocus-based lamps have eliminated most of the uncertainty about centering, but there are still slight mechanical tolerances that require particular attention. Instructions furnished with projectors describe the method of adjusting lamps and reflectors, and also stress the importance of keeping all glass surfaces clean. In illumination tests these rules must be followed.

A third reason for averaging results from a number of lamps is the slight deviation from normal filament temperature. Lamp manufacturers attempt to keep this factor constant so that the design life will be attained. There is, however, enough variation between lamps to necessitate averages. New lamps sometimes show a slight increase of output for the first half or three-quarters of an hour; after which the illumination decreases gradually to about 75 per cent of its initial value before the filament fails. This decrease is caused by changes in the filament and by blackening of the bulb. Curves of illumination plotted against time are valuable because they show initial illumination, the rate of decrease of illumination, and the lamp life. Furthermore, if a sufficient number of such illumination maintenance curves are prepared, it is possible to estimate the probable performance of a lamp in question if only its initial illumination is read. No measurement of projector performance is complete without correcting for the characteristics of the lamp. Lamps that have been selected for correct source area and rated in volts or amperes for the proper filament temperature can be procured from the lamp manufacturers. Ordinarily, however, results from the run-of-the-mill product are of chief interest.

In addition, dependable results require the use of an accurate voltmeter or ammeter, depending upon whether the lamp is rated in volts or amperes. Because the present high-powered lamps draw a fairly heavy load and often cause a drop in the line voltage, resistance adjustments are made and meter readings are taken only when the full projector load is connected across the line. Photometers of all types require frequent checking, especially if the filament temperature of the projection lamp differs from the temperature for which the illuminometer was calibrated.

When the output of a large number of projectors must be ascertained, an integrator-box with a ground-glass or opal-glass screen is placed in front of the projection lens. At the other end of the box is inserted the light-sensitive cell. Or, if a photometer of the visual type is employed, a diffusing glass is placed in each end of the box and readings are taken from the glass farthest from the projection lens. With either type of photometer, readings from the box are compared with values obtained by the conventional point-by-point method at the screen, and a conversion factor is established. Insertion of neutral gray filters of the proper density permits reading from the box directly in screen lumens, although the illuminometer may be calibrated in foot-candles. One objection to the integrator-box method is the impossibility of measuring uniformity over the screen area. On the other hand, it is especially useful when several lamps or lenses of different types are under test.

Some laboratories use more complicated equipment, such as hemispheres into which the beam is projected. Such equipment enables skilled operators to read illumination with great precision, but the ordinary methods just described are accurate enough for this purpose if proper corrections are made.

Tests are usually made with the shutter operating, and this should be stated when the results are given. Except for still-picture projection, the light that passes the rotating shutter is of major interest. Occasionally, however, the efficiency of only the optical system is desired, in which case both the heat screen and the main shutter are blocked open and kept stationary.

METHODS OF EVALUATING PROJECTOR PERFORMANCE

Expressing projector performance in screen lumens is the real criterion, as opposed to the common practice of judging according to lamp wattage. If all lamps, optical systems, and shutters had the same efficiency, the latter method would be practicable. But a comparison of the ratio of screen lumens to lamp wattage for a large number of projectors of different types reveals a surprising discrepancy in efficiency. Twenty-eight typical projectors with regular lens equipment average 0.21 screen lumen per watt, but the maximum is 0.43 and the minimum is 0.07. Although this difference of 6 to 1 is an extreme case, factors of 3 to 1 and 2 to 1 are quite common. Low-voltage lamps with filaments offset toward the condenser are generally high in efficiency, because both the size and position of the filaments permit the condensers to collect larger cones of light. From an efficiency standpoint, projectors with biplane filament lamps are not necessarily superior to those with monoplane filaments. But the type of lamp is only one factor in the final efficiency result; the others are the design and spacing of the condenser and the reflector and the transmission of the shutter and projection lens. Much of the variation in efficiency can be charged to these collecting and transmitting parts of the projectors.

TABLE I

Range of Efficiency with Shutter Transmission of 60 Per Cent

Objective	Screen Lumens per Watt	Screen Lumens; Shutter Running		
		400-W. Biplane	500-W. Biplane	750-W. Biplane
$f/1.6$	0.25 to 0.30	100–120	125–150	187–225
$f/2.0$	0.20 to 0.25	80–100	100–125	150–187
$f/2.5$	0.15 to 0.20	60–80	75–100	112–150

As biplane-filament lamps have been adopted extensively, there is shown in Table I the range of efficiency that may be expected from a well-designed 16-mm. projector having a shutter transmission of at least 60 per cent. Table I is given merely as an illustration of favorable design conditions. The figures, therefore, should not be applied indiscriminately to any projector with the equipment tabulated.

Rather wide limits of efficiency and luminous flux are given because not all objectives with the same $f/$ value have the same transmission. Moreover, there is a slight decrease of efficiency with an increase of wattage of the lamp and the size of the source.

Eight-mm. projectors of different types have delivered 0.02 to 0.15 screen lumen per watt. Here again, the maximum is attained with offset-filament construction. With centered monoplane lamps and favorable design, 0.06 to 0.08 screen lumen per watt represents average efficiency, whereas biplane filaments give 0.07 to 0.09.

Classifying projectors according to luminous flux output has an additional advantage. It is quite easy to determine the screen size for an assumed illumination, or the illumination for a given screen size by rearranging the formula:

$$F = 0.75W^2E, \quad \text{to} \quad W = \sqrt{\frac{F}{0.75E}} \quad \text{or} \quad E = \frac{F}{0.75W^2}$$

CLASSIFICATION OF SCREENS

Before proceeding with recommendations for screen brightness, it will be necessary to consider the reflection characteristics of the several kinds of screen materials.

Class *1* (Fig. 1) is an arbitrary designation for a matte or diffuse screen, a surface that appears equally bright through a viewing angle of at least 30 to 40 degrees from the optical axis. This surface should be as white as possible, especially for color pictures. Its reflection factor should be at least 70 per cent. A white unglazed paper similar to typewriter paper is a good example of this class.

Class *2* is a semi-matte screen, which, through an angle of plus and minus 30 degrees from the optical axis, has an average reflecting power about twice as great as that of a Class *1* screen. Slightly glossy white surfaces, some beaded screens, and rough surfaces with an aluminum coating fall into this class.

Class *3* is a semi-specular screen, which, as the number indicates, has an average reflecting power about three times as great as that of a Class *1* screen, but only through a 60-degree angle. Many aluminum coated surfaces of a fairly fine texture are included in this group.

Class *4* is about as specular as can be used for projection. It has a high reflection factor on the axis or at an angle of reflection equal to the angle of incidence, but the brightness decreases rapidly until at 30 degrees it is less bright than a Class *1* screen, assuming that both classes are subjected to the same illumination. This kind of screen is used when maximum brightness is demanded, as for Kodacolor film and 8-mm. projectors in the lower price-class. Smooth metal, cardboard, or paper surfaces that have been coated with a specular aluminum finish are included in this class.

Fig. 1 delineates characteristics of the four classes. The curves

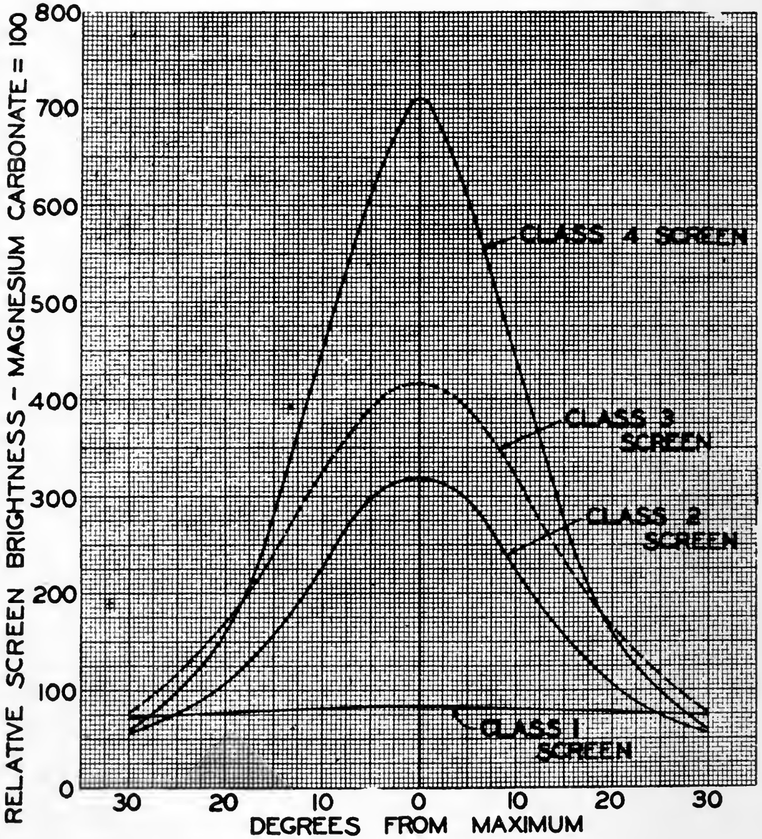

FIG. 1. Characteristics of the four classes of screens.

represent averages of several materials in each group. A block of magnesium carbonate, represented by *100* upon the vertical scale and taken as the reference standard, would be the most efficient Class *1* surface, but since its use as a screen material is not practicable, the Class *1* curve is shown somewhat below the 100 line.

LIMITS OF SCREEN BRIGHTNESS

Screen brightness could be expressed in absolute terms of millilamberts or candles per square foot, but these units become confusing when changing from diffuse to specular screens. Instead, it is simpler to state the limits in terms of *illumination*, shutter running but without film, for each class of surface. For example, with a Class *1* screen the suggested upper limit for illumination is 24 foot-candles. As Kodacolor and Kodachrome present different problems, they are treated separately later. With a Class *1* screen an illumination of more than 24 foot-candles is undesirable for the average black-and-white film, whether it be reversal, duplicate, or reduction print. In the first place, most persons agree that excessive brightness detracts from the pleasing quality of the denser portions of the picture. Shadows become light gray and graininess in medium densities becomes more noticeable. In some cases observers have noted an apparent spreading or enlarging of the highlights. Furthermore, flicker is objectionable, even though most projectors have 48 light interruptions per second at normal projection speed. If there is a slight travel-ghost, it is very apparent at high illumination levels, while with less brightness it may not be visible.

To keep the maximum brightness constant for the four classes of screen material, upper limits of 12, 8, and 6 foot-candles are suggested for Classes *2*, *3*, and *4* screens, respectively.

With a Class *1* screen there is a wide range of illumination from 24 down to about 4 foot-candles, which allows good projection quality. Changes in the eye, the increase in the size of the pupil and the greater sensitivity at lower levels of brightness tend to maintain pleasing quality. Below 4 foot-candles, however, quality again begins to suffer. The usual reaction is that medium densities appear quite black and lose detail, and highlights are weak and unreal. Yet, under some conditions results are passable with only 1 foot-candle. Scenes including a preponderance of highlights, overexposed scenes, light prints, and cartoons may appear bright enough to justify this low value.

Conversely, films that are dark, whether from the nature of the subject, underexposure, or heavy printing, may warrant raising the upper limit of 24 foot-candles. In neither case should the limits be considered inflexible.

Another factor that affects the minimum figure is the level of room illumination. For most 16- and 8-mm. projection the room is dark except for stray light from the projector and light reflected from the screen. If there is too much added light, for example, when projecting classroom films in the daytime, the 4 foot-candle minimum may be too low. If it is necessary to project a dim picture, results

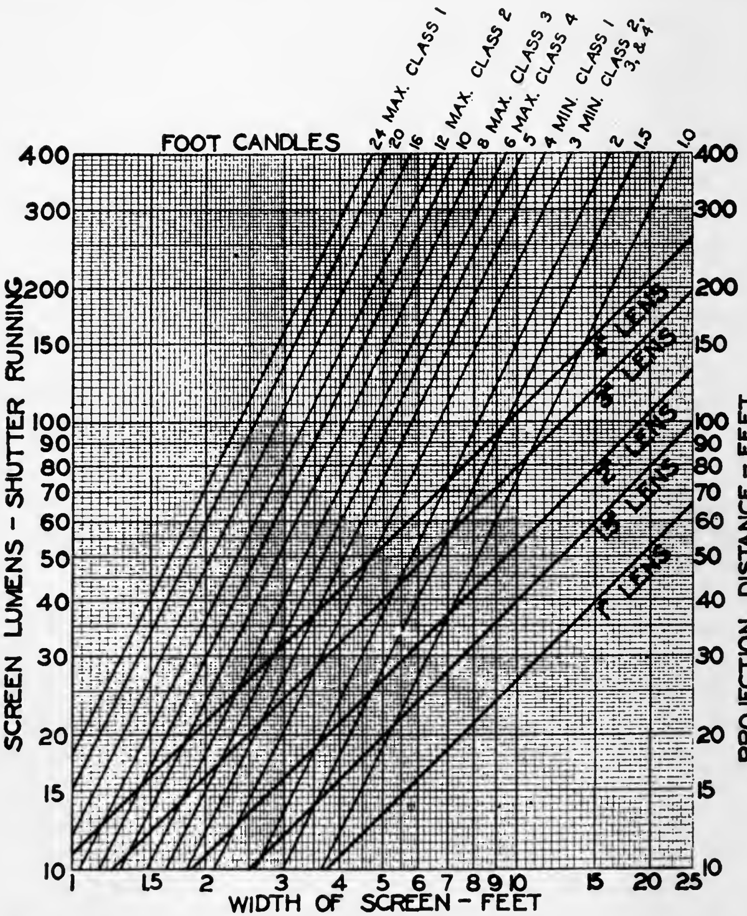

FIG. 2. Chart for determining screen size for 16-mm. projection, with suggested limits of screen illumination.

are better if the room is kept dark for at least 10 minutes before projection to allow the eyes to become dark-adapted.

Minimum values for Class *2*, *3*, and *4* screens are placed at 3 foot-candles. This might be lower for narrow rooms that would require grouping the spectators in an angle of plus and minus 15 degrees from the optical axis. But when large screens are used, many of the spectators are usually relatively close to the screen and view it from a considerable angle. At 30 degrees all four classes of screens are about equal in reflection, while at 20 degrees even Classes *3* and *4* are only about twice as bright as a Class *1* screen. Suggested limits, then, are grouped in Table II.

TABLE II

Suggested Limits of Illumination
(Foot-Candles)

Class of Screen	Shutter Running, No Film in Gate Minimum	Maximum
1	4	24
2	3	12
3	3	8
4	3	6

Kodacolor Film requires special consideration because the absorption of the filter and the limiting *f* value of the optical system reduce allowable screen size. When Kodacolor was introduced, proper color saturation dictated the use of a $16^1/_2$ by 22-inch screen with the illumination afforded by the most efficient projectors available at that time. Since then, the gain in illumination and the substitution of filters having higher transmission factors have permitted increasing the screen size successively to 22 by 30 inches, 30 by 40 inches, and even larger for some of the efficient projectors. Thus, one of the chief obstacles to successfully viewing Kodacolor was removed. In general, this color process requires maximum screen brightness, which means specular screens, high-powered lamps, and fast lenses.

Projection of Kodachrome, the new full-color film, is not handicapped by lenticular embossings or by projection filters. Here the color is in the film itself. Instructions state that Kodachrome can be projected to the same size as black-and-white. Actually, however, the minimum illumination level can not be stretched so much for Kodachrome as for black-and-white, because the colors lose their brilliance. For this film, then, the lower limits suggested in Table II are as low as should be employed. With a normal screen size of about 39 by 52 inches and a projector output of 50 to 200 screen lumens, there need be no special treatment for Kodachrome. In

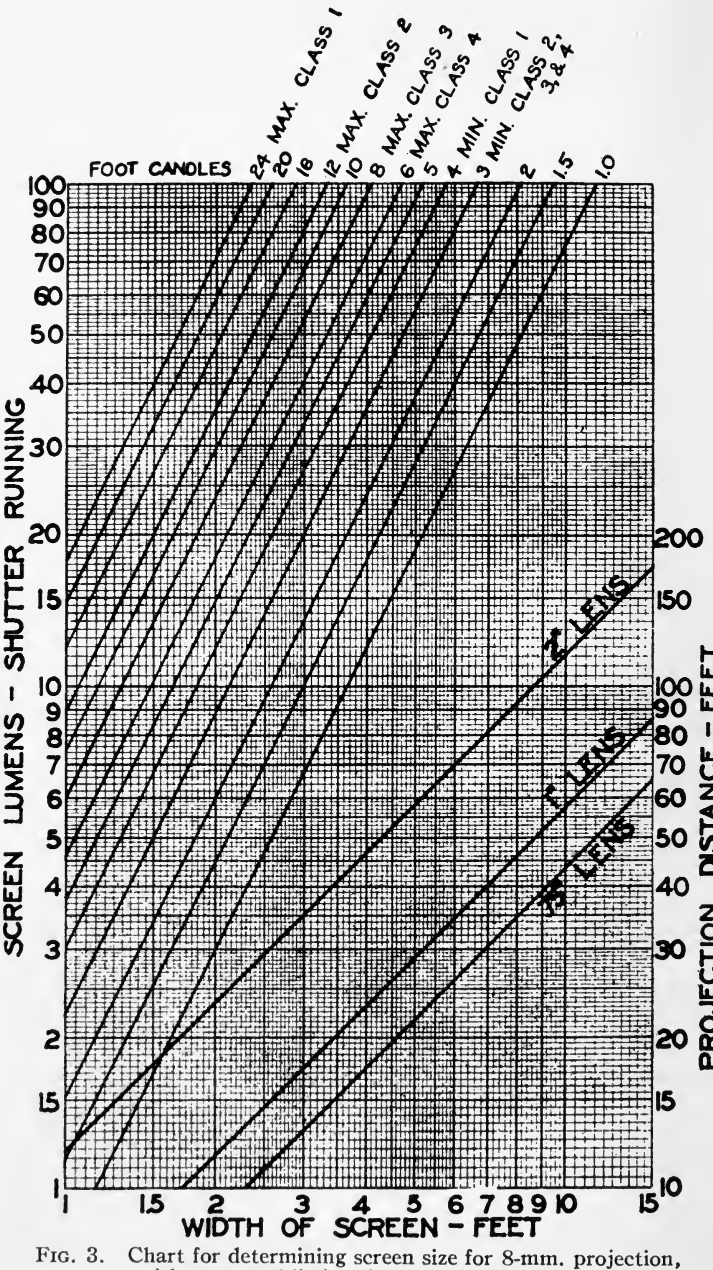

FIG. 3. Chart for determining screen size for 8-mm. projection, with suggested limits of screen illumination.

fact, it can be spliced into black-and-white films and projected under the same conditions with good results.

Except for Kodacolor and large black-and-white screens, then, illumination requirements are not high. Screen size is often fixed by the length of the room and the focal lengths of the lenses available. If this is true, there are two simple ways to control screen

TABLE III

Relation between Screen Lumens and Screen Size
(For Both 16-Mm. and 8-Mm. Projectors)

Screen Lumens; Shutter Running	Width of Screen in Feet							
	Class 1		Class 2		Class 3		Class 4	
	Min. 4 Ft.-c.	Max. 24 Ft.-c.	Min. 3 Ft.-c.	Max. 12 Ft.-c.	Min. 3 Ft.-c.	Max. 8 Ft.-c.	Min. 3 Ft.-c.	Max. 6 Ft.-c.
4	1.2	0.5	1.3	0.7	1.3	0.8	1.3	0.9
8	1.6	0.7	1.9	0.9	1.9	1.1	1.9	1.3
12	2.0	0.8	2.3	1.1	2.3	1.4	2.3	1.6
16	2.3	0.9	2.7	1.3	2.7	1.6	2.7	1.9
20	2.6	1.0	3.0	1.5	3.0	1.8	3.0	2.1
24	2.8	1.1	3.3	1.6	3.3	2.0	3.3	2.3
28	3.0	1.2	3.5	1.8	3.5	2.2	3.5	2.5
32	3.3	1.3	3.8	1.9	3.8	2.3	3.8	2.7
36	3.5	1.4	4.0	2.0	4.0	2.5	4.0	2.8
40	3.7	1.5	4.2	2.1	4.2	2.6	4.2	3.0
50	4.1	1.7	4.7	2.4	4.7	2.9	4.7	3.3
75	5.0	2.0	5.8	2.9	5.8	3.5	5.8	4.1
100	5.8	2.4	6.7	3.3	6.7	4.1	6.7	4.7
125	6.5	2.6	7.5	3.7	7.5	4.6	7.5	5.3
150	7.1	2.9	8.2	4.1	8.2	5.0	8.2	5.8
175	7.6	3.1	8.8	4.4	8.8	5.4	8.8	6.2
200	8.2	3.3	9.4	4.7	9.4	5.8	9.4	6.7
225	8.7	3.5	10.0	5.0	10.0	6.1	10.0	7.1
250	9.1	3.7	10.5	5.3	10.5	6.5	10.5	7.5
275	9.6	3.9	11.1	5.5	11.1	6.8	11.1	7.8
300	10.0	4.1	11.5	5.8	11.5	7.1	11.5	8.2
325	10.4	4.2	12.0	6.0	12.0	7.4	12.0	8.5
350	10.8	4.5	12.5	6.2	12.5	7.6	12.5	8.8
375	11.2	4.6	12.9	6.5	12.9	7.9	12.9	9.1
400	11.6	4.7	13.3	6.7	13.3	8.2	13.3	9.4

brightness: (*1*) by changing to a higher- or lower-wattage lamp, or (*2*) by using a more diffuse or more specular screen. Obviously, it is good economy to use a lamp of low wattage, principally because the initial cost is lower and secondarily because operating expense and heat are decreased. If a high-wattage lamp is desired for Kodacolor or for occasional showings with a large screen, excessive screen brightness with a smaller screen will be avoided by utilizing a diffuse surface. To the advantage of uniform brightness through a wide angle there is added the freedom from texture often visible with specular screens. In some cases it is best to use both means of reducing the screen brightness if the size must remain constant.

Determination of screen size from Fig. 2, which is for 16-mm. film, involves a knowledge of the number of screen lumens. From the corresponding point upon the left vertical scale, follow a horizontal line to the desired foot-candle line, which can be selected after consideration of the class of screen and the illumination limits given for each class. From the intersection of the screen lumen and the foot-candle lines follow a vertical line to the bottom horizontal scale and read the width of the screen in feet. The projection distance for any screen width can be found by using the second set of lines, labelled with the focal lengths of the projection lenses. In this case the right vertical scale shows the throw in feet. Fig. 3 is similar but plotted for 8-mm. projectors.

Table III reveals the same relationship between screen lumens and screen size, but here the range in screen width for the suggested limits of illumination is given. This table applies to both 16- and 8-mm. projection.

Although it is very difficult to make hard and fast rules for limiting screen brightness, an attempt has been made here to outline some of the factors that must be considered if the sensation as produced by projection is to be commensurate with the fine quality that is inherent in correctly exposed films.

SENSITOMETRIC STUDIES OF PROCESSING CONDITIONS FOR MOTION PICTURE FILMS*

H. MEYER**

***Summary.**—Sensitometric and pictorial tests made and processed in eight major Hollywood motion picture laboratories are discussed with special reference to the characteristics of the printed over-all curves. Attention is called to the importance of keeping the difference between contrast and gamma distinct. Several theoretical and practical conclusions resulting from the study of these tests are formulated.*

INTRODUCTION

The following is a report of a series of tests conducted in eight Hollywood motion picture laboratories for the purpose of studying the various conditions under which 35-mm. film is processed. From the data obtained some conclusions were formulated which will be presented later. This is done not with the intention of criticizing existing laboratory practice but rather with the earnest desire to contribute in a modest degree to the understanding of photographic laws and requirements so essential to continuously maintaining standard quality.

TEST METHODS

The tests were prepared with the thought in mind of checking by sensitometric control every phase of processing the pictorial record obtained in the production of motion pictures. For this purpose a roll of supersensitive panchromatic gray-back negative film was exposed in a Bell & Howell camera, on a title board, photographing a vase placed in front of a black-and-white split background. Lighting and exposure were carefully determined by preliminary tests, taking into consideration speed and contrast of this particular negative film type so as to assure a fully exposed negative with normal contrast under average developing conditions. The object was illuminated by Mazda light. The split background consisted of black velvet and

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white glossy cardboard, both areas large enough to permit reading their respective densities in the developed image by a Capstaff densitometer.

The exposed roll of negative was broken into eight parts which were in turn submitted to each laboratory for development under normal production conditions. Each roll was accompanied by a sensitometric strip, exposed in an Eastman time-scale sensitometer, on film from the same roll.

When the processed negatives were returned the sensitometric strips were read and plotted in the usual manner and, in addition, the two density values of the split background in all pictorial negatives were determined. These figures were then marked upon the corresponding sensitometric graphs, thus indicating quite accurately the position of the lowest shadow detail and the strongest highlight in the object. A loop was then made from each pictorial negative and its corresponding sensitometric strip, and returned to each laboratory with the request that it be printed upon black-and-white positive film in one of their regular Bell & Howell production printers, on all odd numbered lights from 1 to 21. These prints then went through the normal positive developing procedure at each laboratory, accompanied by a sensitometric strip exposed on the same type of positive film in an Eastman time-scale sensitometer, in order to obtain a record of the positive solution characteristics. All sensitometric strips representing over-all prints from the original negative strip over the full range of the model *D* Bell & Howell printer were then read and plotted in conjunction with the negative graphs. Again the density values of the split background were determined in each print and marked upon the corresponding over-all curves. In addition, the sensitometric positive solution strips were read and plotted separately.

TEST RESULTS AND CONCLUSIONS

Listed in Table I are the gamma values obtained from each laboratory, including negative gamma, positive solution gamma, printed over-all gamma, and over-all gamma as obtained by multiplying the negative gamma by the positive solution gamma.

The difference between the printed over-all gamma and the over-all gamma obtained by multiplying the negative and positive solution gammas is also listed and expressed in percentage. From this table one will notice that the average negative gamma is close to 0.67 and that the largest deviation from this value is +0.04 and −0.05. The differences between the positive solution gammas as maintained in these laboratories is considerably larger, the average gamma being 2.37, with deviations as high as +0.31 and −0.37. The range of values for the printed over-all gammas ranges from 1.18 to 1.62, with an average value of 1.43, and deviations of +0.19 and −0.25. The printer factor was found in every instance to be close to 11 per cent.

TABLE I

Laboratory	Negative Gamma	Positive Solution Gamma	Printed Over-All Gamma	Over-All Gamma (Gamma Negative × Gamma positive)	Printer Factor (per cent)
1	0.71	2.00	1.18	1.42	12
2	0.65	2.15	1.25	1.40	11
3	0.62	2.34	1.34	1.45	11
4	0.70	2.23	1.46	1.61	11
5	0.66	2.40	1.48	1.58	11
6	0.68	2.48	1.53	1.68	11
7	0.62	2.68	1.54	1.66	11
8	0.67	2.66	1.62	1.78	11

All pictorial prints were submitted to the judgment of several timers, who selected the most satisfactory print from each laboratory. Listed in Table II is the printing light corresponding to each selected print. Also listed is the density range for each selected print which was determined by the readings of the two density values of the split background, and which were marked upon the corresponding over-all curves by *A* and *B*. In the fourth column will be found the globe characteristics of each printer lamp.

TABLE II

Laboratory	Printing Light	Density Range (*A–B*)	Printer Lamp
1	19	0.24–1.62	100-watt, outside frosted
2	13	0.27–1.66	100-watt, outside frosted
3	13	0.27–1.73	75-watt, inside frosted
4	17	0.14–1.82	100-watt, clear
5	13	0.23–1.69	60-watt, inside frosted
6	19	0.24–1.64	60-watt, inside frosted
7	11	0.23–1.78	75-watt, inside frosted
8	13	0.22–1.84	75-watt, inside frosted

Readings of the density range for laboratory No. 4 are not quite satisfactory for the reason that, due to a misunderstanding, the negative loop was printed only up to light 17 while a higher light would have given a better print. The variations of contrast between the selected prints from each laboratory were quite pronounced.

Figs. 1 to 7 show the sensitometric graphs obtained from each laboratory.

The small letters *a* and *b* mark the two densities of the negative background, while the capital letters *A* and *B* mark the corresponding densities of the printed background. Lines were also drawn parallel to the density axis through the toe and shoulder breaking-points of the negative curves and parallel to the exposure axis through the toe and shoulder breaking-points of the positive curves. Although great care was exercised in determining these points the accuracy of their readings can be disputed, because a rather large factor of inconsistency must be recognized due to the influence of directional developing effects upon the toe and shoulder. Furthermore, the breaking from the straight line naturally starts with very small angles of deviation, and for that reason, also, errors in determining the exact breaking-point are liable to occur.

These lines form a border for the family of curves inside which all parts of the printed over-all curves are straight lines without distortion. A comparison of the length of the single straight-line parts within this territory, to the length of the whole curve used in the production of each over-all print, as determined, for example, by *A* and *B*, will clearly show the incorrectness of the conception frequently found that gamma is identical to contrast and is in all cases a means for determining the faithful photographic reproduction of the brightness range of an object.

The law for ideal rendition of tone values by photographic means, according to which gamma negative is equal to the reciprocal of gamma positive, is applicable only in case gamma is identical to contrast, which naturally is true only as long as one deals with straight-line recording and reproduction throughout. In processing motion pictures a large portion of any projectable over-all print, at least with the present technic, can not avoid being recorded in the curved toe section of the positive film. The correct equation, therefore, will stipulate that the over-all contrast or the product of negative gradient and positive gradient must equal unity.

Let us now investigate how close these printed over-all curves satisfy this requirement. Considering the selected printed curve of laboratory No. 2 (Fig. 2) we have a printed over-all gamma of 1.25. Lines drawn parallel to the density axis through density 1.66 (*A*) and 0.27 (*B*) will mark upon the exposure axis the exposure range related to the print. A line drawn parallel to the density axis through the

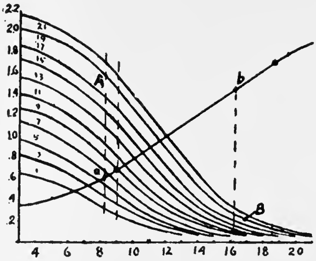

FIG. 1

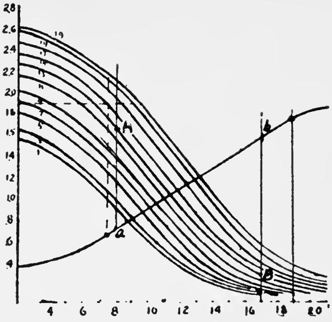

FIG. 2

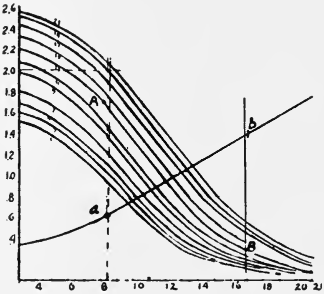

FIG. 3

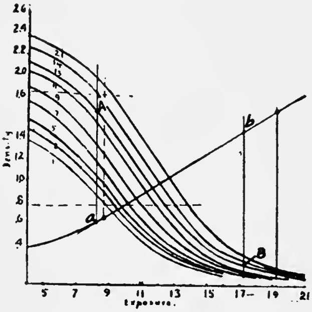

FIG. 4

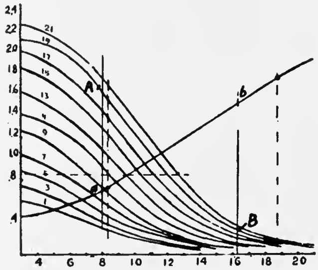

FIG. 5

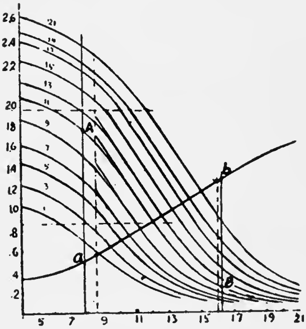

FIG. 6

FIGS. 1-6. Sensitometric curves for various printer lights obtained from the various laboratories (negative and printed over-all curves): abscissas, exposures; ordinates, densities.

Fig.	Lab.	Fig.	Lab.
1	1	4	5
2	2	5	6
3	3	6	7

toe breaking-point of the printed over-all curve and crossing the exposure axis will determine the exposure range related to both the straight-line and curved toe portions. In this case it will be found that the exposure range related to the straight-line portion of the printed over-all curve approximates closely one half the total exposure range, which leaves the other half of that related to the curved portion. The average contrast of the curved part can be approximately determined by connecting B and the toe breaking-point with a straight line and reading its gamma value, which will be found in this case to be 0.80. Adding this value to 1.25 we obtain a value of 2.05, which, divided by 2, will give the figure 1.025 for the approximate over-all contrast, which is ideally close to unity.

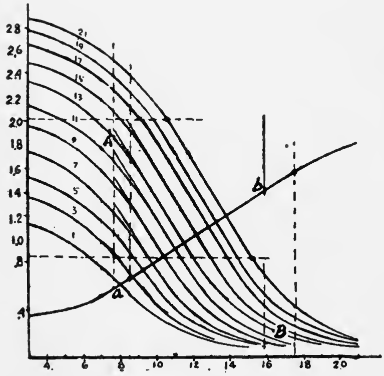

FIG. 7. Same as Figs. 1-6, for laboratory 8.

To avoid misunderstanding, it should be mentioned here that the method of interpolating over-all contrast as demonstrated in this example, can not be considered scientifically correct or even practically applicable in all cases. It leads, however, to values sufficiently accurate for practical consideration in cases where the extension of the exposure range related to the curved section is not larger than that related to the straight-line portion. This method was employed here merely for the simple help it offers in illustrating how an over-all print with a gamma value considerably higher than unity can still render satisfactory contrast.

The extension of the straight-line portion, in comparison to that of the curved portion, will naturally change in every print, depending upon the contrast and the density range of the negative, the printing light, the intensity range of the printer, and other variable factors in exposing and processing motion pictures.

One will further notice when studying the over-all print graphs that the gamma values do not change, regardless of the printer light used. Small deviations noticeable in these graphs can be attributed to errors in density readings, unavoidable inaccuracy in determining the breaking-points of toe and shoulder of both the negative and the positive curves, and to distortions caused by directional developing effects. An automatic lowering of the contrast is encountered as soon as the densities of the over-all print fall below, or above, the area fenced by the various lines drawn through the points of toe and shoulder breaks. This, while undoubtedly known and recognized since sensitometric curves were introduced, is mentioned for the reason that the practical laboratory man usually thinks and expresses himself in terms of gamma, and, perhaps not fully aware of the difference between contrast and gamma, believes quite often that what he notices as a lowering of contrast in a print, due to toe distortion, is caused by lowering of the gamma.

The possible tonal distortions in a picture print, one of which is always present in the form of the positive toe distortion, can be studied from these curves as to their relative importance. The negative toe distortion can be avoided in most types of photography provided sufficient lighting is available, as modern negative film emulsions are distinguished by a latitude or extension of their straight-line portion amply large enough to take care of the brightness range in almost any object. In this connection must be mentioned the desirability of having a large range of printing lights available which will permit an exposure through the highest negative densities, especially since gray-back types, with their additional over-all density, are commonly used. This leads to the practical consideration not to exaggerate or generalize upon the merits of so-called low-key lighting. Only in cases where the brightness range of an object is greater than can be recorded within the straight-line portion of the negative film should the negative toe portion be used. Furthermore, this is preferable to using the shoulder portion, because the distortion caused by the latter will be doubled in the print by the unavoidable toe distortion of the positive film. In addition, distortion ot the shadow rendition in the print, as caused by portions of the negative being recorded in the negative toe section, is less noticeable to the eye.

The distortion caused by the positive shoulder break is of less importance for the same reason and, besides, is practically avoided in current motion picture processing due to the fact that the highest densities in a projectable print seldom extend beyond the shoulder breaking-point of present positive emulsions.

At this point it might be timely to apply some of these considerations to the two principal methods used in Hollywood laboratories for developing negative picture film, which are commonly known under the names of "Test Method" and "Time and Temperature Method." It is not our intention to discuss the practical merits of either method or to express a final opinion as to which one is preferable in practical application. The laboratory, or studio, will decide this question primarily from the point of view of economy in time and labor, and guided by the desire of creating the best means to protect the all-important quality of original production negatives.

Our consideration is limited to the purely theoretical question as to which of the two methods is more satisfactory as regards obtaining a negative that will, under prevailing positive processing conditions, result in an over-all print with an average over-all contrast close to unity. There can not be much doubt that in answer to this question the "test" method must be regarded as superior.

In outdoor photography, for instance, maintenance of a constant lighting contrast is beyond the control of the cameraman. In addition, most laboratories, since the introduction of developing machines, keep their positive developing conditions practically constant as regards speed or time. Last, but not least, it should be remembered that the motion picture industry, up to the present time, is using positive film of one grade in contrast only, and does not utilize different grades, as does the paper print trade. Altogether, this seems to leave the only possibility of balancing inherent light contrasts to the negative processing. To exercise this method correctly one must, however, disregard the gamma and printing density of the negative. Just how far the "test" method is applicable, or preferable, in a practical way is a question of a different nature, the discussion of which does not enter these considerations.

A practical suggestion might be offered and utilized by the laboratories using either method, which would call for a test slate similar to that represented by the black-and-white split background, and which would be exposed by the cameraman before the actual scene is taken. This would enable the laboratory to determine density range and contrast in conjunction with the negative solution curves, and could even be worked out without the direct aid of photography into some general method of measuring the values of highest and lowest brightness of such a test object under the given illumination by means of a photometer upon the set. The figures obtained could be checked against a standard and finally transposed into negative density contrast for a given type under constant developing conditions.

Furthermore, consideration was given to the possibility of avoiding the use of the positive toe completely in processing the print so as to obtain a straight-line reproduction from a straight-line negative. This could be done by developing the print to an over-all gamma of unity and treating this print with a subtractive reducer to the point where the density of the toe portion is chemically dissolved. In order to attain the requisite projection density this print would either have to be correspondingly overexposed before development and reduction, or the normal exposed print would have to be re-intensified after reduction.

Again it must be mentioned that it is not the purpose of this paper to deal with the practical application of this suggestion which undoubtedly presents difficulties and disadvantages not easily overcome. It will be seen from the study of these tests that even the most perfect processing conditions at present will lead to results which still represent only a compromise to the ideal. Fortunately, the human eye, which is the final judge of our photographic efforts, is more tolerant than the critical ear with its objective selectivity.

A study of this test material is recommended especially to the practical laboratory man, not so much for any novelty that it might contain as for the possibility that it offers to establish more definite knowledge of the requirements and limitations in the art of processing motion picture film.

Sincere appreciation is hereby expressed to the major studios and laboratories whose courtesy and coöperation have permitted these tests to be conducted.

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NEW EMULSIONS FOR SPECIAL FIELDS IN MOTION PICTURE PHOTOGRAPHY*

W. LEAHY**

Summary.—*Three special film types, Infrared, Finopan, and Superpan Reversible, recently produced by the Agfa Ansco Corporation, are discussed regarding their photographic characteristics and possible usefulness in special fields. Technical data as to speed, color-sensitivity, and physical properties are given for Infrared and Finopan, in comparison with those of Superpan negative film.*

The progress in photochemical research during recent years has resulted in the creation of highly perfected negative emulsions available for general use in motion picture photography. The developing motion picture technic has never ceased to demand continuous development of certain characteristics in these film types, and it can be readily seen today that the various special requests put before the film manufacturer will lead sooner or later, to an increased development of specialized film types.

Any combination tool, while it is very convenient sometimes, will never give the performance of a line of special tools, and this also applies to a negative emulsion manufactured for all-around use.

There are two principal reasons for the development of specialized emulsions, one of which is the trend of motion picture technic itself toward specialization, as can be seen, for instance, in the fact that certain types of exposures formerly made by the cameraman on the "set" are now placed in the hands of special departments. The second motive leading in this direction is the fact that the film manufacturer, with his established knowledge of photochemical laws, feels more and more that despite all his technical skill and experience, these laws definitely limit further improvement of certain qualities of his products unless other qualities are sacrificed. To reach, for instance, the last possible step in general photographic speed, a product would have to be created that would disregard graininess, keeping quality, and contrast. To produce a film type of minimum

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graininess a reduction in speed and an increase in contrast will be unavoidable.

It might, therefore, be only a question of a short time when the development of specialized film types having single outstanding characteristics will be the last possibility of satisfying the multiplying requests of the motion picture industry for further improvements in special film.

In what follows, three special emulsions recently produced by the Agfa Ansco Corporation are discussed.

(*1*) *Infrared Film.*—This film type is used for recording long-distance shots in outdoor scenes which are obscured by haze, for obtaining special cloud and night effects in daylight, for aerial photography, and for medical and other scientific purposes.

The general speed of Infrared is approximately one-half that of Superpan, that is, when both types are exposed without filters and developed to the same gamma.

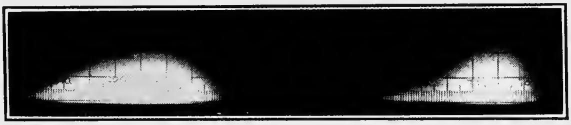

FIG. 1. Spectrogram of Infrared film.

Infrared film, however, must be used with red filters, as it is sensitive to blue light rays like all silver bromide emulsions. It is not sensitive to green-yellow, which permits the use of relatively light red filters, as it is only necessary that these filters absorb blue. For this reason, also, the filter factors are practically the same for all blue-absorbing and red-transmitting filters which have approximately the same transmission factors within the visible range of the red end of the spectrum. All Wratten filters from monochrome *No. 21* up to *29-F* fulfill this requirement and will be found to have equivalent exposure factors. Even filters as light as Wratten *No. 12, Minus blue,* and *15-G* are suitable for most cases, although both transmit some ultraviolet in the wavelength range of 300 Å. The filter factor for Infrared in combination with these filter types, as found by practical tests and sensitometric comparison, is of the order of 10 to 15. At standard motion picture camera speed a normal exposure of Infrared, using Wratten filter *No. 25*, will be obtained with a lens opening of 5.6. The use of deeper red filters is not recommended.

except for special scientific work, as they unnecessarily prolong the exposure due to their lower transmission factor without rendering better picture quality.

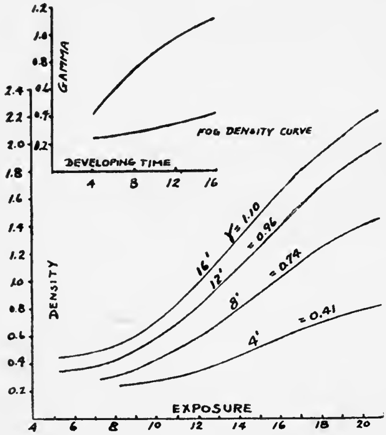

FIG. 2. Sensitometric curves on Infrared film.

Fig. 1 is a spectrogram of Infrared indicating the color-sensitivity over the full range of the visible spectrum.

Fig. 2 shows graphs of sensitometric curves exposed on Infrared film in an Eastman time-scale sensitometer, developed for different times in a regular motion picture negative borax developer. The gamma-time curve and the fog-density-time curve are also inserted in these graphs.

For comparison of relative contrast, similar sensitometric curves were made on Agfa Superpan and developed in the same developer, as shown in Fig. 3. It will be noticed in these that the gradation of Infrared film is considerably steeper than that of Superpan. Exposure of Infrared film through red filters naturally causes an increase in contrast, which was found to be approximately 7 per cent, referring to increase in gamma values.

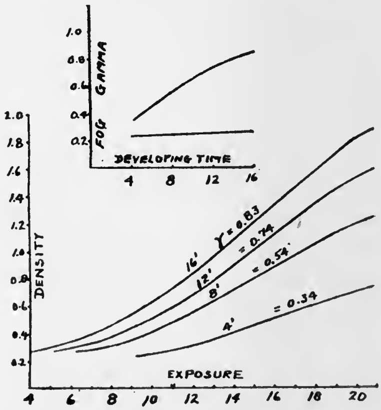

FIG. 3. Sensitometric curves on Agfa Superpan.

The sensitometric curves shown in Fig. 2 were developed using a green safelight, Agfa *No. 103*. Green filters permit the transmission of infrared rays to some degree, but fog an infrared sensitive emulsion during an extended development. This is evidenced in the fog-density-time curve shown in Fig. 2, which marks the rapid increase in fog density with extended developing time. For normal developing time, however, it is permissible to use green lights with the ordinary precautions.

(2) *Finopan Film.*—This film type is principally characterized by extremely fine grain, even excelling that of Infrared film. It might, therefore, be considered for use in photographic work wherein graininess and definition are of special importance. In general speed, Finopan is approximately 2 to 3 times slower than Superpan, the Weston rating being 8 for daylight and 4 for Mazda light.

FIG. 4. Spectrogram of Finopan.

Fig. 4 is a spectrogram of Finopan demonstrating the fully panchromatic response over the color range of the visible spectrum. Fig. 5 shows graphs of sensitometric curves exposed on Finopan in an Eastman time-scale sensitometer, developed for different times in a regular motion picture negative borax developer. The gamma-time curve and the fog-density-time curve are also included in the graph.

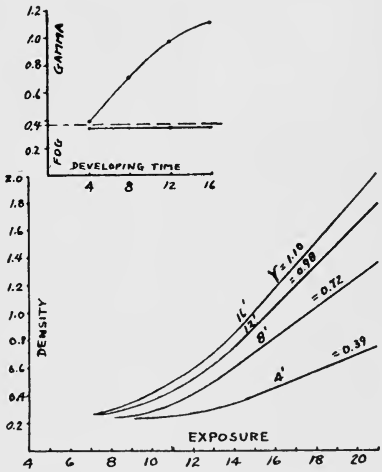

FIG. 5. Sensitometric curves on Finopan.

The contrast of Finopan is also higher than that of Superpan, as will be seen upon comparing the gamma readings on both film types for identical developing times.

Special attention is called to the lack of fog, even for abnormally extended developing times, and also to the unusual length of the straight-line portion.

This film type, due to a superior grain quality, should be of interest in photographing negatives for background projection prints. Its natural contrast might be utilized in the production of titles and inserts. Finopan is also recommended for consideration in the process of making duplicate negatives, in which case, however, special handling is required during development to take care of the contrast.

Dupe prints have been successfully produced both by optical and contract printing, exposing the lavender print from the original negative on light *21* and developing in a negative picture solution to a gamma of 0.70. The dupe negative was then made on Finopan, which was fully exposed and developed to a gamma of 1.0. The final print was very satisfactory, as regards graininess and contrast, for the reason that by means of this procedure it is comparatively simple to register the full range of densities in both the lavender and the dupe negative upon the straight-line portion.

A practical difficulty, however, of applying the method to the technic of making duplicates was recognized in the fact that the studios in many cases utilize stock library lavender prints for making dupe negatives, which naturally are developed to a normal positive gamma.

FIG. 6. Frame of normal print from supersensitive panchromatic negative, compared with reversed positive on reversible Superpan.

(*3*) *Reversible Superpan.*—During recent years a number of Hollywood motion picture studios have experimented with the problem of utilizing the reversible process in motion picture production. So far these attempts have failed mainly because of the limitations of this process itself. It seems to be somewhat early to announce or discuss reversible film types at a time when professional motion picture laboratories are not yet acquainted or experienced with processing reversible film. Therefore, it should be understood that mention of this film type is made merely with the intention of pointing toward future possibilities, which must be fully appreciated before beginning work toward perfecting methods of utilizing them.

The advantages that this film seems to offer in connection with the reversible process include not only that of finest possible graininess but, perhaps more important, that of incomparably better registration and definition due to circumventing the printing operation. Reversible Superpan is practically equal in general speed to regular Superpan negative, its Weston rating being 24 for daylight and 12 with Tungsten light.

In Fig. 6 is shown a single frame of a normal print made from a Supersensitive panchromatic negative in comparison with a reversed positive picture, photographed on reversible Superpan, using the same object and identical exposure.

As mentioned in the introduction, the three film types discussed are not intended to serve for general purposes. For that reason their usefulness and, in consequence, their importance to the motion picture industry will be limited. They form, however, a definite step in the direction of specialization, which will make further developments in response to the increasingly critical requirements and demands of motion picture technic.

While additional film types will undoubtedly multiply his production problems and worries, the film manufacturer is sincerely willing to work in this direction, convinced that his attempts will be appreciated by the motion picture industry as a substantial help in solving their technical problems.

TECHNICAL ASPECTS OF THE MOTION PICTURE*

ALFRED N. GOLDSMITH**

Summary.—*It is shown that the motion picture industry involves the artistic utilization of the products of research and development in the fields of mechanics, sound, heat, light, electricity, and chemistry. It is urged that the closest coöperation between the aesthetic and technical groups be maintained to the end that increasingly effective tools should be produced by the technicians and that these tools may be successfully employed by the artistic groups.*

Depending upon one's point of view, the motion picture in its present form may be any one of a number of things. It may be regarded as an art, or as an industry, or a mode of entertainment, or as a means of instruction. If it be an art, like other arts, it will require appropriate tools. Considered as an industry producing a given product, it will need suitable machines. Considered as an entertainment or instructional agency, it will obviously demand some methods of effective entry to the eye and ear of the audience or students, as the case may be. Analyzed from any angle, motion pictures are not an abstraction but a concrete reality and, as such, they require the physical means to produce them and to make them effective in their chosen function.

Thus the technical aspects of the motion picture, contrary to the belief of some, are not annoying oddities or irrelevant intrusions; they are, instead, essential parts of an organic unity which is the production and reproduction of the sound motion picture. Why then object to them any more than one would object to the typewriter with which the "shooting script" is produced or the liquid powder which may be the base of a make-up? A painter might as well detest easel, paint, canvas, and brushes; an etcher, copper plates, engraving tools, and acid; or a sculptor, model-stand, clay, marble, chisels, and shaping tools. It is incongruous and unjust to fail to give proper attention to the technical aspects of the motion picture, and it involves the risk of missing great opportunities for progress in the art. Let us

* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** New York, N. Y.

never forget that motion pictures are paintings in light and scrolls in sound. The mastery of light and the control of sound are at the very core of this great industry.

Before considering these matters in somewhat greater detail, we may first pay a tribute of genuine respect and admiration to the authors, writers, directors, scenic artists, actors, and all those who contribute the essentially aesthetic, human, and creative impulse to pictures. Their work has held the people of the world enthralled for the last few decades and promises to hold the absorbed interest of humanity far into the future. May we, however, bespeak their continued friendly consideration for that group of their fellow-workers who, striving behind the scenes and far less well known to the public and even to the industry, none the less give their best efforts to shaping and handling the exquisitely delicate and amazingly complicated tools of the field. I refer to the research workers, development engineers, cameramen, sound recordists, projectionists, and other groups who are in close contact with the daily problems of the physical portion of the industry.

It is indeed hard for those without practical experience to understand the difficulties of research. Only those who have struggled with the obdurate obstinacy of nature in attempting to wrest from her one of her secrets; only those who, after months or years of unremitting toil in the search for a better instrument to be used by the industry, have been compelled to accept the bitter conclusion that they were on the wrong track and have been forced to start out once more in a new direction; only those who have endured the unending strain of effort and expenditure of time and money involved in the discovery of improvements of one sort or another—only those of such experience can fully appreciate what is involved in research and development as they are now carried forward. The odds are great, the risks appalling, and the rewards and recognition only too infrequent. Yet along this hard path lies the real future of the industry so far as it depends upon the availability of those tools which will inspire and strengthen the artist, and please and hold the audience.

To consider somewhat more fully the contacts between the motion picture and science in general, it may be useful to adopt for the moment a rather old-fashioned classification of the physical and chemical sciences. It was customary in the past to divide science into the compartments of mechanics, light, heat, sound, and electricity; and then to throw in chemistry for good measure. The distinctions between these divisions have, in the light of our present-day broader knowledge, worn so thin as to be almost meaningless but, nevertheless, they may serve here as a convenient basis for the classification of some of the technical aspects of the motion picture.

The domain of mechanics is drawn upon heavily by the motion picture field. A wide variety of the most diverse materials are used, and their mechanical properties are of importance. Among such materials are the film base, various metals and alloys used in camera, recorder, and projector construction, and a number of more special materials used as acoustic insulators or reflectors. Various mechanical movements are extensively used, both of the continuous and intermittent varieties. Camera cranes and other devices required for special shots can be correctly designed for easy and reliable operation only if correct mechanical principles are utilized. At the other end of the range from such massive structures, we find that a study of the vibrations and mounting of the diaphragms or other elements used in recorders and loud speakers is needed for successful design. One could multiply these examples to a considerable extent without exhausting the contributions which mechanics can make in motion picture technology.

So far as the field of sound is concerned, it is, of course, self-evident that a field which today depends so markedly for certain of its effects upon sound must lean heavily upon acoustic principles and practice. The transmission of sound, the absorption and reflection of sound, and the insulation of sound are all important elements in the design of studio sets, in microphone placement, in successful recording, in informative review room auditions, and in adequate theater reproduction. As a matter of fact, the design of the microphones, recorders, studios, theaters, and sound-heads and loud speakers of the reproducing equipment (which, in their totality, form an elaborate and necessarily consistently coördinated system) constitute one of the most difficult and severe examples of acoustic engineering so far encountered. There are so many variables in recording and reproducing sound for motion pictures, and some of these factors are under such imperfect control, that it is not astonishing that even now the industry is just beginning to attain the essential mastery of the corresponding technic and equipment construction methods.

The field of light or optics is older in its applications to the motion picture in view of the evolution of the present performances from the older silent picture. Accordingly, one might expect the technic of camera, lighting, and projection to be definitive if not final. Oddly enough, such is not the case, and there seems to be many points at which the nevertheless generally acceptable practice of today might yet be improved. The controlled placement, intensity, diffusion, and direction of sources of studio lighting (with the related matters of perfected design of reflectors, condensers, and diffusers) are susceptible of further development along lines of correct optics and electrical and mechanical engineering. Photometric and photographic measurements utilize optical principles broadly and are regarded as matters of further development. To the scientific student of light, the specification and construction of color filters at this time are admirable in some respects, but standardization in this field will nevertheless require a considerable amount of further study. It need hardly be added that the optics of camera lenses (both for ordinary and color photographic systems), of finders, of the lighting system of printers, of projector condensers and reflectors, and of projector objective lenses have been highly developed and are excellent examples of the contributions of the theory of light to the motion picture field. Further applications of the available principles and methods bid fair to improve current practice in these fields as well.

The science of heat has contributed rather less to motion pictures than the preceding. While the control of the heat produced by various illuminants and the air conditioning of studios, laboratories, and theaters are examples of the applications of thermal theory, this field, on the whole, is not so directly related to motion picture practice as some others.

On the other hand, electrical theory and practice have made most substantial contributions to motion picture technology. Electrical generators and motors are extensively used throughout the industry. Portable power plants for "booster" illuminating installations are an interesting example of such an application. Camera motors, recorder motors, and printer and projector drives are other examples. Rotary converters or dynamotors are useful adjuncts. Illumination throughout all divisions of the industry is electrical, and is controlled by more or less advanced electrical methods. Switching comes into use in the studio and in connection with stage, house, and marquee and lobby lighting, where it has the indispensable function of rendering the theater attractive to the public. More recently the technic of electron tubes as amplifiers and the like has found extensive and indispensable application in sound recording and reproduction, and it is not to be questioned that it will in due course find further application in the work of the cameramen and projectionists. So wide is the application of electricity to motion picture work that it can truly be said that one not versed in electrical circuit practice is at distinct disadvantage in the field at present.

And last, but by no means least, the science of chemistry is widely applied in motion picture equipment and practice. The film itself—indispensable forerunner of all that follows—is strictly a complicated and beautifully controlled chemical product. The base, the emulsion, the backing, the paper for wrapping the film, the developing, fixing, and hardening baths (and their maintenance) all make extreme demands upon the skill of the chemist. One might go into considerable detail on the numerous complicated problems which are here encountered. At the other end of the motion picture processes, namely, in the arc-lamp chamber of the projector in the theater, one finds an interesting example of combined chemical control and spectrophotometric applications in the production of arc carbons which have just the right characteristics to give an abundance of properly tinted light upon the screen. Half-way between, the production of the coatings in the photo-cells of the sound-head and the production of the amplifier tubes, all involve many chemical problems, some of which are not yet wholly solved.

It is believed that it will be agreed by those who candidly consider the foregoing comments that motion pictures are undoubtedly a fabricated technologic product, fashioned and controlled in skilled artistic and inspirational manner. For its continued preëminence and public acceptance, those charged with the responsibility for the direction of the motion picture field must encourage its technical aspects and learn ever more fully to utilize them. They must respect and foster the engineering workers who are able to contribute to the art. And above all, there must be no conflict, open or hidden, between artistry, craftsmanship, and technology—for among these there is an essential underlying unity, the realization and encouragement of which is a fundamentally necessary condition for the continued growth and success of the industry.

SOME TECHNICAL ASPECTS OF RECORDING MUSIC*

R. H. TOWNSEND**

Summary.—*A short account of some of the early difficulties of introducing sound commercially and artistically into the motion picture, followed by a description of the development of dubbing, substitution of voices, recording music, etc. Some of the problems of recording sound for long shots, short shots, etc., variation of distance between actor and microphone, are discussed, in addition to various methods employed in scoring musicals and voices for long-shot and short-shot quality.*

The entertainment value of any motion picture is a direct measure of its success at the box-office. Just what constitutes entertainment is a moot question, and there is no place in this paper for an academic or philosophic discussion on the subject. However, in making a picture there are several very definite factors that can and do contribute to the pleasing or disturbing effects that a picture will produce upon an audience.

These factors lie definitely within the realm of engineering as applied to picture making, and while the statement may sound strange, it is nevertheless true that a judicious correlation of engineering principles and psychological reactions become a vital necessity in producing any successful sound picture.

We know, for instance, that a good story is most essential; that the cast should consist of individuals fully capable and desirous of portraying the characters in the story; that the photography should be adequate, and that the lines read by the cast should be so read that the audience can without effort believe them.

Almost any good story will make a good picture, and it is believed that no good picture has been classed as poor entertainment because of improper lighting or distorted sound. These may detract from the over-all charm and intelligibility of a picture, but the picture may still be a good one in spite of photographic shortcomings and furnish entertainment for those who view it.

Photography and sound have long been considered the technical

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** Fox Film Corp., Hollywood, Calif.

phases of picture production, and the application of each of these arts is capable in no small measure of adding to or detracting from the general entertainment value of any production.

Before the advent of sound, motion pictures had attained a high state of development, in the art of pantomime, and in extreme flexibility—of action. An audience, figuratively speaking could be taken instantly to any part of the world, into the future, into the past, and back into the present again, all within the space of a few minutes. The shadowy individuals upon the screen could move about close to or far away from the camera without producing any conscious awareness upon the part of the observers that the subject had moved. In short, for a full and complete enjoyment of the picture the audience was called upon to exercise but one of its five senses, *i. e.*, that of sight.

One October night in New York City in 1927, however, something happened that projected the entire motion picture industry into a series of artistic, technical, and directorial convulsions, and which, in spite of a wide variety of sedatives and palliatives in the form of executive and engineering experimenting, still recur at altogether too frequent intervals. This was the night Warner Brothers' *Jazz Singer* electrified Broadway in more ways than one.

Over night almost, the whole technical structure underlying the production of motion pictures experienced a tremendous shake-up. Any one who has had any connection with the industry during the past seven years has at least some idea of what has happened. Flimsy out-door platforms, known as stages, covered with cheap muslin screens, were replaced at a cost of millions of dollars with massive concrete structures, the walls of which were thick and solid enough to withstand artillery fire. Stars whose names had blazed from electric lights upon thousands of marquees all over the world suddenly faded into oblivion because the public was unable to reconcile queer sounding vocal renditions with beautiful profiles, voluptuous curves and manly figures. Somehow it didn't seem quite right to see upon the screen a real "he-man" with a gun in each hand galloping into the scene upon a fiery broncho and then hear him in a thin falsetto voice demand that the villain "unhand that there maiden." It was a real calamity for a producer to be faced with the realization that his glamorous star of the heretofore silent screen, when the story called for a song to her lover in the moonlight, had a vocal range of less than half an octave and most of her few tones just a little bit flat.

Nothing in the line of lighting, photography, action, or beautiful scenery could overcome those handicaps. Something had to be done and out of that something has been developed a recording and re-recording technic that, even in its present state, is truly amazing.

One of the first problems confronting producers after it was demonstrated by the first successful sound picture that sound was here to stay, was the disposal of the silent pictures already made and those in production. For the most part, pictures already completed were temporarily held up, and a print sent to a recording laboratory which up to that time had been devoted entirely to the production of phonograph records. A musical score for the entire production was composed and arranged by the laboratory staff personnel together with composers and arrangers employed by the picture producer. Recordings were made of the score and the picture released with a disk record of music accompanying each reel of picture.

Later, as recording equipment became available to the picture studios, certain sequences in pictures were made with sound; dialog and sound effects were recorded at the time the particular scenes were photographed. The remainder of the picture carried a musical score with occasional incidental sound effects, and the entire production was released upon either film or disk. Most of the early productions were made with disk records. The installation of sound reproducing equipment in the theaters was meanwhile progressing, and more and more pictures were being made complete with sound until today practically everything is released only upon film.

The fact that in early pictures only certain scenes were recorded with dialog, because other scenes had already been photographed and could be retaken only at great expense, brought into operation a system called "dubbing." The operations were essentially these: a sequence already photographed was projected upon a screen; the characters who originally appeared in that scene were assembled before the screen, and each at the proper times spoke his lines into a microphone, and the voices were recorded upon a recording machine which was electrically synchronized with the projector. The resulting sound-track was then printed with the picture and the result was a sound picture. Sometimes the audience wondered why the lip motion of the characters upon the screen seemed to be ahead of or behind the voice, but for the most part the illusion was adequate to "get by" largely because of the novelty of the entertainment.

The next step was the substitution of voices. If a character had a poor recording voice, why couldn't a good voice be used instead? It could, and was in many instances done. It was only a short time until a beautiful girl who couldn't carry a tune in a basket appeared upon the screen to be singing with all the assurance and delightfulness of a grand opera star. As many a star of the olden days was provided with a double for risky or dangerous stunts, so was an inarticulate star of the new régime provided with a vocal double whose tender tones added additional charm to the already popular screen personality. At the present time, however, little or no vocal substitution is done in pictures for the stars whose names grace the marquees.

There is, however, a very considerable amount of dubbing being done at the present time by all studios. During the filming of a scene there may be reasons why a good recording of a voice is impossible to obtain, and in such instances the scene is shot silent and the voice recorded later. The speaker watches the projected picture and speaks into a microphone, fitting his phrases to the lip motion of the character upon the screen. The sound-track is later printed with the picture.

Making musical films presents a multitude of problems, each of which requires its own solution and not any of which is present in making an ordinary talking picture in which only dialog is to be recorded. In many instances, a musical picture is more or less spectacular inasmuch as it involves magnificent, lavish sets, hundreds of persons, and a great deal of action. The principals must, of course, have their share of close-ups, and almost invariably there are scenes involving the principals and a large chorus at the same time.

To record an entire musical satisfactorily thus becomes a major problem, and requires untold ingenuity upon the part of the sound department. Take, for example, the filming of one scene of a typical musical. There is usually a prima donna, a leading man who sings, perhaps a trio or a quartette supporting the two, and a mixed chorus in the background. In order to accommodate such a large cast the set must of necessity be large. It is usually photographed with anywhere from three to six cameras, each of which uses a lens of different focal-length. Hundreds of incandescent lamps and arcs pour light into the set, and when everything else is ready, the unfortunate sound man is faced with the task of putting a microphone, or a series of microphones, in places where he can secure a good sound pick-up and, at the same time, not cast shadows upon the scene or the actors. The chances of his accomplishing this are somewhat less than zero and, consequently, he has to resort to quite different means.

On such a problem the sound man is severely handicapped. The cameraman can set his camera in any one of a dozen positions, close to or considerably removed from the object or objects to be photographed, and by choosing any of half a dozen different lenses, he can attain the desired photographic result. The sound man, on the other hand, is forced to use a metal ear in the form of a microphone, and no matter how many microphones he may use, or try to use, he is able to accomplish only the effect of dividing a single ear into that many parts. Where it is possible to photograph a close-up and a long shot with two cameras simultaneously and secure excellent results in each case, a sound man can record either close-up quality or long-shot quality. He can not have both, because he has but a single recording channel with which to work.

In order to overcome such a condition and to record successfully in spite of the very definite limitations imposed upon him due to this "distance factor," the sound engineer is compelled to resort to all sorts of manipulations. The fact that he has at his disposal a recording channel with certain predetermined electrical characteristics that remain constant does not alter or improve the situation continually confronting him in his attempt to make a single sound record match a half dozen different camera shots of a single scene.

It is comparatively easy in a broadcasting studio, where sound is of paramount importance, to secure the proper voice quality and balance, because there the microphone can be placed in an optimal position with respect to the speaker, singer, or other sources of sound. Upon a motion picture set, however, obtaining a satisfactory pick-up becomes an entirely different matter. In broadcasting, a microphone can be placed where it will do the most good, and usually that place is directly in front of the artist. In pictures such a placement is obviously impossible, and the microphone must be placed above and in front of the speaker. This immediately brings in at least two distinct complications.

The first is the matter of shadows, for no matter what else happens one can not have shadows upon either the face or the clothes of the artist, nor on the walls or furnishings of the set. In the event that the subject stands still during the take, there is ordinarily little likelihood of shadow trouble; but if the action involves movement by the artist, then the difficulty of avoiding shadows is greatly increased because most of the set lighting is from overhead.

The second problem confronting the sound man has to do with a change of voice quality as the microphone is moved with respect to the speaker. In real life we are accustomed to listen to a speaker from a position somewhat directly in front of him. In pictures we listen to him from a position above his head, since this is where the microphone is invariably placed. As long as the microphone is fairly close to the speaker it receives a large amount of direct sounds and very little of reflected or indirect sounds. As the distance between the microphone and the speaker increases, the amount of direct sound picked up decreases and the amount of indirect sound reflected by the walls and floor of the set increases. This produces a very definite quality difference which is much more noticeable with a microphone pick-up than when listening with unaided ears. In the former case the reverberation appears to be much greater and if the microphone is moved too far away from the sound source, the reflected or indirect sounds increase to such an extent as to render the recording altogether unsatisfactory.

Fortunately for the sound man, it is seldom in these days that a director will insist upon shooting a close-up camera and a long shot camera at the same time. It is usually only on large spectacular shots that more than one camera is used, and in such instances only mass sounds or crowd noises are recorded when the picture is photographed.

Assume a typical case: the proposed action, let us say, requires that the two principals be found sitting upon a bench in a garden. Romance is in the air, and under the soft moonlight the hero pours out his heart in a love song. He sings a verse and a chorus. She sings a chorus, then they sing a duet, and while they are singing a group of beautiful girls come into the picture, dance through a chorus, and the scene ends with a grand ensemble of all the voices and a full orchestra.

In general, this is how such a scene would be made. Several days before the scene is to be photographed, the orchestra and singers are assembled in the recording room where all music is recorded. Several sound-tracks are made of the vocalists accompanied by the orchestra, and if there is to be a dance chorus, there is a recording of the orchestra alone. The following day the sound-tracks are heard by those concerned and the one most suitable as to tempo, rendition, *etc.*, is selected for use.

A print of this recording is then taken to the set on the day when the picture is to be photographed, and used for playback purposes. The cast is assembled upon the set, and the record is played back to them as many times as necessary for rehearsal. When the routines are established and everything is in order, the scene is shot with cameras only while the cast go through the action to the recorded music from the reproducer, which is electrically interlocked with the cameras. When close-up shots of the principals are desired, the cameras are moved into position and the scene is repeated either wholly or in part, but each time to the same playback record.

By this means any number of camera angles can be obtained. Later any combination of these shots can be intercut, and the final assembly will match, not only as to pitch and tempo, but the action and sound will be perfectly synchronized as well, since all the picture cuts are printed with the original sound-track. Of course, it is important that during close-up shots the artist be careful to move his lips to conform to the words coming from the playback horns. In the event that either or all the principals can not sing it is easy to substitute singing voices of other artists during the original recording and the scene is shot with the screen star before the camera and the sound-track of the other voice on the playback machine. This method is usually known as "pre-scoring."

There are many other ways by which these results may be accomplished and it may be of interest to discuss some of them briefly. One way is to make a recording of an orchestra only, playing an arrangement in the form of an accompaniment for a song. At another time, perhaps weeks later, a singer goes into the recording room and makes a record of the words of the song while listening to the orchestral accompaniment in a pair of ear-phones. The two records upon separate films can then be re-recorded into a single track of voice and orchestra. The combined track may then be played back upon a set while the artist does the scene before the cameras. This picture may then be printed with the re-recorded sound-track to produce a composite film. This method has the advantage that it permits the balance between the voice and the orchestra to be altered at will during the re-recording process. For example, if an orchestra is shown in the picture and the singer moves about, perhaps to some distance from the orchestra, while the camera moves with him, the illusion is aided by dropping the orchestra level while still holding the voice at a normal level.

Another method is to record a piano track of the selection to be used in the picture and reproduce this track upon the set at a volume level just loud enough for the artist to hear while he does his routine or song before the cameras and microphone. The picture and the piano track are then taken to the re-recording department where an orchestra is assembled. The picture is shown upon a screen in the recording room where a musical director can see it, and as he sees the picture he listens to the piano track over a pair of ear-phones. The reproducing machine and the picture projector are electrically interlocked; hence the two run in synchronism.

After a few rehearsals a recording is made of the orchestra playing the necessary accompaniment while the director beats time for them to the tempo of the track he hears reproduced in the head-phones. Sometimes only the piano track is used and sometimes both the vocal track and the piano track are reproduced for the director. Of course, the microphone during this recording "hears" only the orchestra. At a later time the vocal track shot upon the set and the orchestra track are combined by re-recording and cut into the finished picture.

Another variation in recording technic may be adopted when a singer and an orchestra are available in the recording room. It is always desirable to match long-shot sound with long-shot picture and close-up sound with close-up picture; but when a pre-scoring job is done, no one knows when and where the picture will be cut to these shots because no picture has yet been made. If now recordings are made of the singer and orchestra with close-up quality throughout, this sound will not match a long-shot picture when they shoot it, and the audiences will experience a feeling of dissatisfaction and will sense the unreality of the illusion, probably without knowing why. On the other hand, if the recording is made with long-shot quality, it will be equally bad when played with a close-up picture. To overcome this trouble and to provide for any amount of cutting later, any combination of three different methods may be used to record the original sound:

(*a*) The sounds may be picked up by a microphone or microphones placed near the singer and orchestra, and called "close-up" quality. At the same time another microphone placed some distance away from the source of sound feeds "long-shot" quality sound to a second recording channel and a second recorder which is electrically interlocked with the one on the first channel. Either track may be used later upon the set as a playback while the picture is being photographed, and this reproduced sound recorded upon the set at the same time, but for cueing purposes only when the picture reaches the cutting room.

The picture may then be cut in any desirable way, and when a long-shot scene is used, the corresponding portion of the original long-shot sound-track may be cut in. When a close-up picture is used, original close-up sound-track is used, and the finished picture

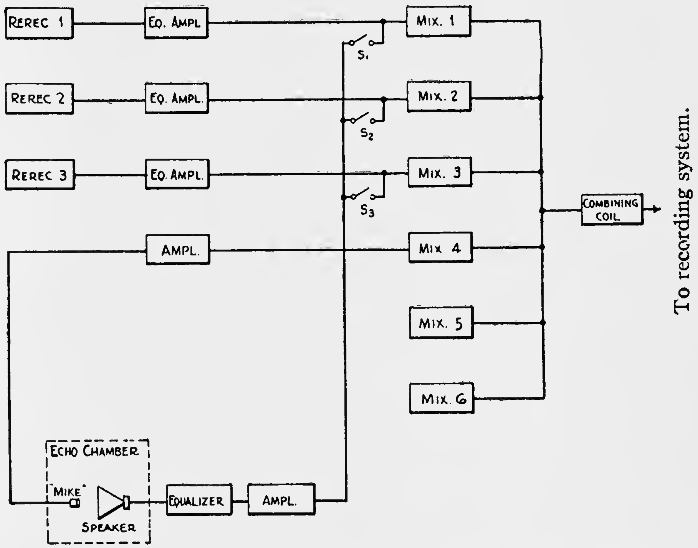

FIG. 1. Schematic diagram of a circuit for producing artificial reverberation.

will then preserve and present to the audience at least a semblance of reality.

(*b*) A modification of this procedure may be made use of as follows: Recordings are made simultaneously with long-shot and close-up microphones, and either track used for playback purposes while the picture is being photographed. However, instead of cutting in long-shot or close-up track into the finished picture, another procedure may be followed. The two tracks are reproduced simultaneously by two high-quality reproducers and re-recorded into a single track. By watching the picture and by means of cue marks, the re-recording engineer can fade in or out either track at will, thus accomplishing electrically what was, in the case of (*a*), done with a pair of shears, and often do a better and smoother job.

(*c*) A third method of creating the desired illusion is to record a single track of the singer and orchestra with microphones so placed as to attain a satisfactory over-all balance with respect to each, and without regard for either close-up or long-shot quality. A print of the track thus made is then used for playback purposes, as in the two preceding illustrations. Whether this reproduced sound is or is not recorded upon the set during the filming is unimportant except for checking synchronization when the "rushes" are screened the following day. A print of the original track is then taken to the re-recording department, reproduced on a high-quality "dummy" and re-recorded. During this re-recording process, however, a little "doctoring" is done. Reference to Fig. 1 will serve to make clear what happens.

The sound-track is reproduced from any one of several "dummies," fed into a preliminary equalizing amplifier and thence to a mixer or control panel in the usual way. By means of a simple switching arrangement this signal is divided just ahead of a mixer position (*1*), part of it going into the mixer pot and part of it being fed through an amplifying system and into a speaker unit.

The speaker unit is located at one end of a highly reverberant room, or echo chamber—one having hard plaster walls and ceiling and a wooden or concrete floor. The room need not be very large, the shape being more important than the actual cubical content. At some other point in the room is located a microphone which picks up the signal from the speaker. This signal is increased through a regular microphone amplifier and fed back through a trunk-line into another position (*4*) on the mixer panel.

It is now possible to combine electrically a portion of the original signal from the dummy and another portion of the same signal after it has passed through a time-delay circuit. The time delay is controlled by the distance between the microphone and the speaker in the echo chamber. In addition to the time delay, this chamber, being highly reverberant, imparts a distinct quality change to the original signal. The engineer, by varying the relative amounts of each of these two signals coming into his mixer panel, is able to change the character of the resulting signal from the original quality with little or no reverberation to the other extreme where it may sound as though the original recording were made in the Grand Central Terminal.

REPORT OF THE PROJECTION SCREEN BRIGHTNESS COMMITTEE*

The standards of the Society contain, at present, a list of nine items under the heading "Recommended Practice." These items, while not so fundamentally important as the dimensional standards, are valuable as suggestions for the guidance of the industry. A recommendation of screen brightness should logically be included in this section.

The newly organized Projection Screen Brightness Committee has been given the task of preparing a report upon the basis of which the Society can make such a recommendation. The job is not a new one in the history of motion pictures. It is, indeed, somewhat discouraging to discover that, in the past twenty years, no less than five previous committees of our own and other societies have worked upon this specific problem. Most of these committees have attacked the problem by attempting to work as groups to gather data on existing conditions in the theater.

The present Committee feels that it can best serve the Society, not by turning itself into a research body to obtain additional data on theater screen brightness, but rather by stimulating individual authors to prepare reports dealing with the most important phases of the subject. What the Committee proposes is that a symposium of papers shall be presented at a forthcoming meeting of the Society, and that these papers shall be followed by a final report of the Committee which will summarize the whole situation and will make definite recommendations.

SCREEN BRIGHTNESS SYMPOSIUM

The following proposed program of the screen brightness symposium is, of course, only tentative. Additions and changes will, no doubt, seem necessary as the work progresses. It is the hope of the Committee that our selected authors will be able to gather up the loose ends of the existing data and fill in the missing items to such an extent that definite recommendations can be made.

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

(*1*) A study of the literature bearing upon the question of screen brightness (covering all known relevant data of physiological optics and suggesting subjects for research necessary for a complete understanding of the problem. This paper should consider the work of Helmholtz, König, Trolland, Nutting, Reeves, Feree and Rand, Luckiesh and Moss).

(*2*) An analysis of the published results of theater and screen illumination measurements (covering the various papers on the subject as, for instance, those of Dennington, Burrows, and the various Committee reports).

(*3*) An analysis of release print characteristics (a statistical study of the highlight, shadow, and average transmission of scenes of release print quality).

(*4*) An experiment to determine the screen brightness requirements of the public (a statistical study of the desires of a typical audience—the matter of individual taste, the influence of subtended visual angle, the influence of auditorium illumination).

(*5*) A note on laboratory screening room measurements (an account of the data obtained in release-print laboratories, with a discussion of the relation between theater and laboratory screen brightness).

(*6*) Methods of measuring screen brightness (a paper to guide the Committee in its forthcoming recommendation of standard practice in measurement).

(7) Projector characteristics, screen characteristics, and obtainable brightness (an attempt to combine the existing data on screen reflection and source output in the form of tables and curves usable by the theater manager).

(*8*) A report by the Committee (final recommendations of (*a*) screen brightness limits, (*b*) method and instruments of measurement, (*c*) best brightness as a function of screen size (visual angle) and auditorium illumination).

PROJECTION SCREEN BRIGHTNESS COMMITTEE

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SYMPOSIUM ON NEW MOTION PICTURE APPARATUS*

During the Spring Convention at Hollywood, Calif., May 20–24, 1935, a symposium on new motion picture apparatus was held, in which various manufacturers of equipment described and demonstrated 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.

THREE NEW KODASCOPES

N. B. GREEN**

Model L 16-Mm. Kodascope.—A successful 16-mm. projector must be attractive in appearance, easy to operate, simple to adjust, quiet and steady in projection, efficient in its optical system, cool to the touch, centrally controlled, mechanically satisfactory over long periods of time, and easily adaptable to all projection conditions or limitations. The design of the Model *L* Kodascope (Fig. 1) was studied mechanically, optically, and electrically, and then a casing designed to bring the whole into a unity without unpleasant projections, awkward corners, or conflicting angles.

The controls for forward, reverse, and still-picture projection are all governed by one lever, which is mounted upon a single plate with the switches controlling the starting and stopping and turning the lamp on and off. In replacing a lamp the new lamp is properly positioned by turning a coin-slotted screw either in or out. Lenses, gates, condensers, and lamps are all easily removed for cleaning and as easily replaced. No tools are necessary.

Four lenses and three lamps can be used on this projector, thus making possible a lens-lamp combination to suit a great variety of requirements. The lenses are: 1-inch, *f*/2, for use in close quarters; 2-inch, *f*/1.6, for average showings; 3-inch, *f*/2, and 4-inch, *f*/2.5 for longer throws. Available lamps are: 400-watt, 115-volt *T-10;* 500-watt, 115-volt *T-10;* 750-watt, 115-volt *T-12.* All are of the biplane filament type, prefocus base.

Every part of the frame and casing is of cast aluminum. Every shaft has double bearings, properly aligned and fitted. All shafts are ground within a tolerance of 0.0003 inch. All metal gears mesh with phenolic resin gears, which latter are mounted in metal hubs to guarantee against misalignment from warping. The cams governing the intermittent are ground within a tolerance of 0.0003 inch, and each intermittent is individually fitted. The result is a mechanism that will run, and has run, hundreds and thousands of hours without undue wear.

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.
** Eastman Kodak Co., Rochester, N. Y.

The cooling system is of great importance with the new high-wattage lamps. A centrifugal type of fan, driven by the projector motor, is mounted beneath the lamp, and delivers air to a housing (Fig. 2) around the lamp, designed to eliminate eddy currents and dead spots and flared above the lamp filament to allow for expansion of the heated air. The cooling is so efficient that the lamp life in the Model *L* surpasses the rated life given by the manufacturers.

The Optical System.—Maximum screen illumination from the light-source has been obtained with this projector. The standard *f*/1.6 lens was designed especially to provide flatness of field and maximum light transmission. With the single-blade shutter and this optical system, it has been possible to set a standard of 210 screen lumens for the 750-watt lamp.

Kodascope Eight, Model 80.—With the omission of the reverse, the mechanism of the Kodascope Eight, Model *80* (Fig. 3), is simplified. As in the Model *L*, great care is taken in parts and assembly to the minutest detail; and the intermittent is blanked and formed to its final shape, and then copper-plated and shaved on its wearing surfaces only. It is then pack-hardened, and the copper plate is removed. This leaves all wearing surfaces hard, so as to withstand long service, but the body of the intermittent is soft and easily adjusted and fitted.

The operation of the Kodascope Eight, Model *80*, is very simple. The switch in the cord controls both lamp and motor, and has a receptacle for a table or floor-lamp. One lever controls still projection and rewinding. "Still" projection is accomplished by merely shifting the drive belt to an idler pulley. Rewinding is accomplished by merely threading the film back upon the empty reel and throwing the rewind lever. This is made possible by the use of smaller and lighter reels which carry a maximum of 200 feet of film. The belt tension is therefore light, and no undue strain is put upon the film during the showing of stills. The patented elevating feature has a spring that compensates for the weight of the projector and makes it easily operable either in raising or lowering. The same principles of cooling the lamp are used as in the Model *L*. Another patented feature is the arrangement made for adapting different lamps. Although the standard lamp is the 300-watt, coiled-coil lamp, the 300-watt, biplane filament can be installed by loosening the socket clamp and resetting the socket.

The optical system, designed for 8-mm film, compares favorably in efficiency with the best of 16-mm. projectors. The *f*/1.6 lens can be purchased as an accessory.

Kodascope Eight, Model 40.—The optical system of the Model *40* (Fig. 4) is remarkably efficient. The specially designed objective lens with the polished condenser and silvered glass reflector, together with the 200-watt lamp, give a screen illumination equal to that of the original Model *60*.

The mechanism is simple but rugged. The sprocket shafts and the intermittent shafts are hardened. The slower running shafts run in bearings drawn from the mechanism frame, but the faster running intermittent and shutter shafts run in bronze bearings. Oil reservoirs supply lubricant to the intermittent shuttle. The shutter has three blades of equal width. Fixed sprocket guides and strippers and an easy threading gate make loading extremely simple. Focusing is accomplished by turning the lens in or out. The cooling fan is mounted directly upon the motor shaft, and its housing is directly beneath the lamp housing. A simple baffle directs a blast of air toward the lamp but also allows a portion of the air to cool the lamp circuit resistor.

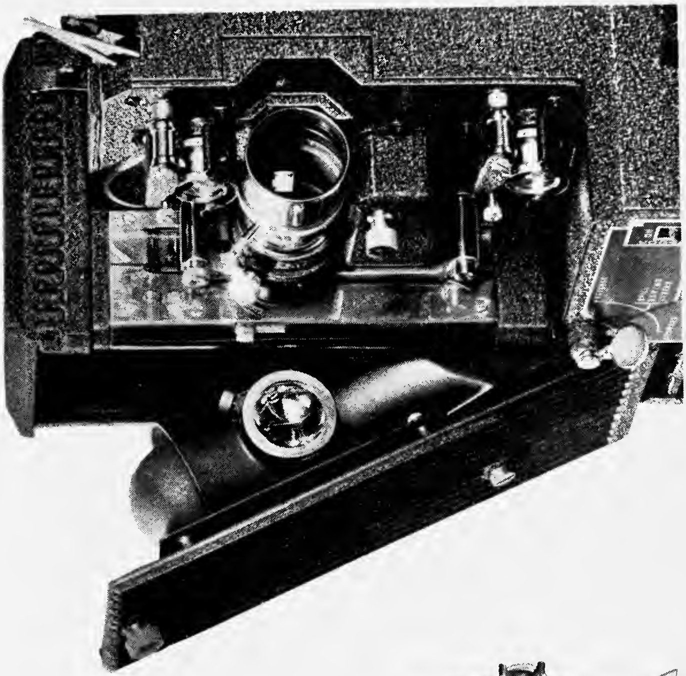

FIG. 2. Close-up of lamp housing, gate, and lens assembly; Model *L* Kodascope.

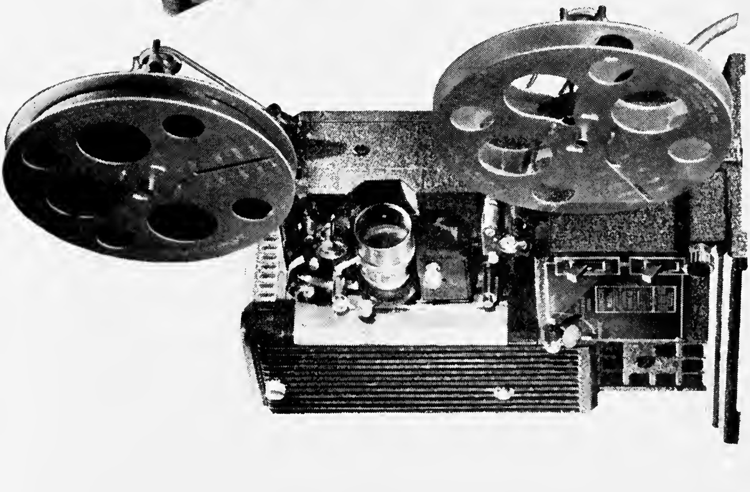

FIG. 1. Model *L* Kodascope.

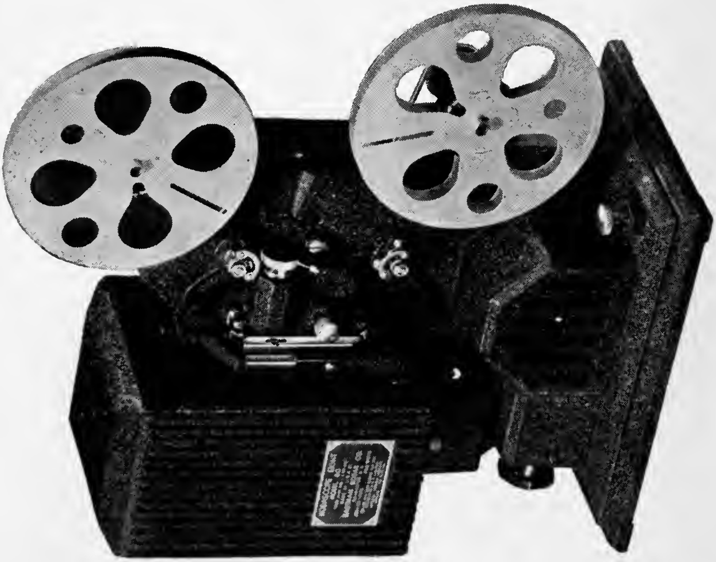

FIG. 3. Kodascope Eight, Model *80*.

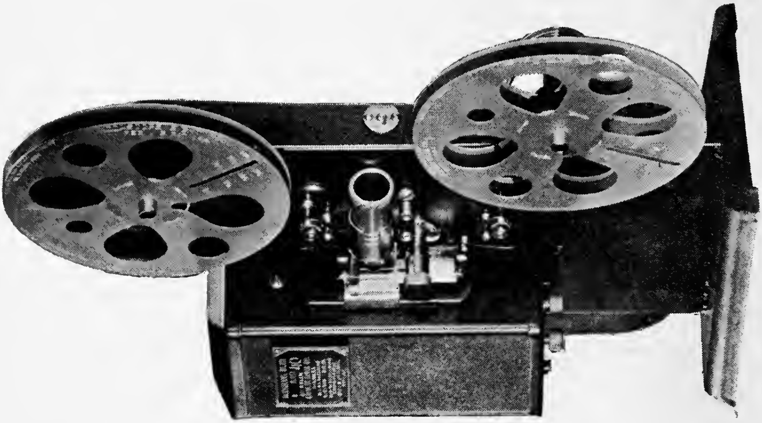

FIG. 4. Kodascope Eight, Model *40*.

A NEW SOUND READER AND FRAME VIEWER

I. SERRURIER*

A new machine added to the line of film editing equipment manufactured by this company consists of two parts, the machine head, Model *SRV*, and the combined amplifier and speaker, Model *UR*. The machine head (Fig. 5) consists of two curved film slides with a guide roller at each end of each slide. The film slide for the sound-film is equipped with an adjustable rail and adjustable guide rollers so that either standard 35-mm. film or split film may be used. An exciter lamp unit, the same as used on all Moviola sound reproducing equipment, is supported above the small opening in the slide under the sound-track, and a caesium type of photoelectric cell is located in the compartment provided for it beneath this slide. The slide for the picture film has a frame-size aperture illuminated through an opal glass pane by a small electric lamp. A set of viewing lenses, the same as those used in all Moviola film viewing machines, is arranged over this illuminated aperture and can be hinged out of the way when threading the film over the slide and under the guide rollers.

In Fig. 6 the machine head is shown with the viewing lenses swung away for threading. Two small switches are provided in front of the machine head, one for the exciter lamp and one for the viewing lamp. The machine head is connected to the amplifier and speaker cabinet by means of two shielded cables which may be readily detached, one for the 6-volt current supply to the exciter lamp and one for the photoelectric cell connection.

The amplifier and speaker cabinet (Fig. 7) contain a 5-tube amplifier, a dynamic speaker, and a transformer to supply the current for the exciter and viewing lamps. These are the same as used in connection with all Moviola film editing equipment. A knob for operating the volume control and a combined switch and red pilot light for the power supply to the amplifier are located on the front of the amplifier cabinet.

To operate the sound reader it should be placed between two rewinders, preferably double rewinders, and the film or films should be drawn through it by means of the rewinders. It may be used to advantage in connection with a two-sprocket synchronizing machine, such as shown in Fig. 7, and should be useful in the cutting room for quickly locating words or sound effects to be added or eliminated.

A JERK-ABSORBING DEVICE FOR FILM VIEWING AND SOUND REPRODUCING MACHINES WITH FILM ON REELS

Moviola film editing machines are started, stopped, and reversed quite frequently, and the adjustment of the friction devices upon the take-up spindles is often neglected, with the result that some film may become unwound from a reel. When the machine is started and the slack is taken up the film must suddenly start the reel in motion, and a jerk results. To eliminate damaging the film from this cause, rollers have been added upon hinged and spring-held arms in such

*Moviola Co., Hollywood, Calif.

FIG. 6. Same as Fig. 5, with viewing lenses swung away for threading.

FIG. 5. Sound reader and frame viewer; Model *SRV*: machine head.

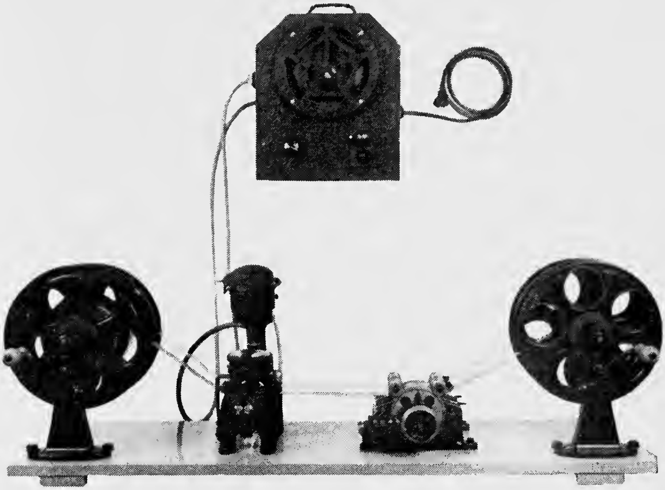

FIG. 7. Complete set-up, with sound reader placed between two rewinders, showing amplifier and loud speaker cabinet.

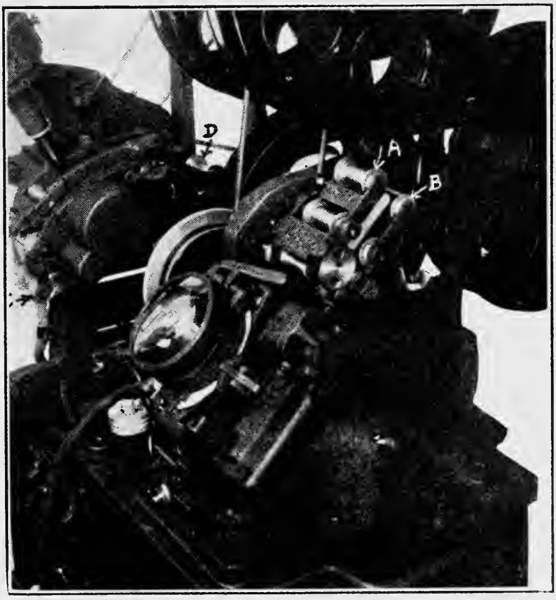

FIG. 8. Moviola Model *UDS*, equipped with jerk-absorbing device.

manner that the roller gives when the film becomes taut, and the jerk on the film is thus eliminated. Fig. 8 shows a Moviola Model *UDS* equipped with these jerk-absorbing devices for forward and backward take-up devices of the picture head as well as of the sound-head.

ARC SUPPLY GENERATOR FOR USE WITH SUPREX CARBONS

W. K. HARTMAN*

For a long time a demand has existed among the smaller theaters for a source of white light similar to that obtained from the d-c., high-intensity arcs and at a price that the average theater owner could pay. This demand seems to have been met by the new d-c., high-intensity arcs with non-rotating positive carbons.

These carbons, commonly referred to as Suprex carbons, have unusual characteristics and are unlike any carbons previously used on d-c. arcs. It was immediately apparent that the existing conversion equipment to transform alternating to direct current was entirely unsuited to the new carbons. The 75-volt, multiple-arc set with an external ballast resistor in series with each arc, even with a changed ballast, resulted in a highly inefficient installation and unsatisfactory characteristics.

The new carbons have a voltage drop of about 35 volts across the arc, as compared with 50 to 55 volts for the older low-intensity reflector type of arc. Furthermore, because of the snow-white light obtained, it is extremely important that a non-fluctuating, non-pulsating source of direct current be available. With normal current, the supply voltage should have a slightly drooping characteristic, and it is important that the striking current be kept down to avoid destruction of the crater and resultant poor light while the crater is being reformed. To fulfill the exacting demands of the new carbons, this company has developed a new type of motor-generator set radically different from the older and more conventional type of multiple-arc or series arc sets that have been used for many years.

The motor-generator set is built as two units, direct connected by a flexible coupling and mounted upon a rigid structural steel bed-plate.

The motor is of the conventional design but the generator really consists of two independent generators in the same housing. These two generators are entirely independent electrically, and furnish direct current to two Suprex carbon arcs, each generator having in its own circuit a rheostat for independently adjusting its output and a voltmeter so connected that the voltage in either circuit may be read at will.

In designing this machine, account has been taken of the mechanical requirements of quietness of operation, rigidity, and accessibility. Mechanical quietness is obtained by careful dynamic balance of the armature, by use of a coupling without pins, requiring no lubrication, and with no parts to work loose and cause noise. The rotating element floats freely in sleeve bearings with end-play in either direction, and prevents any noise due to end-thrust. The four-bearing construction admits of ready accessibility and compactness.

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* Century Electric Co., Los Angeles, Calif.

In the electrical design of the machine precautions are also taken for quiet operation, because in the smaller and moderate-size theaters, the motor-generator set is frequently mounted adjacent to the projection room and any considerable noise would be objectionable. Magnetic noise is minimized by specially proportioning the windings of the motor and the generator with skewed armature slots and with specially shaped pole-tips.

By virtue of the fact that there is an independent generator winding for each arc, it was possible so to proportion the windings that the voltage characteristics particularly suit the Suprex carbon; with relatively flat, slightly drooping characteristics in the normal operating range, and with a low striking-current to avoid the explosive effect at the crater, which would occur with higher amperage. Each generator operates independently of the other, and consequently is not affected by the load on the other (excepting minute voltage changes occasioned by changes in speed due to the load), so the change-over from one arc to two arcs is made without any disturbance in either electrical circuit.

The motor is designed so that there are no excessive speed changes during the short-time peak load at change-over. The set has a speed of 1770 rpm. with one arc burning, and approximately 1745 rpm. with two arcs burning, operating on a 60-cycle polyphase circuit.

This design permits the elimination of all external resistances; and by avoiding resistor losses the efficiency is kept rather high, being approximately 61 per cent with one arc burning at 50 amperes or 71 per cent with two arcs burning at 100 amperes. The efficiency is somewhat lower with one arc in use because of the field losses occuring in the generator end that is not in use but is generating a voltage.

This unusual motor generator set, which is sold under the trade name *Actodector*, has been developed after extensive field and laboratory tests and was placed on the market early in 1935, since which time many installations have been made in all parts of the United States.

A PROFESSIONAL 16-MM. PROJECTOR WITH INTERMITTENT SPROCKET

H. A. DEVRY*

When the use of 16-mm. equipment began to be extended to sales and advertising activities of large firms for small group showings, and the possibility of the use of 16-mm. equipment in small-town theaters became apparent, we surveyed the field and decided to make an equipment particularly adapted, if possible, to more or less continuous service, and in this connection decided upon the use of an intermittent sprocket instead of the customary claw movement, in order to increase the life of the film and make its use most profitable.

The 16-mm. equipment is now going through the same refinements and improvements through which the 35-mm. projector went. All early motion picture machines before a standard 35-mm. film was evolved, and before the existence of

* H. A. Devry, Inc., Chicago, Ill.

the Society of Motion Picture Engineers, were of the claw type and, consequently, for exhibition purposes short-lived. The last of the claw type 35-mm. machines made and sold in this country for theatrical use was the Selig *Polyscope*, which engaged four perforations of the film at a time. This model was discontinued about 1910, and was replaced in the theaters by intermittent sprocket projectors, which rapidly found great favor among the exhibitors because of the longer life of the film made possible by using the sprocket instead of the claw movement. At that time rental films were scarce; most exhibitors bought their films outright, and traded or sold them after they had served their purpose.

The regular Geneva movement, of course, is too slow and unsuitable for 16-mm. projectors, so we decided upon a modification of this, with an 8-point star- or pin-wheel and a larger and heavier cam.

Special machinery had to be developed to cut a cam with a movement of about six to one or better, so that it would be practically noiseless. The star-wheel is revolved one-eighth of a revolution for each revolution of the cam, and is generated to mesh into the cam in the same manner as a silent chain meshes into a sprocket, or as one gear meshes into another, so as to keep constant contact, as in the Geneva movement, and eliminate as nearly as possible all noise and wear.

Casual tests indicate that the life of the film operating upon an intermittent sprocket driven by such a star and cam movement will be many times that of a film operated by a claw movement, to say nothing of the annoyance, inconvenience, and interruptions in showing film not in perfect condition when operated with the usual claw movement.

EUGENE AUGUSTIN LAUSTE*

In any future anthology of the inventors and inventions that have combined to make possible the modern sound picture, the work of Eugene Augustin Lauste, who died in Montclair, N. J., on June 26th, will inevitably receive important consideration. In terms of time, his experiments may be said to date before what have been described as the "dawn days" of the motion picture and to extend down to the present time.

A slight, shy Frenchman, Mr. Lauste lived at 12 Howard Street, Bloomfield, until his last illness. He was born in the Montmartre district of Paris on January 17, 1857. Surviving him are his wife, Mrs. Melaine Lauste, a son, Emile Lauste of London, and two stepsons, Clement LeRoy and Harry E. LeRoy, both of Bloomfield.

The work of Mr. Lauste, starting in the eighties, represents a link between the group that later conducted epochal experiments in sound transmission and reproduction and the group that laid the groundwork for the future cinema by their experiments in step photography based upon the optical phenomenon of "persistence of vision." His inventions had to do with the fundamentals of both the silent and the sound motion picture. In 1889, while he was with Thomas A. Edison at Orange, N. J., he shared with W. K. L. Dickson in many of the experiments relative to the development of the kinetoscope and the kinetograph. In 1894, he became associated with Major Woodville Latham, and while in his employ he designed and constructed one of the earliest film projectors and cameras, the Eidoloscope. He was first to record sound and scene simultaneously upon the same film. His patent application filed in Great Britain on August 11, 1906, discloses most of the processes fundamental to the modern sound picture, except amplification. From 1906 to 1910 he devoted his efforts to attaining adequate results in sound recording and reproduction. Then one day in London, after he had recorded upon film a brief passage from a French gramaphone record by means of his first mechanism of the string galvanometer type, and was dubious of success, his amaze-

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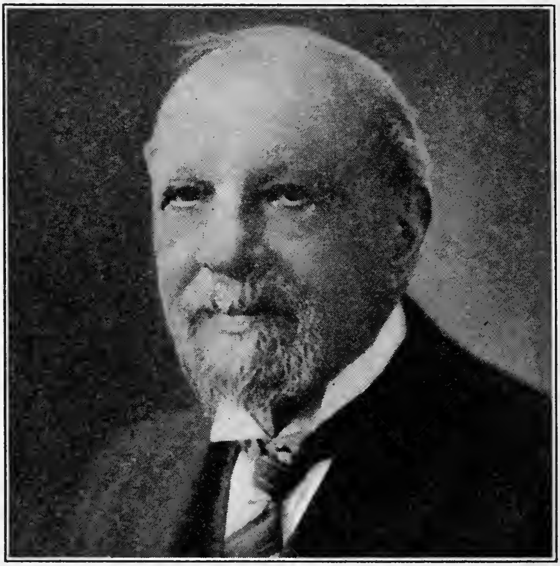
* For a detailed description of some of Mr. Lauste's work, see *J. Soc. Mot. Pict Eng.* **XVII** (Oct., 1931), No. 4, p. 632.

ment and delight knew no bounds when he heard in his ear-phones very distinctly the words "J'entends très bien maint...." From this point on his progress was rapid. He devised several types of recording apparatus using one and two non-magnetic wires in a magnetic field, several of which are still in existence and illustrate his ingenuity as well as his fine mechanical ability.

All present methods, however, of recording and reproducing sound for talking motion pictures rely for their practicability upon the vacuum-tube amplifier. Without amplification by that device,



Eugene Augustin Lauste.

the feeble current from the microphone would be unable to produce in the recording devices effects of sufficient magnitude. Without amplification the reproduced current could not operate high-power loud speakers. Given the possibility of distortionless magnification of a sound-bearing current, and also the general advanced state of the communication arts to which the vacuum-tube itself has been no mean contributor, and there became possible some of the things for which Lauste struggled prematurely.

He came to America for a short visit in 1911 with the idea of interesting capital. While in this country he photographed a short-length picture, recording sound and scene upon the same film. This has been described as the first sound picture to be taken in the United States. He was attempting to devise an amplifier for his sound-films when lack of capital and the outbreak of the World War halted his experiments. He was still seeking financial aid in America when there came the sudden flood of sound-film patents.

As for Lauste, himself, but for one happening, it might have been necessary to write finish to his career in the tragic fashion that has marked the conclusion of the histories of so many inventors, great and small. Seeking out the genesis of sound pictures in a painstaking effort to assemble an authoritative and historic record of the development of the new art, Bell Telephone Laboratories was impressed by the evidence of Lauste's pioneer work in this line. He was sought out in 1929 and retained as a member of its technical staff. He was assigned two tasks: one to assemble such of his own apparatus as could be located, and by replacements to reconstruct the entire system that he had built in the early 1900's; and the other to assist the patent department by his knowledge of the prior art. His contributions to the development of sound pictures may have failed to bring him the wealth for which he hoped or the success that is measured by money, but at least they sufficed to bring him a measure of the recognition, comfort, and security during his last years, that has more often than not been denied inventors whose success depended upon progress in allied fields.

The Smithsonian Institution has accepted the gift of Lauste's historic apparatus. Accompanying this exhibit is a very complete record of photographs and manuscripts covering its authenticity and indicating which parts are restorations along the lines of the original design.

Eugene A. Lauste was elected an Honorary Member of the Society of Motion Picture Engineers in October 4, 1931. He received his scroll in person while attending the banquet for the pioneers of the industry held at Swampscott, Mass., on October 7, 1931.

FALL, 1935, CONVENTION

WASHINGTON, D. C.
WARDMAN PARK HOTEL
OCTOBER 21–24, INCLUSIVE

Headquarters

The headquarters of the Convention will be the Wardman Park Hotel, where excellent accommodations and Convention facilities are assured. Registration will begin at 9 A.M., Monday, October 21st. A special suite will be provided for the ladies. Rates for S. M. P. E. delegates, European plan, will be as follows:

One person, room and bath	$3.00
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	5.00
Rates for connecting parlors	5.00

A modern fire-proof garage is located on the Hotel property, and a special 75 cents per day rate has been arranged for.

Technical Sessions

An attractive program of technical papers and presentations is being arranged by the Papers Committee. Sessions will be held in the *Little Theater* of the Hotel, off the west lobby, as follows: Monday to Thursday mornings, inclusive; and Monday, Tuesday, and Thursday afternoons.

Film Programs

Exhibitions of newly released motion picture features and short subjects will be held in the *Little Theater* on Monday and Tuesday evenings. Passes to various motion picture theaters in Washington will be available to the members registering for the duration of the convention.

Apparatus Exhibit

An exhibit of newly developed motion picture apparatus will be held in the east lobby of the Hotel, to which all manufacturers of equipment are invited to contribute. The apparatus to be exhibited must either be new or contain new features of interest from a technical point of view. Information concerning the exhibit and reservations for space should be made in writing to the Chairman of the Exhibits Committee, Mr. O. F. Neu, addressed to the General Office of the Society at the Hotel Pennsylvania, New York, N. Y. No charge will be made for space.

Informal Get-Together Luncheon

The usual luncheon will be held at noon on October 21st in the *Continental Room* of the Hotel. An address of welcome will be delivered by the Honorable Sol Bloom, member of Congress from New York. Other speakers will be announced later.

Semi-Annual Banquet

The semi-annual banquet of the Society will be held in the *Continental Room* of the Hotel on Wednesday October 23rd at 7:30 P.M. Addresses will be delivered by eminent members of the industry followed by dancing and entertainment. The presentation of the scroll of honorary membership to Thomas Armat, of Washington, D. C., awarded last May at Hollywood, will be made, and, in addition, the recipients of the Journal Award and the Progress Medal of the Society will be announced and the presentations made.

Points of Interest

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

Recreation

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

PROGRAM

Monday, Oct. 21st

9:30 A.M.	Registration
10:00 A.M.	Society business
	Technical papers program
12:30 P.M.	Informal get-together luncheon
2:00 P.M.	Technical papers program
8:00 P.M.	Exhibition of newly released motion pictures

Tuesday, Oct. 22nd

10:00 A.M.	Technical papers program
2:00 P.M.	Technical papers program
8:00 P.M.	Exhibition of newly released motion pictures

Wednesday, Oct. 23rd

10:00 A.M.	Technical papers program
12:30 P.M.	Free afternoon, for recreation or special trips and visits
7:30 P.M.	Semi-annual banquet

Thursday, Oct. 24th

10:00 A.M.	Technical papers program
2:00 P.M.	Technical papers program
6:00 P.M.	Adjournment of the Convention

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXV **October, 1935** **Number 4**

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JOURNAL
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MOTION PICTURE ENGINEERS

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THE TECHNICAL ASPECTS OF THE HIGH-FIDELITY REPRODUCER*

E. D. COOK**

Summary.—*One of the essential requirements of a high-fidelity talking motion picture performance is a satisfactory reproducer. The most important limitation to such reproduction at this time, and one that is seriously handicapping those who desire to provide better recordings, is the general lack of sufficiently constant film speed in reproduction. This prevents full use of the advances made in recording machines and technic. In certain kinds of subject material, the performance is ruined for a critical audience by this limitation.*

For various reasons, little has been published on this problem. This paper describes the technical details of the Photophone high-fidelity reproducer. Measurements of its mechanical constants, together with an elementary analysis of the underlying theory of operation are given.

From the layman's point of view, the talking motion picture has been regarded as a remarkable achievement. However, the engineer has realized that it was a combination of well-known ideas and that the real achievement lay in its improvement. It has always lacked realism. The range of frequency actually covered was quite restricted, wave-shape distortions were prevalent, the volume range available was relatively small, and what was probably worse was the lack of sufficiently constant motion in both recording and reproduction.

During the early development, it was difficult to estimate how much of the latter defect was separately chargeable against the individual processes, but very soon better recorders were made available and laboratory reproducers were built upon similar principles. It was then quite simple to demonstrate that even the best commercial reproducers left much to be desired in this respect, if realism were sought. The limitation, imposed upon reproducers in common use by the lack of sufficient constancy of film speed, has been overcome in a large measure by the high-fidelity sound attachment shown in Fig. 1.

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

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

In producing a device designed to make possible a higher standard of theater performance, there have been other problems such as those due to optical deficiencies, noises due to mechanical vibration, uneven and limited response of loud speakers, and in some cases even the amplifiers were not above reproach. Many seemingly trivial details related to the major problems had to be considered. That this was the case may be shown by a few examples. If the frequency range is to be widened materially in reproduction, the

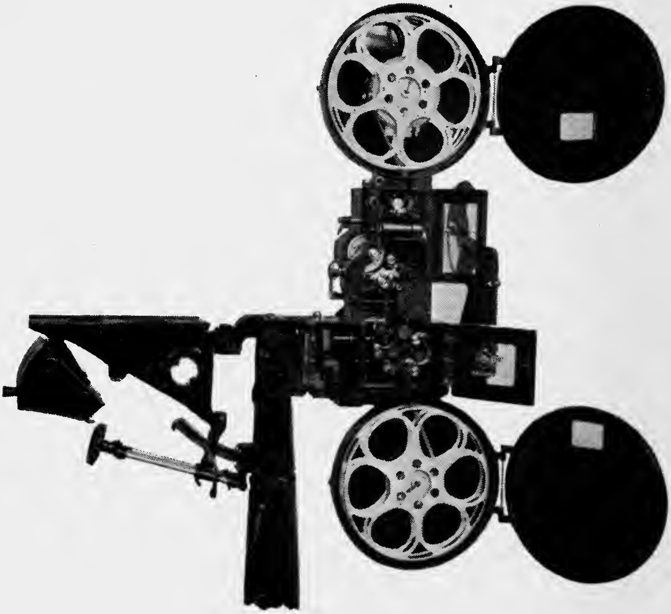

FIG. 1. The high-fidelity sound attachment (*PS-24*).

general problem of ground-noise becomes more serious. The contributory factors have to be examined and more complete solutions provided than have been the case in the past. It might seem to be desirable to decrease the width of the reproducer aperture in order to decrease the high-frequency losses, yet this may not be continued to such an extent that the signal-to-ground noise ratio is likewise decreased to any considerable degree unless a more-than-offsetting gain in this ratio may be achieved in some other way, for example, upon the film itself, and it is evident that a definite limit exists in any such direction of attack upon the problem.

Another detail is to be found in the photoelectric cell, its output coupling device, and associated amplifier. It is desirable that the amplifier be located remote from the projector, and in order to do this, a photoelectric cell coupling transformer and a relatively low impedance coupling line have been employed on Photophone equipment. With the extended frequency range, it was considered necessary to provide greater shielding against any inductive disturbances that might affect this circuit. In the attachment shown, the main metal casting has been used to assist in the shielding, and the photoelectric cell is located directly behind the drum so that the leads to the photoelectric cell transformer are not only quite well protected from outside disturbances but very short. This choice of location for the photoelectric cell has made threading a simple matter.

Another problem is found in compensating the commercial reproducing amplifier. This can not be treated in the same manner as laboratory or demonstration equipment where the entire process of recording and reproduction is under more complete control. The products of various producers require varying amounts of correction for flat response at the higher frequencies.

These questions, and many others, are vital in developing high-quality reproducing equipment. A discussion of them might provide the subject matter for an interesting paper, but since many of them are well known and some are adequately treated elsewhere, it was felt more appropriate at this time to consider the means employed in the *PS-24* sound attachment to eliminate the specific and, in general, more serious problem of film speed variation. Although this always has been a major problem, for various reasons it has never been adequately treated in the literature. Only the phases of particular interest will be treated in this discussion.

In general, reproducers of the drum type encounter more difficulties in regard to low-frequency speed variations, whereas those of the gate type are adversely affected more by the higher-frequency variations such as those due to sprocket holes, *etc.* This is not intended to mean that both types of disturbances are not found in machines of either type, for such a statement would not be correct. However, it is true that the more constant one desires to make the film speed, the more he is forced to use the drum design. In the reproducer to be described, high-frequency speed variations, such as those due to sprocket hole disturbances, are automatically reduced far below the requirements. This is a necessary consequence of the design of the mechanism, as will be evident from the theoretical analysis to be given later. Since variations of film speed can be impulsive as well as periodic, it is important to consider the design from the general standpoint.

In order to judge any design from its filtering characteristics, it is essential to have some knowledge of the permissible velocity variation and how this is affected by various conditions. Some general knowledge is available from listening tests, using records of different frequencies. It is known that if reflections are permitted from the walls of the room, the effect of speed irregularities is much more noticeable. Furthermore, the main reproduction frequency, as well as the frequency of variation and the general sound level, influence the permissible speed variation, and the results obtained from abrupt speed changes differ from those obtained from gradual ones, even though the total change is finally the same. The problem is further complicated by the varying kinds and the complex character of the sounds that must be treated. If the somewhat contradictory evidence given by any two observers is to be trusted, the sensitivity to speed variation depends, to some extent at least, upon the individual and, no doubt, his reactions are influenced by his varying physical condition. Experience has shown that there are persons who are almost totally insensitive to the deficiencies of a device that would turn a grand piano into a Hawaiian guitar. Yet it is possible to assume some sort of a normal observer and average listening conditions, regardless of how mythical these may seem to be.

No doubt considerable work has been done on this problem, but, so far at least, the published reports are few. Furthermore, it appears that more comprehensive work has been done upon the differential pitch sensitivity of the ear alone than upon the more general problem that exists when the reverberant effects of the room are included.

The problem discussed by Shower and Biddulph[1] was the differential pitch sensitivity of the ear alone (without room effects). For this reason, they employed telephone receivers and concerned themselves primarily with single-frequency sounds. As should be expected, their results for maximum permissible percentage frequency variation were higher than are permissible under the conditions of normal listening. Some of the general conclusions to be drawn from their results may be stated since they appear to be equally true when the reverberant conditions of the room are included. It was found that the rate of variation of frequency for which the ear is most sensitive is relatively low, corresponding to only several cycles per second. Furthermore, it appears that at moderately higher sound levels, the percentage of permissible frequency variation is lower than at the very low levels, while the higher "carrier" or main frequencies must be freer from variation than the lower ones. The manner in which the frequency variation takes place is likewise important, because, as might be expected, the ear is more sensitive to abrupt changes than to the smoother changes even though the periodicity of a cyclic change is made the same in both cases. However, the ratio of the sensitivity for abrupt changes to that for gradual changes of frequency decreases as the carrier frequency is raised above a few hundred cycles.

It is possible to discuss this problem from the point of view of the amplitude of the distortion terms produced by the lack of sufficient speed constancy. Such a treatment has been given by Lautenschlager,[2] who concluded that the square-root of the sum of the squares of the amplitudes of the distortion terms should not exceed a value of approximately 7 per cent, if serious and objectionable distortions were to be avoided.

Under certain conditions, even a frequency change of 0.1 per cent would be large enough to be noticeable; hence it would be desirable to keep as near to such a value as possible. There are too many projectors today having percentages greater than 1.0, with the result that in many theaters the reproduction is almost intolerable for music having sustained tones. However, it must be realized that the boundary between good and bad performance is not sharply defined, and perfectly constant speed is not attainable. Under average conditions, it is probable that a 0.2 per cent frequency change over the important range would be an acceptable value that would not be too difficult to attain.

No attempt will be made to discuss the abstract theory of the fundamental phenomena involved here, but it may be noted in passing that the general subject matter is closely allied to that of frequency and phase modulation. The solutions of those problems have been available for many years, having been discussed by numerous writers, notably Carson,[3] Van der Pol,[4] and more recently by Roder,[5] who gives a rather complete bibliography.

The effect of speed variation in a reproducer is to alter the fundamental output and produce response at numerous side-tones lying above and below the fundamental reproduction frequency that might have been expected from the record. These side-tones correspond to the side-tones that exist in the better known case of radio transmission, and are spaced from the "carrier" frequency by multiples of the "wow" frequency. The amplitude of the various components is Bessel functions whose arguments are functions of what Van der Pol has called "the index of frequency modulation," or what may more crudely be called the amount of "wow." The significant thing about speed variation is that a whole new series of tones may be introduced into the reproduction which, besides having no counterpart in the original sound as recorded, may be totally dissonant with these sounds.

As the frequency range of the reproducer is extended, this problem becomes more and more serious, and since the theater-going public is gradually coming to the point of view of purchasing a quality performance, the future can only force the quality standards toward better reproduction.

The following analysis,* made by the author some years ago, proceeds from a point of view slightly different from that of similar analyses that have come to his attention. Let the ordinate of the wave recorded upon the film be defined by y at any phase position θ.

$$y = A \sin \theta \qquad (1)$$

Then the voltage developed across a pure resistance load for an ideal photoelectric cell may be represented by e when the angular displacement or phase of the record is ϕ as it is moved past the reproducing aperture.

$$e = E \sin \phi \qquad (2)$$

---

* Analyses of this effect have been made by Lautenschlager[2] and Belar[7], both of whom proceeded from the standpoint of a fixed amplitude, d, for the sinusoidally varying part of the film drum displacement, x. Their results, for a frequency having a wavelength λ upon the record, are given in somewhat different form,

$$e = E \sum_{n=-\infty}^{n=\infty} J_n \left(\frac{2\pi d}{\lambda}\right) \sin (\omega_0 + n\beta)t$$

In the analysis given in this paper, the angular velocity of the film is assumed to be a constant, ω_0, with a superposed sinusoidal velocity of amplitude, Ω_0, varying at a frequency of β.

There is no difference in the final result obtained from either relation provided only that the proper variables are correctly inserted in the expressions.

If the angular velocity of the film is $d\phi/dt = (\omega_0 - \Omega_0 \cos \beta t)$, the phase at any time t is:

$$\phi = \int_0^t \frac{d\phi}{dt}\, dt = \left(\omega_0 t + \frac{\Omega_0}{\beta} \sin \beta t\right) \tag{3}$$

or

$$e = E \sin\left(\omega_0 t + \frac{\Omega_0}{\beta} \sin \beta t\right) \tag{4}$$

for which the Jacobi-Bessel[4,6] expansion is:

$$e = E \sum_{n - \infty}^{n = \infty} J_n \left(\frac{\Omega_0}{\beta}\right) \sin(\omega_0 + n\beta)t \tag{5}$$

As the "wow" is allowed to be greater due either to poor design or to some circumstance in the film, the amplitude of the fundamental or carrier frequency is decreased, and the side-tones extend further and further from the carrier frequency and may finally exceed the fundamental in amplitude. The circumstance to be regretted is really the dissonant beating effects with other and desired tones present in the record. Unfortunately, while the case of simple sinusoidal variation of film speed is serious, it is not the most serious case nor is it the only one met in practice. The abrupt variation is much more probable, and, as has been shown, the ear is more sensitive to such variations.

Before discussing the theoretical aspects of the mechanical filtering in the high-fidelity (*PS-24*) sound attachment, it is desirable to examine briefly the practical design features.* Some idea of the disposition of parts as well as the path followed by the film may be obtained from Fig. 2.

In the design, it was necessary to consider carefully many such factors as the driving motor; the gears; the various effects of vibration; induction pick-up; the path of the film on either side of, and adjacent to, the sound translation point; the required mechanical impedance of the film-moving mechanism at the translation point; the guiding; and isolation from the shocks from the take-up magazine.

In so far as the driving motor was concerned, it was desirable to store as much kinetic energy as possible in the rotating element and, for that reason, a high-speed motor was used. It seemed preferable

* The mechanical design of this projector attachment was the work of Messrs. F. J. Loomis and E. W. Reynolds.[8]

to employ only a single-phase supply on a-c. circuits. In order to minimize the effects of shocks and line-voltage variation and to cause the readjustment to such conditions to take place over longer intervals of time, the induction motor was chosen for a-c. circuits. In special cases, three-phase induction motors have been used. In the case of d-c. circuits, additional inertia in the form of a flywheel was added to improve the speed constancy of the main driver.

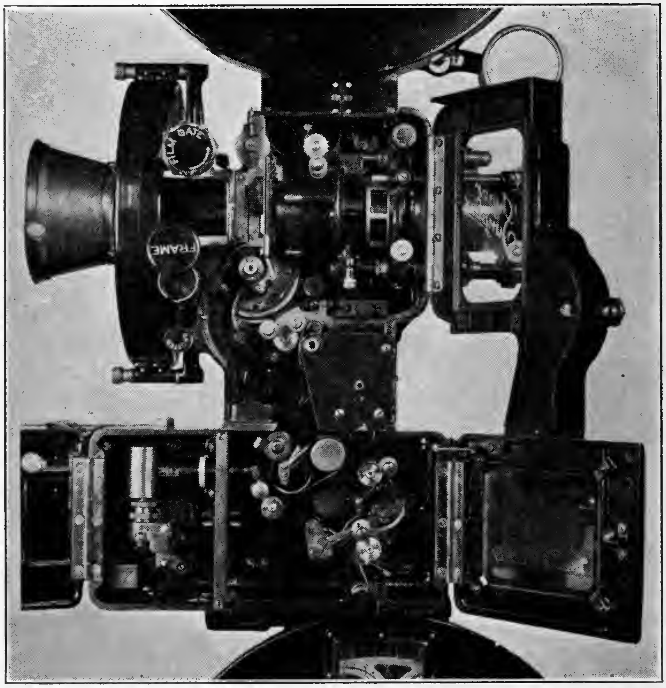

Fig. 2. The film path of the high-fidelity sound attachment.

After leaving the last sprocket in the picture head, the film enters the sound attachment by passing, in a relatively free loop, to the combination guide and pressure roller which holds it in contact with the reproducing drum. The motion of the film upon the drum is controlled by the *rotary stabilizer*,* a device that is fastened to the drum shaft, and which will be described later. These parts are shown separately in Fig. 3.

* This device was proposed by Mr. C. R. Hanna and the present model was designed by Mr. E. W. Reynolds.[8]

As the drum rotates, the film is moved past the reproducing point, maintaining its contact with the drum over some considerable part of the circumference beyond this point by virtue of the film tension established by the main pulling sprocket. Since the film tension is a matter of only an ounce or so, the film leaves the drum in a relatively free loop, and engages the pulling sprocket in such a manner that the directions of the film upon leaving the drum and upon entering the pulling sprocket are nearly at right angles to one another. This feature has an important bearing upon the filtering action for the film motion while the film is in contact with the drum. The best method would have been to use a *U*-shaped film loop between these points, but as that would have presented design difficulties, the pres-

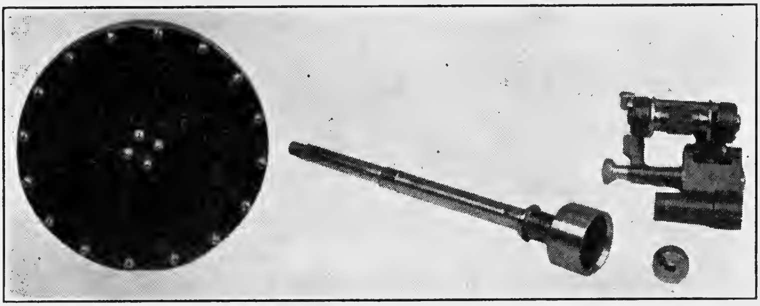

FIG. 3. Rotary stabilizer, film drum, and pressure roller system for sound attachment.

ent method was chosen. The action may readily be visualized by holding a piece of film in the hand so that the described directions are obtained, and moving one end in a direction perpendicular to that of the other end. The motion imparted to the other end is considerably reduced. It is the existence of the film loops together with the relatively high mechanical impedance acting upon the drum shaft that so definitely eliminates sprocket-hole modulation in this machine.

A second sprocket follows the pulling sprocket and is used to aid in isolating the reactions from the take-up magazine, which, because of their possible severity, might otherwise be transmitted through the film loops to the drum.

The function of the rotary stabilizer is to provide an inherently damped positive reactance to coöperate with the negative reactance of the film loops in forming a mechanical filter. This device consists of a very light shell which is fastened to the shaft and within which a heavy flywheel is mounted upon a ball bearing in such a manner that it is concentric with the axis of the shell and may revolve as freely as possible. The clearance between the shell and the flywheel is purposely made very small, and the entire available space inside the shell is filled with oil.

In operation, the inner flywheel revolves at film drum speed and if the film motion is not uniform, the motion of the film drum, and consequently the outer shell of the stabilizer is altered, while that of the inner flywheel is supposedly unaffected. There is a reaction, therefore, between the two elements, and a resultant dissipation of energy in the viscous medium that corresponds to a pure mechanical

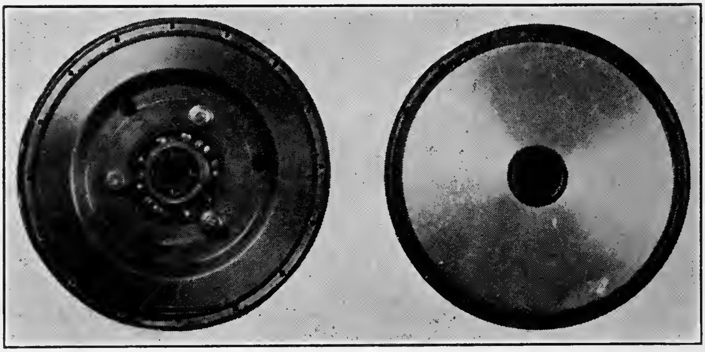

Fig. 4. A disassembled view of the rotary stabilizer.

resistance. It is to be noted that this resistance is not operative in the case of steady motions, and therefore the steady film tension is not increased by employing it. The component parts of the rotary stabilizer are shown in Fig. 4.

The mechanical filtering is accomplished largely by the coöperation between this device and the elastance of the film loops. Since this elastance depends upon the film tension, it is necessary to keep the tension quite low. Therefore, mechanical resistance (frictions), which would tend to demand more torque from the film-pulling sprocket, must be eliminated. To aid in accomplishing this, the pressure roller and the drum shaft are mounted upon ball bearings.

It was apparent from the theoretical analysis of the stabilizer that in order to attain the desired filtering using a strictly elastance-resistance combination (without any inertia connected rigidly to the drum shaft), it would be necessary to provide a much greater viscous resistance than is used at present, because the elastance of the film loops is relatively fixed. This would mean either impossibly small clearances or increased dimensions, and either alternative would demand a heavier inner flywheel to prevent this member from following the velocity variations of the shell. Any variation of velocity of the flywheel due to a corresponding variation in the shell violates the assumption of an inertia-free film drum system because of the tightness with which these two systems are coupled under such conditions.

It was evident upon theoretical grounds that improved filtering action was attainable in the higher-frequency region if some additional inertia were allowed upon the film drum shaft. However, this inertia could not be too large in proportion to that of the inner flywheel of the stabilizer if oscillations are to be successfully damped. To establish the minimum permissible moment of inertia for the outer shell, various amounts of inertia were added to the film drum shaft.

Several things were evident at once: first, with the possible film loop elastance available, it was found that the minimum of additional inertia capable of keeping the speed variation of the drum within reasonable bounds was somewhere between 20 to 30 ounce-inches squared (in weight units); and, second, with such low-loss mechanical devices, at least some minimum of damping resistance was absolutely essential to prevent incessant speed variation. The damping obviously would increase with the inertia of the shell of the stabilizer and the stiffness of the film loops; that is, if the energy stored during oscillation were increased, the means of wasting this energy would likewise have to be increased. The exact relation between these constants will be deduced later in connection with the necessary conditions for critical damping.

In the endeavor to obtain the theoretically indicated relation between the various constants to approach the critical damping condition as nearly as practicable, a certain size for the container shell was indicated even with the lightest possible shell design. This automatically provided several times the minimum required drum shaft inertia, and was therefore very useful in improving the filtering in the frequency range above approximately 3 cycles per second.

Since the damping resistance is derived from the relative motion between the shell and the flange surface of the inner flywheel, it is essential that even the smallest significant change of velocity in the drum shaft should find its counterpart between the component parts of the rotary stabilizer. It is therefore quite evident that the bearing friction of the inner flywheel must be as small as possible if the device is to function properly, and the static friction at this point should be no greater than the running friction, if possible. Therefore, ball bearings are indicated for this purpose.

In the freely oscillating state, any variation of velocity of the film drum shaft corresponding to a definite change of kinetic energy stored in the drum system will be reflected as a change of potential energy stored in the elastance of the film loops. In this interchange of energy, as has already been indicated, the enclosing shell of the rotary stabilizer should be the only seat of kinetic energy change; the flywheel inside the device should have its velocity altered as little as possible if proper damping is to be obtained, or this oscillatory energy is to be wasted rapidly enough so that the film-moving system will return to its non-oscillatory state as quickly as possible. Obviously, if the inner flywheel is too light, its velocity will be influenced too much by velocity changes of the enclosing shell, and hence the alternating difference of velocity between the shell and the flywheel will be decreased, with the attendant circumstance that too little of the oscillatory energy will be wasted in the viscous friction between the surfaces of the two parts. Thus, there must be some minimum ratio between the inertia of the inside flywheel and that of the enclosing shell with its connected film drum and shaft, before any given damping condition can be attained. It is quite evident that the magnitude of the resistance coefficient required for any definite degree of damping in this device, although dependent upon inertia and elastance, is not determined as simply as for the case of the ele-

Fig. 5. A device for measuring film elastance.

mentary circuit of an elastance, an inertia, and a resistance.

It is desirable to show how the constants of the mechanical circuit were determined and their general order of magnitude before discussing the theory of the mechanical operation of the reproducer.

Attempts to determine the elastance of the film loops, as referred to the film drum by measurements made directly upon the projector, did not give as consistent results as might be desired, so the special device shown in Fig. 5 was built. The film path in this device was an exact duplicate of that used in the reproducer, and the frictions

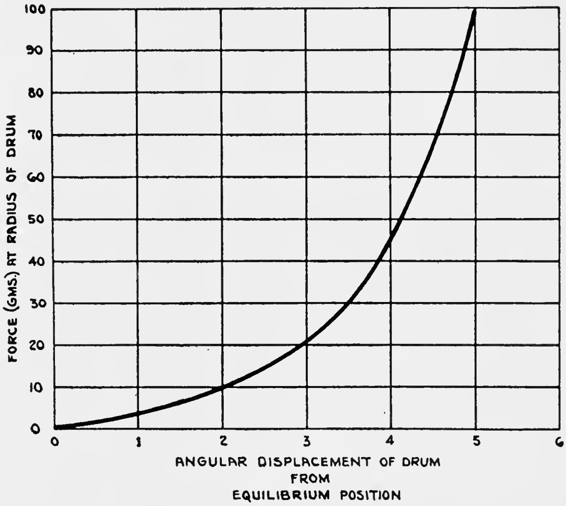

FIG. 6. The force-displacement curve of film loops referred to film drum.

involved in the essential bearings were reduced to a minimum. The measurements themselves consisted in applying a known torque to the drum by means of a weight, and noting the resultant angular deflection. Naturally, variations of the torque-displacement curve were found with various lengths of film between the two sprockets on either side of the film drum, but since the average condition is of greater importance at this time, only the curve for this case is shown in Fig. 6. This curve will naturally vary somewhat for different machines in actual practice but such variations are not serious.

It is seen that the torque-displacement curve is anything but linear and in some ways this may be advantageous. The complete theory for large oscillations would have to consider a variable elastance; but fortunately, in operation, the oscillations are restricted to relatively small angular displacements, and, therefore, under normal conditions the elastance presented to the alternating velocities is approximately constant. This allows the solution to proceed with acceptable accuracy along the conventional lines well-known in the general theory of oscillatory systems. For example, the variation of film elastance would be about 10 per cent at a "wow" frequency of 2 cycles per second unless the total frequency change exceeded 0.3 per cent, which would be an appreciable speed variation even at a carrier frequency as low as 100 cycles.

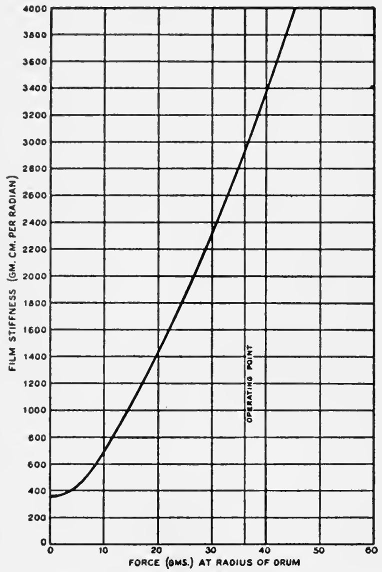

Fig. 7. Incremental stiffness of film loops referred to drum.

This discussion indicates that the effective film stiffness can be evaluated upon the basis of small displacements. Hence, the torque required to produce such a displacement should be written as:

$$dT = \xi d\theta$$

where ξ is the increment of film stiffness. Therefore, the film stiffness (Fig. 7) is derived from the torque-displacement curve (Fig. 6) by evaluating the slope at each position, or:

$$\xi = \frac{dT}{d\theta} \tag{6}$$

In one projector the film loops were required to transmit a force of approximately 36 grams to the drum during operation. In this case it will be seen from Fig. 7 that the incremental film stiffness was approximately 2950 gram-centimeters per radian.

In determining the moment of inertia of the various parts involved in the mechanical filter circuit used to attain a sufficiently steady speed of the film upon the drum, use was made of the well-known properties of the torsional pendulum. A disk whose moment of inertia, I_s, was accurately known by calculation, was suspended horizontally by a very thin steel wire fastened to a rigid support. The period of oscillation, P_s, was then carefully measured. The part whose moment of inertia was to be found was suspended from the disk so that its axis of rotation coincided with that of the torsional pendulum, and the new period of oscillation was determined. The moment of inertia, I, of the part to be measured, was determinable from the relation:

$$I = I_s \left[\left(\frac{P}{P_s} \right)^2 - 1 \right] \tag{7}$$

where P is the period of oscillation of the combination of the unknown and the standard. Since the theory of this device may be found in any standard work on mechanics, it need not be given here.

The moments of inertia found for the essential parts of the test reproducer are given in Table I. The accuracy of the results is quite sufficient for the present purposes.

TABLE I

	Approximate Weight (Ounces)	Approximate Moment of Inertia (Weight Units) (Ounce-Inches Squared)
Outer shell	15.0	99
Inner flywheel	78.5	462
Film drum and shaft	13.25	1.5

The final constant, necessary for calculating the performance of the rotary stabilizer, is the damping resistance due to the viscous oil film. A true mechanical resistance is one that requires a torque or force directly proportional to velocity, to overcome the friction. Viscous friction obeys this law. The constant is therefore determinable directly from the torque-speed curve of the device, and, like incremental film stiffness, is the derivative of the curve at the point of operation.

In order to produce an anti-hunting device, the torque of the resistance must oppose the resistance applied. Therefore, the resistance is defined as:

$$r = \left(- \frac{dT}{d\omega} \right) \tag{8}$$

Equation (8) would be equally useful for those cases where the speed-torque curve should not happen to be a straight line, provided only that the oscillations were restricted to small amplitudes. This must be true in the present case in order to satisfy the conditions imposed upon a reproducer of this type.

In the particular device involved here, the speed-torque curve is a straight line. This is fortunate from an analytical standpoint, because it makes the equations easier to deal with, and in practice the existence of constant coefficients prevents the generation of subharmonics of an applied sinusoidal force. For design purposes, the speed-torque curve can be calculated with sufficient accuracy for all practical purposes, from the following relation:

$$T = \mu 4\pi l \left(\frac{a^2 b^2}{a^2 - b^2}\right)(\Omega_2 - \Omega_1) \tag{9}$$

where μ = viscosity of the fluid
l = axial length of outer cylindrical surface of inner flywheel upon which the torque is developed
a = radius of inner surface of enclosing shell
b = radius of outer surface of inner flywheel
Ω_2 = angular velocity of shell in radians per second
Ω_1 = angular velocity of flywheel in radians per second.

In this equation, the effects of the ends and edges of the cylindrical surfaces have been neglected, but this is not serious because the stabilizer has been designed to derive a minimum torque from these parts.

The variation of the viscosity factor, μ, with temperature of the fluid was at first thought to be a serious handicap to the device. Several years of commercial use, however, have shown that the fear was unwarranted, for although the variation does exist, the necessity for maintaining critical damping, or any other given degree of damping, has been found to be commercially unnecessary. It is essential only to damp the oscillations with reasonable rapidity.

Several authors have attempted to discuss the variation of μ by empirical relations. Notable among such attempts is the work of Slotte,[9] who gives the following approximation:

$$\mu = \mu_0(1 + \beta t)_{-\eta} \tag{10}$$

where η and β are constants for a given fluid and t is the temperature in degrees centigrade above the reference point for which the viscosity is μ_0.

Although the calculated torque-speed relation is useful for design purposes, the device must obey certain test limits in production; hence the mechanism shown in Fig. 8 was constructed to measure the developed torque. It is essentially a speed-changing gear-box, so arranged that the output shaft rotates always in one direction. The device is driven by a synchronous motor, and the speed changes are made by shifting several external gears. Thus, the exact speed can be known as accurately as desired.

The torque-speed curve of the stabilizer as measured on this device, is shown in Fig. 9. It is to be noted that this curve must vary somewhat between samples because it is not economical to hold the manufacturing tolerances too close, and commercially the results attained would not warrant this refinement. An average value of the resistance obtained in this manner would be approximately 126.5 gram-centimeters per radian per second.

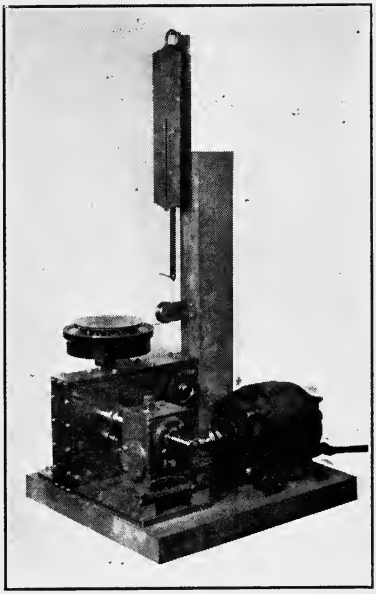

FIG. 8. A device for measuring the damping resistance of the rotary stabilizer.

The operation of the system as a mechanical filter can be readily appreciated by transferring the problem into electrical terminology regarding the velocity analogous to the current and the torque analogous to the voltage. It will be instructive to trace the circuit analogue for the present case, assuming that the more serious causes of speed variation reside in either of the sprockets on either side of the film drum. This assumption is entirely in accord with the facts.

It must be noted at the outset that the mechanical system connected to either of these sprockets is very ponderous and stiff, and a relatively great amount of energy would be required to drive the projector from the sprockets, even assuming that the various parts would stand the strain. This merely means that if the source of disturbance is to be regarded as a generator, it possesses a very high internal impedance; which is merely another way of saying that the generator should be regarded as a constant-current device. A more detailed examination of the various kinds of disturbances will reveal the essential correctness of this view. Furthermore, since the elastances of the film loops upon either side of the film drum are to be considered jointly, the sprockets upon either side of the drum may likewise be regarded as one generator having a current wave of complex shape. In the analysis, it will be sufficient to discuss the effect of a single sine wave, or, in the limit, the effect of an instantaneous change of speed.

It is noted that if the pulling sprocket is angularly displaced θ radians in time, t, and if the film is assumed absolutely inelastic for the moment so that all the motion is transferred to the film drum, the total displacement of the drum is less than that of the sprocket by the ratio of the diameter of the sprocket to the diameter of the drum. In this case, the ratio is approximately 0.578. Moreover, if a given force is applied at the sprocket, still assuming a rigid

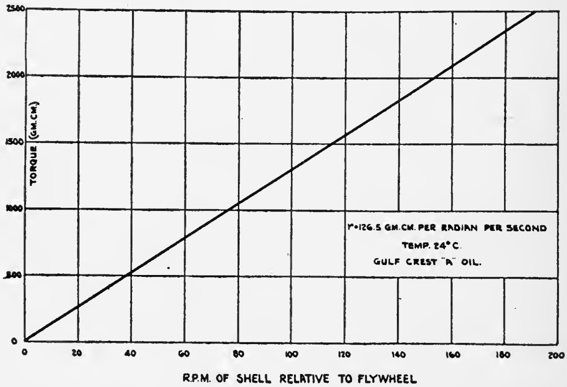

FIG. 9. The speed-torque curve of the rotary stabilizer.

film connection between it and the drum, the force applied to the drum will be equal to it; but, because of the difference between the radii, the torque on the drum will exceed that applied to the sprocket by the ratio of the drum diameter to the sprocket diameter. It is obvious, therefore, that some form of transformer action exists between the two parts so that the velocities are decreased and the torques increased as they affect the drum. However, this ideal transformer likewise passes the steady motions. If the alternating effects are the only characteristics of interest, this action may without error be represented by an ideal, mutually coupled transformer. Fortunately, the case fulfills the requirements of the principle of superposition closely enough so that the direct-current action may be neglected in the present analysis, and hence no further time will be spent upon this added complication. In passing, it may be noted that the principle of superposition assumes linear equations.

Assuming that the character of the various circuit elements is known, the circuit diagram of the analogue may be readily traced; for, if a change of velocity is impressed upon the pulling sprocket, not all this change instantaneously reaches the film drum even after allowing for proper transformer action. Some is momentarily lost in the elastance of the film loops. Hence, it is seen that the loops correspond to a condenser connected in parallel with the film drum circuit. That portion of velocity change that affects the film drum encounters the inertia of the drum, the drum shaft, and the shell of the rotary stabilizer before passing on to the enclosed elements. It has been assumed that the friction and inertia of the film-guiding system, as well as the bearings of the drum shaft, are a second order

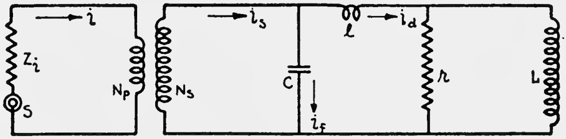

FIG. 10. The circuit diagram of the electric analogue of the film-moving system of the sound attachment.

effect, an assumption that is warranted in practice. Furthermore, it is readily seen that any change of velocity of the film drum does not instantaneously reach the inner flywheel of the stabilizer, but some is lost in the viscous resistance of the oil film, through which the transfer to the flywheel is made. This loss is transformed into heat and is not regained. Thus, the viscous resistance is connected in parallel with the inertia of the inner flywheel in the analogue.

The circuit diagram is shown in Fig. 10.

where S = sprocket generator
Z_i = high internal impedance of generator
i = impressed alternating velocity
N_p = primary "turns" of an ideal transformer (sprocket diameter)
N_s = secondary "turns" of an ideal transformer (drum diameter)
a = ratio of secondary current to primary current $= \left(\frac{i_s}{i}\right) = \left(\frac{N_p}{N_s}\right) =$ 0.578
C = elastance of film loops measured on film drum (impedance $= Z_c$)
l = inertia of drum, shaft, and stabilizer shell
L = inertia of inner flywheel of stabilizer
r = mechanical resistance due to viscous action as measured on film drum
Z = impedance of r and L in parallel
Z_0 = impedance of l and Z in series.

then:

$$i_d = \left(\frac{a}{1 + \frac{Z_0}{Z_c}}\right) i \qquad (11)$$

or:

$$i_d = \left[\frac{a(r + pL)}{p^3lLC + p^2(l + L)Cr + pL + r}\right] i \tag{12}$$

In order to give the complete solution for the expression, the type of stimulus and the roots of the denominator must be known. In any complicated numerical case, these may be determined by Dandelin's[10] method. For the steady-state case, assuming that the applied velocity is a sine wave, the above relation is readily reducible to:

$$i_d = (a\epsilon^{j\gamma}i) \sqrt{\frac{r^2 + (\omega L)^2}{(r - \omega^2[l + L]Cr)^2 + (\omega L - \omega^3 lLC)^2}} \tag{13}$$

where γ is the phase angle for the radical.

This equation permits the calculation of the percentage of mechanical filtering developed at the film drum of the reproducer when a sine wave of velocity variation is applied at the sprocket. The calculated

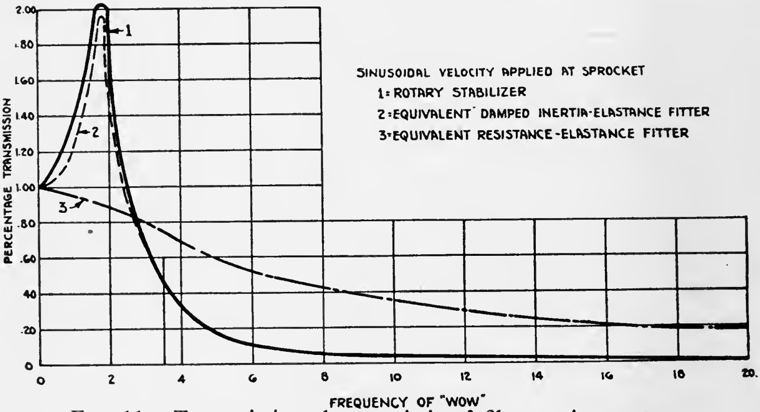

Fig. 11. Transmission characteristic of film-moving system.

performance of the system under these conditions is shown in curve *1* of Fig. 11. The constants used in these calculations were those measured as described above. The characteristics of the equivalent damped inertia-elastance filter are shown in curve *2*, where it is assumed that a flywheel equal to the stabilizer shell alone is fixed on the drum shaft and the damping resistance is made equal to that of the stabilizer. In practice, such damping would have to be added in some external manner that would not increase the steady film tension. This curve shows approximately the same resonance peak and practically coincides with curve *1* above this frequency, from which it may be deduced that the inertia of the inner flywheel does not contribute materially to the effective inertia of the shell, and hence does not enter into the filtering action except to provide a surface against which the shell may react. The results attainable from an equivalent resistance-elastance filter is shown in curve *3*, in which it was assumed that no inertia appears upon the drum shaft and the damping resistance and film elastance are made equal to the constants used in the rotary stabilizer case. As in curve *2*, it is obvious that this resistance would have to be obtained by some external means; and because of the assumption of constant elastance, the film tension can not be increased over that used in the case of the stabilizer. The filtering action is seen to be inferior to that of the stabilizer except in the region below approximately 3 cycles. Both filters would be so poor in this region as to be practically useless. The stabilizer has been designed so that this falls below the important range of frequencies for normal operation.

It is of interest to determine the necessary ratio of inertia of the shell to that of the flywheel to permit the effective use of enough viscous resistance to establish the condition of critical damping. This may be done by equating to zero the discriminate of the reduced cubic expression derived from the following equation. If the discriminate were made positive, the device would be over-damped.

$$[p^3 lLC + p^2(l + L)Cr + pL + r] = 0 \tag{14}$$

The reduction of this cubic is accomplished in the usual manner by assuming:

$$p = \left[x - \left(\frac{l + L}{3lL}\right) r\right] \tag{15}$$

and the result is:

$$[x^3 + ux + v] = 0 \tag{16}$$

where the constants u and v are functions of the circuit elements.

For critical damping, the condition expressed by the following relation should exist:

$$\left(\frac{v^2}{4} + \frac{u^2}{27}\right) = 0 \tag{17}$$

If, in addition, it is assumed that $\eta = (L/l)$, this becomes:

$$[4C^2(\eta + 1)^3 r^4 - \eta^2 lC\{n^2 + 20\eta - 8\}r^2 + 4\eta^4 l^2] = 0 \tag{18}$$

or:

$$r = \sqrt{\frac{\eta^2 l}{C}\left(\frac{\{\eta^2 + 20\eta - 8\} \pm \sqrt{\eta(\eta - 8)^3}}{8(\eta + 1)^3}\right)} \tag{19}$$

This result* states that the ratio, η, of the inertia of the shell, l, and the flywheel, L, must be approximately equal to 8 or more,

* This result was given by Hanna without proof in an unpublished memorandum.

before it is possible to use sufficient viscous resistance to obtain critical damping.

The transient solution for small shocks or impulses of velocity that are not great enough sensibly to vary the film loop elastance, is quite interesting. Naturally, such conditions are not maintained because the impulse is superposed upon the average or steady sprocket velocity, and this presupposes the existence of an oppositely directed impulse at some later time to return the system to its normal state. Since this merely involves the proper superposition of two similar but oppositely directed solutions, it is sufficient to investigate only the first impulse. This is a consequence of the assumed linearity of the fundamental equations. It must be realized that the solution will not apply to the case in which the film loop is disturbed by displacing it by the finger. Here the displacement is ordinarily made large enough to observe, in which case the elastance of the loops varies so greatly as to violate the conditions of the fundamental equations, which assumed constant coefficients.

The resultant solution will be shown for the particular reproducer that was used in some of the test work and for which the measured constants have already been given. Since the discriminate of the fundamental cubic given below is negative, it is known that two of the roots are complex and the third is real. Practically, this means that critical damping is not attained. The correctness of the statement that this condition is not necessary in practice will be shown by the rapidity with which oscillations decay.

$$[p^3 + 8.33p^2 + 160p + 234.4] = 0 \qquad (20)$$

The roots of this equation can be shown to be approximately:

$$\left.\begin{aligned} p_1 &= (-1.5692) \\ p_2 &= (-3.3804 + j\,11.741) \\ p_3 &= (-3.3804 - j\,11.741) \end{aligned}\right\} \qquad (21)$$

Therefore, the transient part of the numerical solution for an impressed velocity of the unit function type (*i. e.*, such that before the application of the shock, the velocity was constant and equal to the average velocity, i_b, whereas after the instant application of the shock, the impressed velocity was constant and equal to $i_b + i$), applied at the pulling sprocket, may be shown to be:

$$i_d = ai[1 + 0.0739\epsilon^{-1.5692t} + 1.1151\epsilon^{-3.3804t}\cos(11.741t + 2.868)] \qquad (22)$$

The transient response of the rotary stabilizer for unit impulses is shown in Fig. 12. The rapidity with which the oscillations decay is well illustrated in this graph. The ordinates indicate the velocity of the film drum above its average velocity. The fact that the curve decays to a value of unity is the direct result of omitting that part of the impulse that would have existed in practice, and which would return the pulling sprocket to its average rotational velocity. The effect of a disturbance consisting of an instantaneous change of speed of the pulling sprocket, followed by a similar return to normal speed after any assumed time interval, t, may be readily determined by adding an identical curve of opposite sign to that of Fig. 12 but displaced along the time axis by the interval t.

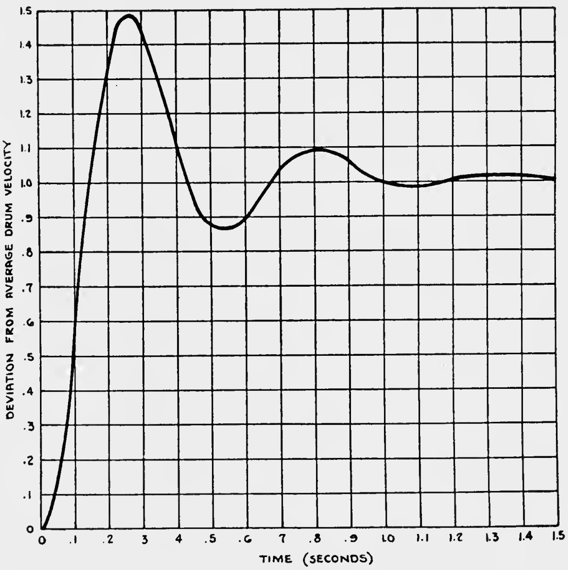

FIG. 12. Transient response for unit function impulse.

The advantage of this solution and its graphical representation is that it shows whether or not the particular design chosen is adequately damped. Likewise, it reveals the period of the natural oscillation of the system and, when combined with the data obtainable from the steady-state filtering curve for sine wave disturbances, gives a rather complete insight into the performance of the device.

It might be mentioned that these results have been checked by observations upon the natural period of oscillation and the rate of decay, and have been found to agree with the observations for the conditions under which they were calculated. Comparisons between this reproducer and many others of different designs have been made over a period of several years of commercial operation, and in no case, so far, has equal performance in the matter of faithfulness of reproduction or freedom from objectionable speed variation been found.

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DISCUSSION

MR. LUBCKE: Do I understand that the flywheel floats entirely free?

MR. SCHULTZ: Yes, the inner flywheel floats as freely as possible, except for the coupling through the viscous oil medium. It acts merely as a surface against which reaction of the viscous medium can take place, and as long as its inertia is sufficiently large that it moves essentially at constant speed the design considerations are fulfilled.

MR. FRAYNE: Does the passage of splices affect the motion?

MR. SCHULTZ: The passage of a splice would correspond to a small transient disturbance, which would be very rapidly damped; the amplitude of operation, due to the design constants, is sufficiently small that it is not perceived by the ear.

MR. TASKER: Referring to Fig. 10, I suspect that, in common with many others, it was Mr. Lubcke's first impression of this circuit that the effectiveness of the filter must be very much less than it would be if the large flywheel were solidly coupled to the shaft and thus used in the orthodox manner. That such is not the case may perhaps be better understood from the following brief, though non-rigorous, comments.

In Fig. 10 we are concerned with the current i_d, which corresponds with the motion of the film over the drum, to which drum is firmly attached the mass of the outside shell of the rotary stabilizer. The electrical equivalent of this shell is properly shown as the inductance l. It is quite true that the reactance of this element is small compared to that of the large floating mass represented by L. It is also true that speed variations impressed upon the filter encounter, in addition to the shunt reactance C, only the small reactance of l and the comparable resistance r, and are not affected by the much greater positive reactance of L.

In spite of the fact that a comparatively large amount of "flywheel effect" residing in L is not effectively used, the filter may still be effective if the value of C is made large enough. It is obvious from the diagram that the amount of alternating (as speed variation) component appearing in i_d depends upon the relative impedances of the shunt branch C and the series branch $l + r$ at any "wow" frequency for which the reactance of L is large, and hence provision of a very large C (*e. g.*, very soft film loop) may result in good filtering. Now, if the resistance r were omitted, so that the very large positive reactance $L + l$ became effective in the series branch, the filter would be undamped, and to attain corresponding damping, the appropriate resistance would be inserted either in series with the positive reactance $L + l$ or in series with the negative reactance C. In either event critical damping will require that this resistance be proportional to the square root of the ratio of the effective inductance divided by the effective capacity, and hence must be much larger than the small resistance r shown in Fig. 10. If placed in series with the inductance, the steady component of i_d must flow through this resistance, resulting in greatly increased film tension (hence smaller C); and if placed in series with capacity C, it will increase the impedance of this shunt branch to such an extent as to offset the increased impedance of the series branch $L + l$. In consequence, the benefits of the much greater series element, L, is by no means fully realized, or may even result in a penalty.

A further study of Dr. Cook's very thorough analysis will point to more precise conclusions. It has been my purpose only to indicate the general effect of this new design as compared to a more conventional type.

MR. KELLOGG: The ball bearing that carries the flywheel inside the shell does not run continuously. Once the machine is up to speed there is no relative motion between the flywheel and the shell except for what speed changes the shell undergoes. There is no bearing that does not have some initial breakdown torque with even a light load.

When this machine was proposed I was skeptical as to whether we could make the friction of the bearing upon which the free-running flywheel runs, low enough to insure that the flywheel and the outer shell would not practically lock together when the amplitude of oscillation fell below a certain critical value, thereby preventing any relative motion and likewise preventing damping. That such a condition is not encountered has been established by numerous tests. If the flywheel and shell are locked together the action is very different, and a small disturbance starts an oscillation that persists for a long time.

We have not been able to observe any oscillation of such small amplitude that relative motion and consequent damping do not occur. It seems to me that the reason may be that the radial force or load upon the bearing is continually changing direction relative to the bearing. A slight irregularity in the bearing which might, in the case of an ordinary bearing, prevent relative motion when a small force is applied, is relieved and the bearing freed when it is turned the other side up.

NON-THEATRICAL PROJECTION*

R. F. MITCHELL**

Summary.—*Various factors involved in projecting 16-mm. pictures for industrial and educational purposes are fully analyzed, according to three main divisions: (1) the illumination of the screen and how it is modified, (2) the effectiveness of projection as regards the audience, and (3) miscellaneous related factors. Each broad division is broken down into sub-divisions enumerating the principal items involved. Curves show the relative cost of attaining desirable screen illumination with various lamps, and the relations between lumens, foot-candles, and screen sizes.*

Based upon the analysis, recommendations as to a standard method of measuring screen illumination, and a list of suggested screen sizes for various lamps and lenses, are given as having been found satisfactory for ordinary work.

INTRODUCTION

There has been a vast increase in the use of motion pictures in recent years for industrial, educational, and similar purposes. The most outstanding progress has been in the application of 16-mm. equipment in industry and education—so much so that 16-mm. is no longer a purely amateur standard but fills a definite sphere of usefulness all its own. In fact, 16-mm. projection has reached the stage where the term "sub-standard" conveys a totally different meaning from the rather "off"-standard implication it used to convey. The advance has been due to the high technical and mechanical excellence of the equipment available; improvements have been made so rapidly that it is hard to keep up with them. It is not surprising, therefore, that so much interest has been evinced in trying to tabulate the material available, in formulating consistent methods of judging the possibilities, and in evaluating the problems of the field. In its broader aspects, this is the function of the Non-Theatrical Equipment Committee, and involves photography, projection, printing, *etc.*, as with the 35-mm. film. It involves, also, reduction printing, reversal and other technical aspects, in addition to problems arising from the fact that non-theatrical equipment is used by amateurs. This paper is an

* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** Bell & Howell Co., Chicago, Ill.

attempt to enumerate and analyze the various factors involved in non-theatrical projection. Although mainly concerned with 16-mm. problems, the essential data and conclusions are valid for film of any size and are applicable in many respects even to purely theatrical projection.

Analysis of the Non-Theatrical Problem.—The sharpest dividing line between theatrical and non-theatrical projection is in respect to the size of the film used and the fact that incandescent lamp illumination is used almost exclusively for non-theatrical work. This tends to limit somewhat the maximum size of satisfactory picture attainable, but the difference is nowhere as great as it is generally regarded. This is due to the powerful lamps now available with 16-mm. machines and to the efficient mechanisms and fast lenses now characteristic of such units. The discussion necessarily covers the more powerful and more efficient models of 16-mm. projectors such as would be used for the industrial and educational work. The requirements of these fields have been in mind in working out this paper. It is convenient to divide the analysis into two main divisions: (*1*) the projection problem (the picture on the screen); and (*2*) the audience problem (the efficiency of the projection as far as the audience is concerned). Each of these main divisions may be broken down as follows:

(*1*) *The Projection Problem*
- (*a*) Efficiency of the intermittent movement.
- (*b*) The optical system.
- (*c*) The lamp.
- (*d*) The picture size.

(*2*) *The Audience Problem*
- (*a*) Screen reflection characteristics.
- (*b*) Screen deterioration.
- (*c*) Auditorium illumination level.
- (*d*) Film density.
- (*e*) Color.

(*3*) *Miscellaneous Related Factors*
- (*a*) Flicker.
- (*b*) Steadiness.
- (*c*) Visual contrast and resolution of detail.

(1) THE PROJECTION PROBLEM

(*a*) *Efficiency of the Intermittent.*—The intermittent mechanisms employed in 16-mm. projectors are, in general, more efficient than those employed in 35-mm. equipment. The shorter stroke and lower inertia permit a faster acceleration and deceleration. In addition, there is more than one intermediate flick for each frame, in most 16-mm. projectors, so flicker is reduced (this is covered further in section 3*a*). Even so, the average efficiency of 16-mm. projector intermittents can be regarded as being approximately 60 per cent, as compared with about 40 per cent for the average theatrical projector. Although the efficiencies of the different makes of 16-mm. projectors vary, they are all close enough to 60 per cent that the differences need not be considered in this analysis. It is sufficient to make the point of the higher efficiency of 16-mm. projectors in general.

(*b*) *The Optical System.*—No 35-mm. projectors are optically as efficient as the 16-mm. projectors. Thirty-five-mm. projectors, especially portable projectors, employ $f/4.5$ to $f/2.3$ lenses, whereas most 16-mm. projectors use lenses varying from $f/2.5$ to $f/1.6$—

TABLE I

Relative Light Transmission

Focal Length *f*/Number	0.64 4	3/4 2.5	1 2.6	1 1/2 1.8	2 1.65	2 2.1	2 1/2 1.9	3 2.3	3 1/2 2.7
Relative Light Transmission	1	2.5	2.4	5	6	3.6	4.4	3	2.2
		1	0.9	1.9	2.3	1.4	1.7	1.2	0.8
			1	2.1	2.5	1.5	1.9	1.3	0.9
				1	1.2				

on the average, three times as fast as the equivalent 35-mm. portable and at least 1 1/2 times as fast as the best theatrical projection equipment. This additional optical speed, in conjunction with the high intermittent efficiency, explains why 16-mm. projectors can project such large pictures in comparison with 35-mm. portable projectors of equivalent lamp wattage. The optics of 16-mm. projectors vary within considerably wide limits, but as far as the projectors that would be used for serious work are concerned, the fastest optical combination is about 2 times, perhaps 3 times, as fast as the slowest 16-mm. industrial projector combination—enough to warrant further analysis.

For most industrial purposes the regular 2-inch lens can be used, having an average speed of about $f/1.65$. However, for auditorium projection involving long throws, longer focal length lenses are used—3, 3 1/2, or 4 inches. The average speed is about $f/2.7$ which is 2 1/2 times as slow as the 2-inch, $f/1.65$ lens. On the other hand, for continuous projection with display cabinets, smaller screen sizes and, usually, shorter focal length lenses are employed, because of the necessity of counteracting daylight or other light incident upon the screen. These relations are covered by Tables I and II.

TABLE II

Width of Picture Attained with Filmo Projection Lenses

Distance from Screen (Feet)	Focal Length of Lens (Inches)								
	0.64	3/4	1	1 1/2	2	2 1/2	3	3 1/2	4
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
1	0 7	0 6							
2	1 2	1 0	0 9						
3	1 9	1 6	1 1	0 9					
4	2 4	2 0	1 6	1 0	0 9				
5	2 11	2 6	1 10	1 3	0 11				
6	3 6	3 0	2 3	1 6	1 1	0 10			
8	4 8	4 0	3 0	2 0	1 6	1 2			
10	5 10	5 0	3 9	2 6	1 10	1 6	1 3	1 0	
12	7 0	6 0	4 6	3 0	2 3	1 9	1 6	1 3	1 1
16	9 4	8 0	6 0	4 0	3 0	2 4	2 0	1 8	1 6
20	11 8	10 0	7 6	5 0	3 9	3 0	2 6	2 1	1 10
25	14 7	12 6	9 4	6 3	4 8	3 9	3 1	2 8	2 4
32			11 11	8 0	6 0	4 9	4 0	3 5	3 0
36			13 5	9 0	6 9	5 4	4 6	3 10	3 3
40			14 11	10 0	7 5	6 0	5 0	4 3	3 9
45				11 3	8 5	6 9	5 7	4 9	4 2
50				12 6	9 4	7 6	6 3	5 4	4 8
64					11 11	9 7	8 0	6 11	6 0
75					14 0	11 3	9 4	8 0	7 0
100					18 9	15 0	12 6	10 8	9 4
125					23 5	19 8	15 7	13 4	11 8
150					28 1	22 5	18 8	16 0	14 0

(*c*) *The Projection Lamp.*—For many kinds of industrial work, especially continuous, the optics and screen size are fixed, so that any desired increase of illumination must be attained by some other means. This problem came up in practically all such continuous installations at the recent Century of Progress Fair at Chicago, so the discussion of this aspect will include other conditions in which additional illumination is attained by using more powerful projection lamps or by modifying the existing lamp set-up. Obviously, the use of a more powerful lamp is the first alternative; but beyond that, further increase of illumination can be attained within certain limits by over-voltaging the lamp. In such cases the additional cost due to shortening the lamp life is regarded worth while. Conversely, when a powerful projector is used for showing pictures upon comparatively small screens, economies can be effected by operating the lamp at voltages below normal. These relations are shown very clearly in Fig. 1. These curves must be used in combination with the table accompanying them, because the price of lamps bears no comparative relation to the emitted light or the life. The curves warrant careful study, however, because they show how much more economical it is to use a high-wattage projector at low voltage. For

SCREEN ILLUMINATION PERCENT			LAMP LIFE HOURS	VOLTS PERCENT
1000 W.	750 W.	500 W.		
68	48.1	30.8	107.5	90
71.5	50.5	32.4	92.5	91
74	52.2	33.5	80.3	92
77	54.4	34.9	68.7	93
80	56.5	36.2	60	94
83	58.7	37.6	52	95
86.5	61.1	39.2	44.5	96
89.5	63.3	40.6	38.2	97
93	65.7	42.1	33	98
96.5	68.2	43.7	28.8	99
100	70.6	45.3	25	100
103.5	73.2	46.8	22	101
107.5	76	48.7	19.3	102
111.5	78.8	50.5	17	103
115	81.3	52.1	14.8	104
119	84.1	53.9	13.3	105
122.5	86.6	55.5	11.5	106
126.5	89.5	57.3	10.3	107
131	92.5	59.4	9	108
135	95.5	61.2	8	109
139	98.3	63	7	110

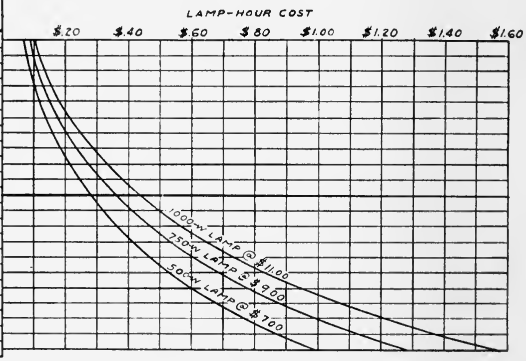

FIG. 1. Lamp-hour cost chart: 1000-w. lamp used as basis of comparison, and assuming same screen size and projector used with the three sizes of lamps shown in table.

instance, a 1000-watt projector at 90 per cent voltage provides 68 per cent of the screen light at a cost of 10 cents per hour. (For convenience, the 1000-watt projector at normal voltage is assumed as providing 100 per cent of screen brilliancy.)

To obtain the same intensity of light with a 750-watt projector, the lamp would have to be operated at 99 per cent of the normal voltage at a cost of 22 cents per hour—twice as much. Even operating the 750-watt projector at 10 per cent overload, the screen illumination would still be slightly lower than the 1000-watt projector operated at normal, and the cost is $1.13 per hour as compared to $0.43 per hour. However, if only a 750-watt projector is available, it is of great help to know that the equivalent illumination of a 1000-watt machine can be attained. If the projector is overloaded for periods shorter than the full lamp life, the comparative cost would be less, as the figures are necessarily based upon the assumption of operating the lamp for its full life at the voltage indicated. It is quite evident that the screen illumination from any given projector can be varied within quite wide limits according to what lens and lamp combination is employed—practically all 16-mm. industrial projectors are designed so that lenses and lamps can be interchanged. Therefore, it seems logical to outline a standard set of conditions under which the normal screen lumen rating of any projector may be determined. With that established, we are in a much better position to apply the special modifications covered above. The following procedure was used to establish the data given in Fig. 1 and is offered as a contribution toward a Society recommendation for Standard Practice in this field.

PROPOSED STANDARD METHOD OF DETERMINING THE SCREEN LUMEN RATING FOR 16-MM. PROJECTION

The parts involved in the process of illuminating the screen are the lamp, condenser, shutter, and lens; and their efficiency, separately and in combination, determines the relation between the amount of light reaching the screen and the total spherical luminous energy emitted by the lamp. The screen lumen output value of a projector is a measure of its projection illumination capacity. This value remains the same (within reasonable limits) regardless of the screen size. The following procedure is suggested for determining the screen lumen rating of a projector:

(*1*) *Make the Test with the Projector Running* (*at Approximately Normal Speed*) *without Film.*

(*2*) *See that All Optical Parts Are Scrupulously Clean.*

(*3*) *Use the Lens and Condenser Regarded as Standard Equipment.*

When other than standard equipment (2-inch focal length) lenses are used, the projector may be found to produce more or less illumination than with standard equipment. The special lens may be of larger or smaller aperture, or the condenser may be more or less efficient.

(*4*) *Use a Rated Lamp, at the Correct Voltage.*

A rated lamp is one that has been checked by its manufacturer as to its efficiency of operation at various voltages in relation to its normal efficiency at the design voltage and as to its design life. A rated lamp can be operated at the design voltage in a brief test without serious loss of accuracy; but as the test period is usually extended, and usually more tests than one are required of a lamp, it is better to use a lamp rated at a voltage that is about 80 per cent of the design voltage. The foot-candle reading is then multiplied by the conversion factor for the particular lamp. The exact voltage and the conversion factor are supplied by the lamp manufacturers, and are marked upon the lamp.

(5) *Use a Screen Size That Yields an Intensity of About 6 to 10 Foot-Candles.*

This tends to eliminate errors in reading the foot-candle meter.

(6) *Take Five "Foot-Candle Readings," One at the Center, One Each at the Centers of the Side Edges, and One Each at the Centers of the Top and Bottom Edges.*

The average of five foot-candle readings taken at the points mentioned will be so nearly the exact average foot-candle value for the screen that a larger number of readings will not be necessary.

In 1920, W. F. Little published[1] two sets of screen foot-candle readings: one set giving the light intensities at sixteen points of the screen and the other giving readings at 256 points. The latter table is reproduced as Table III. It is significant that the average of the sixteen readings in Little's first table is 10.0 foot-candles and the average of the 256 readings is 10.1 foot-candles. In Table III nine readings have been set in bold-faced type that seem to represent fair intensities at those points. The average of the readings at the five points recommended is 10.0 foot-candles, while the average of the nine points is 8.6. Experience indicates that the nine-point reading usually made in theatrical work gives an average lower than that actually realized. It is obvious that any discussion of screen illumination (which is obtained by multiplying the average foot-candle intensity by the area in square-feet) must recognize the necessity of standardizing the manner of determining the average intensity.

It is suggested that the subject be considered further by the Projection Screen Brightness Committee and the Standards Committee. Also, it is recommended that the illumination at the center of the picture be not more than 15 per cent greater than at the top and sides.[2]

TABLE III

(*Measurements Made by 256-Point Method*)

10.0	10.7	11.0	10.7	10.9	11.1	11.4	**11.5**	11.3	10.8	10.6	10.1	9.9	9.4	8.7	**6.9**
10.7	10.8	10.7	11.0	11.1	11.1	11.7	11.8	11.6	11.2	10.8	10.2	9.9	9.7	8.9	7.7
10.3	10.8	10.9	11.1	11.2	11.5	11.7	11.6	11.8	11.2	10.9	10.7	10.6	10.2	8.9	7.4
10.3	11.2	11.4	11.5	11.6	11.9	12.4	12.4	12.1	11.5	10.8	10.7	10.7	10.5	9.4	7.2
10.9	11.2	11.3	11.2	11.4	11.6	12.3	11.9	12.0	11.5	11.1	10.9	10.7	10.2	9.4	7.5
10.3	11.2	11.1	11.4	11.5	11.6	12.0	12.0	11.9	11.5	10.9	10.6	10.4	10.2	9.5	7.8
10.6	11.6	11.7	11.5	11.4	11.4	11.6	12.0	11.7	11.1	10.9	10.6	10.6	10.3	9.4	7.9
10.8	11.1	11.4	11.1	11.5	11.6	11.7	**11.9**	11.7	11.4	11.1	10.8	10.7	10.3	9.4	**7.8**
9.7	11.2	11.2	11.3	11.4	11.6	11.7	11.9	11.6	11.4	10.8	10.4	10.2	9.9	9.4	7.6
9.8	11.1	11.1	11.1	11.2	11.3	12.1	12.1	11.8	11.5	10.6	10.5	10.0	9.8	9.1	7.6
10.4	10.6	10.6	10.6	11.0	11.1	11.3	11.5	11.5	11.1	11.1	11.0	9.7	9.5	9.0	7.4
9.0	10.2	10.2	10.3	10.6	10.9	11.0	11.3	11.4	11.0	10.3	9.9	9.4	9.1	9.1	6.9
8.7	9.9	9.9	10.1	10.6	10.7	10.7	10.7	10.7	10.3	9.6	9.0	8.8	8.6	8.4	6.8
8.4	9.3	9.4	9.6	9.9	10.3	10.4	10.5	10.2	9.6	9.1	8.4	8.2	8.0	7.8	6.7
6.9	8.2	8.2	8.8	9.3	9.1	9.4	9.3	9.1	8.4	7.9	7.8	7.7	7.4	6.9	6.0
5.6	6.9	7.3	7.4	7.9	7.9	8.2	**8.1**	7.7	7.1	6.8	6.4	6.7	5.9	5.3	**4.7**

Average of 256 readings—10.107

(7) *Multiply the Average of the Five Readings by the Lamp Conversion Factor, if Necessary.*

If the lamp is undervoltaged the reading must be multiplied by the conversion factor in order to obtain the value of the design voltage. As there is considerable variation in color distribution between the outputs at the two voltages mentioned, as well as some variation among different types of lamps at the design voltage, a meter filtered and graduated to correspond to the sensitivity curve of the human eye is most desirable. (A meter not thus equipped will require the use of further individual correction factors for obtaining accurate values.)

(8) *Deduct the Room Illumination in the Region of the Screen.*

If a black-walled room is available for the test, no deduction is necessary and a more accurate test can be expected.

(9) *Reduce This Remaining Value by a Factor Representing the Average Efficiency of the Lamp for Its Life Period.*

As the lamp output continuously decreases during use, the average output during the lamp's lifetime becomes the best measure of the illuminating value. This falling-off is due to the gradual blackening of the bulb and the gradual increase of electrical resistance as the tungsten evaporates from the surface of the filament. For the usual 25-hr. (approx. 3300°K) lamp, the average lifetime output of prevailing types of lamps is, for the biplane filament, about 86 per cent of the new lamp output, and about 93 per cent in the case of a monoplane filament. These figures are approximate; the percentage varies with the type of lamps.

(10) *Multiply This Reduced Value by the Area of the Screen (in Sq. Ft.) to Obtain the Screen Lumens Value.*

This value represents a true measure of the average screen-illuminating capacity for the life of the lamp. When it is compared with the total spherical lumens output of the lamp (also lifetime average), the efficiency of projection is indicated.

The output of the rated lamp matches only the average output of a large number of stock lamps; therefore, it is evident that a stock projector with a stock lamp is not likely to match the rated lamp as to screen lumens. The lamp manufacturing tolerance, in watts, for stock projector lamps is ±5 per cent, the equivalent of which in lumens is ±12 per cent. Voltage variations of ±5 per cent in projection may add another ±18 per cent in lumens.

(*d*) *The Picture Size.*—It is apparent that any given projector gives just so much total light. By placing the projector near the screen or far from it, or by using lenses of various focal lengths, the image brilliancy can be varied. The foot-candle intensity is a direct function of the screen size, and can, therefore, be shown in convenient chart form as in Fig. 2. The lumen output of any projector being known, it is a simple matter to determine the size of the picture

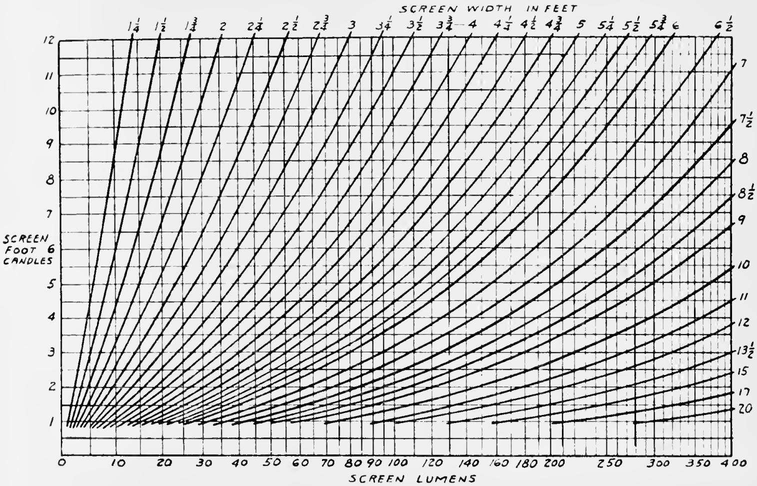

FIG. 2. Chart of screen illumination and screen width.

for any desired intensity. Experience indicates that an intensity of 6 foot-candles is quite adequate for non-theatrical black-and-white projection. The points of view of several projector manufacturers on this score will be found in the Report of the Committee on Non-Theatrical Equipment.[3] In this connection it is interesting to note that an intensity of 6.9 foot-candles afforded "very comfortable" projection, of "good" visual acuity, and that an intensity of only 3.8 foot-candles was rated "comfortable" and "fair" in a report of the Theater Lighting Committee.[4] The Projection Screens Committee's preference[5] of 7 foot-lamberts illumination is also of interest even though it refers to arc illumination.

(2) THE AUDIENCE PROBLEM

All the material presented above covers the illumination reaching the screen. As a matter of convenience, such tests are made with the machine running without film, and the resulting illumination is measured at the screen. The Weston photoelectric foot-candle meter used in the tests is probably as convenient and as reproducible a standard as available. The photo-cell should be fitted with a filter for translating the readings to the visual response curve. This filter is especially valuable because it corrects for a wide variation of color temperature.[6]

(*a*) *Screen Characteristics.*—A point that seems to be overlooked

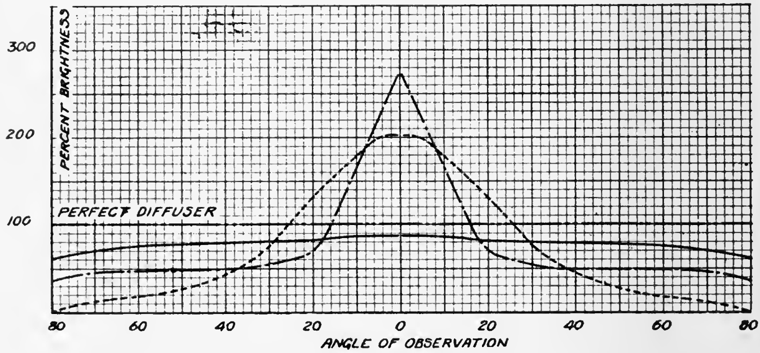

FIG. 3. Brightness characteristics of Da-Tone perforated motion picture screens: solid curve, type *Z* screen; dot-and-dash curve, beaded screen; dotted curve, silver screen.

or, at least, not considered as fully as its importance seems to warrant, is that concerning the *effective* image brilliancy as regards what the audience sees. Everyone realizes that the efficiency of the screen varies—that is the main reason why the convenient method of measuring at the screen is used so widely. At the same time, the screen reflection factor should be checked, as well as its polar distribution (Fig. 3). The percentage reflection of the screen can easily be determined by merely taking a series of readings with the photocell turned *toward* the screen as well as with the photo-cell facing the projector. (Obviously the photo-cell must not throw a shadow upon the screen. Such a test is best made with the photo-cell about a foot or so away from the center of a fair-sized screen.) This will give the intensity of the light reflected at right angles to the screen; the difference at various angles can most readily be calculated from curves supplied by the screen manufacturers, such as those in Fig. 3. For example, suppose on a standard size of screen an average reading of 6 foot-candles was obtained with the photo-cell facing the projector and 4.5 foot-candles with the cell facing the screen. This would indicate a screen reflection efficiency of 75 per cent at right angles. Viewing a beaded screen at a 10-degree angle the audience would see an image of intensity 160/270 of 4.5, or 2.67 foot-candles. This probably represents about the poorest condition encountered in average non-theatrical projection of acceptable quality. It is recognized, however, that the term "acceptable quality" is rather loosely used; this paper is written with a view of assisting to establish a workable definition or specification of this condition.

(*b*) *Screen Deterioration.*—As is well known, the screen reflection efficiency is not at all stable, but changes with the age and use of the screen. That is one of the main reasons why it has become customary to read initial "screen" brilliancy instead of "audience" brilliancy. It would therefore seem necessary in any adequate specification to indicate some acceptable average screen efficiency, measured at right angles to the incident beam. A factor of 75 per cent is suggested as a basis, keeping in mind the high efficiency and comparatively good cleaning qualities of beaded screens, which seem to be used most widely for non-theatrical work. Moreover, screens used for non-theatrical work are not perforated, for which reason they have a higher initial efficiency than theatrical perforated screens, amounting to about 6 or 8 per cent.

(*c*) *Auditorium Illumination Level.*—The efficiency of projection, so far as the audience is concerned, depends also upon how much or how little extraneous light there is in the hall to conflict with the light coming from the screen, as well as cigar and cigarette smoke which is occasionally a factor in non-theatrical work. Smoke diffuses the light throughout the room, in addition to cutting down the initial light reaching the screen.

(*d*) *Film Density.*—The film density affects the quantity of light reaching the audience. This factor is difficult to standardize for non-theatrical work as it seems to vary more than in theatrical release printing. Sixteen-mm. non-theatrical films can be divided into the three broad classes of direct reversal, 16-mm. contact, and 16-mm. reduction prints.

(*e*) *Color.*—Color should probably be added now as an additional classification, because there commended screen brilliancy will probably be different from what is required for black-and-white. Because color pictures have a color contrast usually considered in black-and-white work, a lower relative screen brilliancy is generally acceptable for color than for monochrome pictures. This, fortunately, offsets to some extent the loss of light due to the absorption of the colors in the film. Existing concepts of color absorption will have to be modified now that the 16-mm. Kodachrome process is available, but it should be possible to establish some recommendation for desirable screen intensity. Due to the high transparency of the colored image of the Kodachrome film, and remembering the gain in visual acuity due to color contrast, it would seem that the recommended intensity for black-and-white work would be adequate, although perhaps a somewhat higher intensity, say, 8 to 10 foot-candles, might be desirable. We have not had sufficient experience with the new color process to permit definite recommendations, but believe that the screen sizes suggested in Table IV will be found satisfactory.

(3) MISCELLANEOUS RELATED FACTORS

It is rather painfully evident that existing methods of rating or regarding projection efficiency have all been from the point of view of the machine, lamp, and screen efficiencies. The basic physiological factors are not adequately known, and so are considered only from a more or less empirical standpoint. Strictly speaking, we should start from the eye of the observer and work back to the screen, and establish our recommendations from that point of view. Some of the factors to be considered in this connection are as follows:

(*a*) *Flicker.*—Flicker is a function of the speed of the projector and of the extent and number of flicks during the projection of each frame. In general, with 16-mm. projectors, it is less important than in theatrical work (see section 1*a*). Visual acuity is improved appreciably, and there is a lower fatigue factor,[2,7] both matters of extreme importance in educational work.

(*b*) *Steadiness.*—As far as we know, 16-mm. projection (assuming the higher grades of projectors are used) is steadier than theatrical. Travel-ghost, or improper shutter timing, is practically unknown. A recent War Department specification called for a maximum image jump of $^1/_4$ inch upon a screen six feet high. In really high-grade 16-mm. projectors the jump upon a 6-foot screen is less than $^1/_8$

inch.[2] This is also most important in educational work on account of the lower fatigue involved in viewing rock-steady pictures.

(*c*) *Visual Contrast and Resolution of Detail.*—The effective contrast of the picture as seen by the eye depends upon all the factors involved in projection, and it is accordingly very difficult to define or specify what acceptable visual contrast may be. It depends, first of all, upon the color as well as upon the intensity of the light. It depends upon whether the film is colored or whether the silver image in a black-and-white film has been stained. It depends upon the grain structure and the resolution of detail in the print, which, in turn, are affected by the contrast characteristic of the lens. It depends also upon the color of the screen and the detail resolving power of the screen. The last factor is further dependent upon the distance of the observer as related to the magnification of the image.

CONCLUSION

Due to the multiplicity of the factors involved in any comprehensive discussion of the visual efficiency of projection, the accepted method of measuring screen illumination is regarded the most conveniently satisfactory method for general use—provided that the measurement is made under clearly defined conditions and that the screen characteristic be considered more fully than usual, at least in non-theatrical work. The recommendations in Table IV for suitably sized beaded screens for ordinary purposes are the results of extensive consideration of the many factors outlined above.

TABLE IV

Recommended Screen Sizes

Wattage of Projector Lamp Used	Lens Speed (*f*/Number)	Size of Screen Recommended for B & W	Size of Screen Recommended for Kodachrome (Tentative)
1000	1.65	6 × 8 feet	5 × 7 feet
750	1.65	5 × 7 feet	4 1/2 × 6 feet
750	2	4 1/2 × 6 feet	3 × 4 feet
500	2	3 × 4 feet	30 × 40 inches
400	2	30 × 40 inches	22 × 30 inches
300	2	22 × 30 inches	18 × 24 inches

These screen sizes are suggested upon the basis of a screen illumination of the order of 6 foot-candles, with the projector running without film and fulfilling the ten requirements as detailed above. The sizes given in the table can be doubled for special cases. It is recommended also that projectors suitable for serious non-theatrical work project steady pictures with less than $^1/_4$ inch of jump in a picture six feet high. Also, it is recommended that the illumination be uniform over the entire screen, within 15 per cent.

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DISCUSSION

MR. CRABTREE: It would seem from these data that it is highly desirable to designate the potential illumination by screen lumens rather than by wattage. In other words, if you have a 500-watt lamp with a very inefficient optical system, it might not give you as high a screen brightness as, perhaps, a 250-watt lamp with an efficient projector.

MR. DUBRAY: That is true, and the evident scope of the paper is to suggest such a procedure.

MR. FARNHAM: The matter of operating a higher wattage lamp at a lower voltage in order to gain lamp life, and still apparently have enough screen illumination has rather interesting possibilities. It seems to me that if you can get along with the fullest output of the lamp, it might be better to reduce the cost of the projector; in other words, to buy a smaller projector with a smaller lamp, and operate the lamp at full brilliance. My experience shows that it is generally better to control the light at the projector, and operate it at full brilliancy. Some screen illumination tests made a few years ago showed that when the observer adjusted the amount of light, in almost every case he took all the light he could get.

The table in your paper must include lenses along with the lamp wattage, because the lens has considerable effect upon the screen illumination. Projectors vary as greatly as two to one, as to light from a given lamp, so I don't believe an evaluation by wattage of the lamp will work out as well as one in terms of the lumen output of the projector.

MR. DUBRAY: No true evaluation of light efficiency can be made if the whole optical system of the projector is not taken into consideration.

As to regulating the screen intensity by undervolting the lamps, although Mr. Farnham's remarks are very true, it must be borne in mind that the portability of 16-mm. projectors prompts their use under greatly varying conditions. In industrial or classroom or school auditorium projection, one may have to project one day in a hall where the projector is set 100 or more feet from the screen; the next day or in another classroom, the same operator may have to use the same projector for 20- or 30-foot throws. Control of screen illumination through voltage control is most desirable under such conditions.

MR. FARNHAM: Under such conditions the machine might be operated by a skilled operator who knew what was involved; but as a general recommendation to all users of projectors, I am afraid more difficulties may be caused than good accomplished.

MR. DUBRAY: We have found, however, a great response on the part of users of our equipment in assimilating the rather simple fundamental principles that govern good projection.

MR. SHAPIRO: The cost per hour of the 1000-watt lamp, giving illumination equal to that of the 750-watt lamp, indicated that it would be more economical to use the higher-wattage lamp underloaded in order to effect lower lamp hour cost. That is particularly interesting in connection with the general complaint about the high original cost of these projection lamps, and may be a deciding factor in projector design, particularly where the requirements are flexible, such as in the case cited by Mr. Dubray, in which the projector was used with a throw of 100 feet and then with one of 25 feet.

MR. FARNHAM: In Fig. 1 the light of the 500-watt lamp was shown to be only about 45 per cent of that of the 1000-watt lamp. In other words, the increase of screen illumination, changing from the 500- to the 1000-watt lamp, seems to be greater than the increase of wattage, which is not in accord with usual practice. I am wondering whether the table does not involve an improved lens system, along with the higher-wattage lamp. That would tend to influence the costs and make them not strictly comparable.

MR. MITCHELL:* Your assumption is correct that the efficiency of the optical system of the 1000-watt projector is greater than that of the optical system of other projectors that may have been used for this work. Attention is directed specifically to the fact that the same projector can use different lenses, so that its efficiency can vary as shown in Table I.

MR. FARNHAM: The increase in screen illumination is seldom in accordance with the wattage.

MR. KELLOGG: Do I understand, Mr. Dubray, that 48 interruptions per second was regarded as far as it was desirable or practicable to go for reducing flicker?

MR. DUBRAY: Yes; that has been our practice. We project 16 frames per second and 3 interruptions per frame. The one-bladed shutter of the projector revolves three times while the picture frame is stationary.

MR. KELLOGG: As I understand it, then, the interruption at the rate of three times a picture is desirable when projecting 16 frames a second, but at 24

* Communicated.

frames a second you hardly notice the benefit of three interruptions per picture, as compared with two.

MR. DUBRAY: Two interruptions per second were used when sound came into existence for 35-mm. film. The linear speed of the projector was at that time 9 feet per minute. For 16-mm. projection, the machine must be versatile, so that sound or silent pictures can be projected with it. The three interruptions per second are therefore necessary.

It happens very often, also, that for analysis work a 16-mm. projector may be run at as low a speed as 10 picture frames per second, and an apparatus that can project without flicker at that speed is obviously very desirable.

MR. SHAPIRO: In our experiments we have found at 48 interruptions per second the flicker becomes perceptible at a speed of less than 12 frames; but at 24 frames we can get along with about two-thirds of that number of interruptions per second without appreciable flicker at that speed.

MR. FARNHAM: The paper stated that the brightness at the corners of the screen should not be more than 15 per cent less than the brightness at the center. I believe that you will find in actual experience that most projectors exceed that and it can be exceeded without serious effect, or without being seriously noticeable. The specification, probably, should be extended to take care of sudden changes between the corners. In other words, a 15 per cent change from the center of a picture to the corner is practically unnoticeable, whereas a 15 per cent change in a very short distance from the center becomes quite noticeable. The abruptness of the change is a factor, as well as the amount of the change.

MR. DUBRAY: May I suggest, Mr. Farnham, that the recommendation made in the paper is not to take readings at the corners; but at the center, the top center and bottom center of the screen, and the left and right centers of the screen.

STUDIO ACOUSTICS*

M. RETTINGER**

Summary.—*The possible means are discussed for obtaining the same amount of recorded reverberation with a directional microphone as is obtained when recording is done, in an equally configurated studio, with a non-directional microphone. First, there is assumed an equal distance between microphones and the source of sound; and, second, equal mean absorption in the two studios.*

The directional properties of the velocity ribbon and the unidirectional microphone have introduced a new and important factor in the theory of studio acoustics, namely, the imaginary solid cone of reception associated with the microphone. Mathematically, a solid angle is defined as the ratio of the surface of the portion of a sphere enclosed by the conical surface forming the angle to the square of the radius of the sphere. The unit is the steradian, and there are 4π steradians to a sphere.

For the sake of simplicity in the calculations it must be assumed that this cone of reception is clearly defined—that is, that the only sound actuating the microphone lies within this cone, and that all sound without it is ineffective. While no such sharp boundary actually obtains, a 100 per cent response existing only along the normal to the ribbon, the error introduced by regarding the solid cone as sharply limited is not very large, nor smaller nor larger for different frequencies, because the directional characteristic of the velocity microphone is practically independent of the wavelength of sound.

For a non-directional system of recording the energy density due to the direct sound at the microphone is

$$E_d = P/D^2 4c\pi \tag{1}$$

where P = power output, or rate of sound emission of the source; assumed to be constant.

D = distance between the microphone and the sound source.

c = velocity of sound.

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** Pacific Insulation Co., Los Angeles, Calif.

Within a room having walls of average absorption a, the energy density due to reflected sound after steady-state conditions have set in, is[1]

$$E_r = 4P(1 - a)/cSa \tag{2}$$

where S = total surface in the room.

Dividing (*2*) by (*1*), we get

$$E_r/E_d = 16\pi D^2(1 - a)/aS \tag{3}$$

which ratio represents a measure of the received reverberation.

In the case of the directional microphone, however, the reflected sound energy actuating the microphone is less, in the ratio of the solid cone of reception divided by 4π; thus, for steady-state conditions

$$E'_r = 4P(1 - a)K/cSa4\pi \tag{4}$$

where K represents the solid cone of reception, expressed in steradians. Therefore, the amount of received reverberation becomes

$$E'_r/E_d = 4D^2K(1 - a)/aS \tag{5}$$

which differs from equation (3) by the factor $K/4\pi$,which represents the difference in recorded reverberation when a directional microphone is used, provided the same studio and the same recording distance are used.

Assuming now, for the sake of illustration, two studios—studio A and studio B—which have the same shape and volume and in each one of which sound is recorded at the same distance from the source. Suppose in studio A that a condenser microphone is employed, and that the mean absorption in the studio is such as to permit good recording. The question arises as to what may be the mean absorption in studio B in which a directional microphone is used? Setting equation (3) equal to equation (5), we may write

$$16\pi D^2(1 - a)/aS = 4D^2K(1 - a')/a'S$$

or

$$a' = aK/[aK + 4\pi(1 - a)] \tag{6}$$

where a' represents the mean absorption in studio B, in which the directional microphone is the same distance away from the source as the condenser microphone is in studio A. This mean absorption, a', to repeat, will make for the same amount of received reverberation in studio B as the mean absorption, a, makes in studio A.

The following table shows the relation between a and a' if K is taken equal to π

a	a'
0.1	0.0276
0.2	0.0555
0.3	0.0970
0.4	0.1430
0.5	0.2000
0.6	0.2730
0.7	0.3690
0.8	0.5000
0.9	0.6820
1.0	1.0000

As was pointed out to the author by E. C. Wente, this table should be regarded with some caution. If the sound is picked up by a non-directional microphone within a room and the source is suddenly interrupted, there will be a drop in the generated voltage as soon as the direct sound has passed the microphone. After this the voltage, on the average, will decay logarithmically in accordance with the decay of the reverberant sound in the room. If now a directional microphone is used, there will similarly be an initial drop, somewhat greater, depending upon the value of K, after which the voltage will again decay logarithmically at the same rate as with the non-directional microphone. This rate of decay can not be altered by a change in the directive properties of the microphone. If, however, the absorption in the room is increased, not only will the initial drop be greater, but the rate of decay of the subsequently developed voltage will be greater. It is thus seen that the character of the voltage generated by a microphone when actuated by sound, such as speech or music, will not be quite the same when the ratio of E_r to E_d is reduced by making the microphone more directive as when this reduction is effected by an increase in the absorption within the room.

This method of decreasing the mean absorption in order to obtain the same amount of received reverberation has the advantage of obtaining a more uniform absorption characteristic in the studio, since materials having a comparatively small absorption coefficient at frequencies of 500 and 1000 cycles per second do not show such an abrupt decrease in their absorptivity at the low frequencies as do materials that are highly absorptive at the above-mentioned frequencies.

There is another method of obtaining the same reverberation with a directional microphone that exists when recording is done with a non-directional microphone. It consists in lengthening the distance between the source and the microphone. Again setting equation (3) equal to equation (5), but assuming now the same mean absorption in both studios, we get

$$16\pi D^2(1 - a)/aS = 4D^2_1(1 - a)K/aS$$

or

$$D^2_1 = 4\pi D^2/K \tag{7}$$

where D_1 represents the distance between the directional microphone and the source of sound.

Again assuming K equal to π, we get

$$D_1 = 2D \tag{8}$$

which means that we can double the distance between the source and the directional microphone and still obtain the same amount of reverberation that exists when recording is done with a non-directional microphone D units of length from the source.

This method appears to be the more economical one, as the recording in the studio can be done with both the directional and the non-directional microphone without having to install variable absorbents. However, for scoring stages it may be more advisable to decrease the mean absorption in the stage when recording with a velocity microphone, because musicians, as a rule, can play better in live than in dead rooms.

The author wishes to express his sincere appreciation to Professor V. O. Knudsen and Messrs. Townsend and Hansen of the Fox Film Corporation, whose interest in the author's work has been of great value to him.

REFERENCE

[1] EYRING, C. F.: "The Reverberation Time in Dead Rooms," *J. Acoust. Soc. Amer.*, 1 (1930), No. 2, p. 217.

THE ARGENTOMETER—AN APPARATUS FOR TESTING FOR SILVER IN A FIXING BATH*

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Summary.—*The Argentometer consists essentially of a light-source, a glass cell for holding the solution to be tested, a photronic cell, and a microammeter. The action of the instrument depends upon the change of transparency of a solution containing silver and hypo after the addition of sodium sulfiide and certain other chemicals. Formulas for the three solutions required and complete instructions for making a silver determination are given. Estimations can be made on hypo solutions containing either potassium or chrome alum and the results can be read directly from a scale upon the microammeter.*

For many years the activity of fixing baths has been estimated by noting the time taken to clear a piece of unexposed film. When electrolytic silver recovery was introduced to the motion picture industry, this test proved insufficient and it became necessary to devise routine analyses for each of the more important constituents of the bath.

The material which exerts the greatest influence upon both fixing and regeneration of the bath is the soluble silver salt derived from the material being processed. Many tests are available for the silver, but only the colorimetric sulfide reaction is quickly and easily applied. At its simplest, a sample of the bath is diluted with water and treated with a little sodium sulfide solution. A brown precipitate or color is produced, the depth of which is roughly dependent upon the silver present. The quantity is estimated by comparing the color of the test solution, held before an illuminated screen in a glass tube, with other tubes containing a known concentration of silver sulfide.

There are two serious drawbacks to this procedure. The standardized comparison solutions alter in color in an unpredictable manner and become unreliable after the second month. The color developed from the solutions under test varies not only with the quantity of silver, but with the acidity, the sulfite and alum content, the quantity

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of gelatin and stale developer, as well as the metallic salts from the tanks and pipes, accumulating in the bath.

The method of silver estimation presented here dispenses with the silver standards and minimizes or eliminates the disturbing chemical factors. The method comprises (*1*) a photoelectric comparator, *i. e.*, the "Argentometer"; (*2*) a precipitation procedure employing buffered solutions.

THE ARGENTOMETER

The silver comparator illustrated in Figs. 1 and 2 is a hollow metal box which contains a lamp *A*, a transparent vessel *B* for the liquid

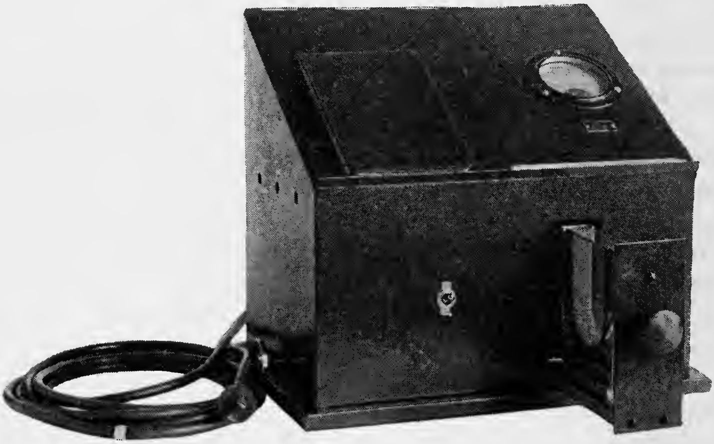

FIG. 1. The Argentometer, complete.

under examination, and a photronic cell *C*. The box is closed with a sloping lid (Fig. 2), to one side of which is inserted a microammeter *D*, scaled in grams of silver per liter (Fig. 3). The lid forms a convenient rest for pencil and notebook. If there is any point of novelty in this simple instrument, it is that the need for a standard lamp and regulated voltage is obviated. The solution under test is diluted with water and placed into the glass vessel, which is then pushed into the box. The current is switched on and the lamp is moved forward or backward upon its adjustable slide *E* (Fig. 1), until a standard deflection of 150 microamperes is registered upon the lower scale of the meter. This deflection is adopted as the measure for *zero* content of silver, and is so marked upon the upper silver scale. The glass vessel is now withdrawn and the precipitating solutions added, stirring; after which the vessel is again thrust into the box. The meter needle recedes to a lesser deflection, which corresponds to the depth of color generated in the solution by the interaction of the reagent and the silver salts. The quantity of silver present is read directly upon the upper scale, which is calibrated *backward* from the place of maximum deflection.

It will be noted in Fig. 3 that the scale is most open and the sensitivity is greatest for solutions poorest in silver—a very practical advantage. The establishment of the zero point at the place of maxi-

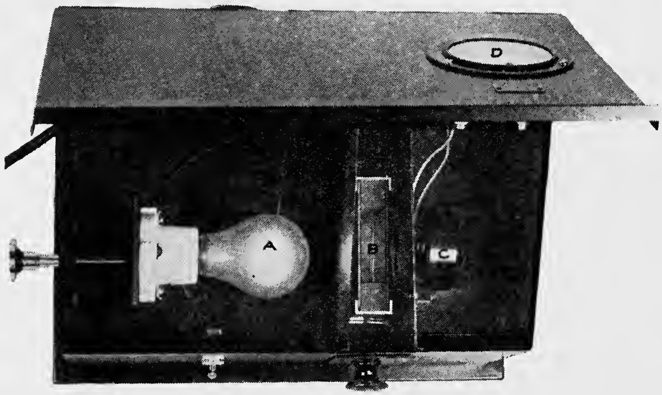

FIG. 2. Showing the three important elements of the Argentometer: (*A*) the light-source; (*B*) the glass cell for holding the solution; (*C*) a photronic cell; and (*D*) a microammeter.

mum deflection renders the instrument relatively unaffected by changing conditions. Should the lamp burn out or should it be necessary to change to another voltage, a new lamp may be inserted and the appropriate position found upon the lamp slide. Should the test solution be dark colored or cloudy instead of colorless and transparent, the opacity is compensated by the lamp setting, and only the *additional* opacity conferred later by the silver sulfide is registered.

THE SOLUTIONS

The opacity of a given concentration of silver sulfide depends upon the covering power of the colloidal sulfide particles, and this in turn depends upon the *p*H, the neutral salt content, and the "protective" powers of the solution. In fixing baths containing hypo, alum, and, perhaps, iron, the acidity should be high enough to prevent precipitation of alumina and chromic hydrate or ferrous sulfide, and sufficiently low to prevent the separation of colloidal sulfur. Citric acid and sodium citrate are used to keep the *p*H in the proper range, and it is satisfactory to find that the addition of a standard quantity of these reagents will adjust fixing bath samples of widely different composition and condition. The "protective" power of a fixing bath varies enormously with its age, and it is thus necessary to add sufficient gelatin to the test solution to give a large excess over any likely to be present. A plain sodium sulfide solution has been found unsatisfactory as a precipitant because it may generate colloidal sulfur upon meeting the acidified sample. Accordingly, sodium sulfite is added to the stock solution of this reagent.

FIG. 3. The microammeter is calibrated directly in grams of silver per liter.

OPERATION

The action of the estimator depends upon the change of transparency of a solution containing silver and hypo after the addition of certain chemicals. These are made up as in Table I to form stock solutions *A*, *B*, and *C*:

TABLE I

	Metric	Avoirdupois
Solution A:		
Citric Acid	9 gm.	1 1/4 oz.
Sodium Citrate	100 gm.	13 oz.
Water to make	1000 cc.	1 gal.
Solution B:		
Gelatin	4 gm.	1/2 oz.
Water to make	1000 cc.	1 gal.
Clove Oil (few drops for preservation)		
Soak the gelatin in a small amount of water until well swollen; then heat gently, stirring, until all is in solution; dilute to proper volume with water, pour into a bottle, add the clove oil, and shake a few times.		
Solution C:		
Sodium Sulfide (C. P. crystals)	10 gm.	1 oz.
Sodium Sulfite (anhydrous)*	6 gm.	3/4 oz.
Water to make	100 cc.	10 oz.

* Sodium bisulfite or metabisulfite must on no account be used.

PROCEDURE

The instrument as supplied is fitted with a 110-volt, 40-watt, frosted bulb lamp. The plug at the side of the box is therefore connected to a 110-volt source. Should the house-supply differ from 110 volts, the lamp should be changed to a 40-watt, frosted bulb of the appropriate voltage.

To make an estimation, a sample of the hypo solution is measured out with a 2-cc. pipette and allowed to drain into a 50-cc. graduated cylinder. Five cubic centimeters of solution *A* are added, and then 5 cc. of solution *B;* after which the cylinder is filled to the 50-cc. mark with water. The contents are now transferred to the glass cell, which is placed into the sliding carriage and pushed into the estimator box as far as it will go. This will locate the cell in position between the light-source and the photronic cell. The current is switched on and the light moved backward or forward, until the needle of the microammeter points to zero upon the upper silver scale (150 microamperes upon the lower). The cell is pulled out and 1 cc. of the sodium sulfide solution *C* added from a pipette. The solution is stirred with a glass rod, the end of which is protected by a short piece of rubber tubing, and the cell is pushed back into the box. The microammeter needle will assume a new position from which the silver content of the sample can be read upon the upper scale.

It occasionally happens that the current supply for the lamp fluctuates so badly that the zero setting alters during an estimation, giving faulty results. When this is suspected, or when great accuracy is required, it is best to take a check-zero reading as follows: After the sample has been mixed with solutions *A* and *B* and the additional water, and placed into the cell, the latter is pushed into the instrument as before, and a careful zero adjustment made. The cell is withdrawn and the position of the needle upon the microampere scale is noted. This is the check-zero, to which the lamp can be adjusted, should the current alter during subsequent proceedings. It is well to find the zero and the check-zero two or three times in succession. The sodium sulfide solution can now be added and the estimation carried out as before. Immediately before and after taking the reading for the silver, the cell should be withdrawn to see that the needle points exactly to the check-zero. If it does not, the position of the lamp should be adjusted.

If the glasses of the cell become broken, they can be replaced by new ones which need not be accurately of the same kind or thickness as the broken ones. It is, however, essential that the plates be adjusted to remain exactly $^5/_8$ of an inch apart. The spacing can be adjusted by inserting shims between the edges of the glass plates and the brass frames.

SCOPE OF OPERATION

The estimation may be performed upon hypo baths containing either potassium or chrome alum, since the color of the chrome alum is compensated for by moving the light until the needle indicates zero before the sodium sulfide is added.

Concentrations of silver as high as 3 grams per liter are often encountered in commercial fixing baths for prints, and 8 to 10 grams per liter for films. Proper fixation can not be attained with such overworked solutions, traces of silver being left in the paper and in the emulsion. This ultimately causes yellowing of prints and the growth of a brown surface sheen upon negatives or motion picture film. Complete removal of silver is desirable for permanence, and is imperative if the materials are to be toned or dyed. The safe upper limit for the silver content of print fixing baths may be placed at $1^1/_2$ grams per liter, with 4 grams as the upper limit for films. Desirable working concentrations are 0.5 gram and 1.5 grams per liter, respectively.

REPORT OF THE PROJECTION PRACTICE COMMITTEE*

PROJECTION ROOM PLANNING

The following recommendations for projection room planning have been formulated after an exhaustive study by the Committee and are submitted for adoption as standards. The Committee urgently recommends their acceptance by all architects and builders in constructing and remodeling projection rooms so that a greater uniformity of projection room construction will exist in the future.

In following these recommendations the proper authorities should in all cases be consulted for possible deviations therefrom. Any fire protection requirements specified herein are in accordance with the regulations of the National Board of Fire Underwriters. However, these requirements are neither complete nor in detail, and it is the plan of the Committee to work with the Fire Underwriters in the near future in the preparation of a comprehensive set of recommendations for adoption as standard regulations by the industry.

PROJECTION ROOM CONSTRUCTION

General.—Three layouts are presented, *viz.*, Figs. 2, 3, and 4, which were planned with careful regard for flexibility, simplicity of construction, and ease of operation. The particular plan to be followed should be selected according to the size of the theater and the manner of operating it. The key to the symbols used on the plans is shown in Fig. 1.

The projection room shall be fire-proof and sound-proof, and all walls exposed to the theater shall be of tile, brick, gypsum, or other approved fire-resisting material. It shall have a minimum height of 10 feet and a maximum of 12 feet. The minimum depth shall be 12 feet. The length of the projection room shall be governed by the quantity and the kind of equipment, as shown in the plans and in accordance with local requirements. Consideration should always be given for probable future needs.

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

The Committee recommends that the projection room be located outside the fire-wall of the theater, and that it be so situated that the projection angle shall not exceed 15 degrees.

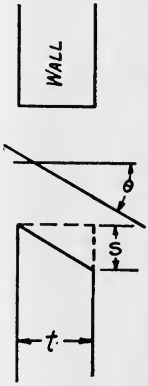
Floor.—The floor of the projection room shall be sufficiently strong and solid for the load it is to bear, and shall be constructed in accordance with local building regulations. A generous factor of safety should be allowed.

A type of floor construction that is recommended consists of (*1*) a reënforced concrete floor-slab not less than 4 inches thick; (*2*) a tamped cinder fill above the floor-slab not less than 2 inches thick;

TABLE I

Splay of Projection and Observation Ports

Thickness (t) of Wall (Inches)	4	6	8	10	12	14	16
Angle of Projection (θ)	Splay (Inches)						
5	3/8	1/2	3/4	7/8	1 1/8	1 3/8	1 1/2
10	3/4	1	1 3/8	1 5/8	2	2 1/4	2 5/8
15	1 1/8	1 5/8	2 1/8	2 3/4	3 1/4	3 3/4	4 1/4
20	1 1/2	2 1/4	2 7/8	3 5/8	4 3/8	5 1/8	5 7/8
25	1 3/4	2 7/8	3 5/8	4 7/8	5 7/8	6 7/8	7 3/4
30	2 3/8	3 1/2	4 3/8	5 7/8	7 1/8	8 1/4	9 1/2



and (*3*) a trowelled cement finish above the cinder fill not less than 2 inches thick.

Ceiling.—The ceiling shall be of plaster or cement suspended on metal laths or other suitable material.

Walls.—The finished walls of the projection room shall be not less than 6 inches thick, including an inside and an outside layer of plaster at least 3/4 inch thick. In all cases, the inside surface of the front wall shall be smooth and without structural projections.

Acoustic Treatment.—The inside walls and ceiling of the projection room shall be finished with an acoustic plaster or other sound-absorbing material approved by the proper authorities.

Projector Ports.—The finished projector ports shall be 10 inches wide and 12 inches high (Fig. 5). The bottom of the opening shall be splayed in accordance with Table I.

Tables II and III apply to certain well-known makes of projectors. Table II gives the distance from the front wall to the center of the conduit outlets in the floor for the projectors. Table III gives the dis-

- Ceiling Outlet—"Reelite"
- Wall Bracket
- Ceiling Outlet—Canopy Switch Type
- Ceiling Outlet
- Outlet in Floor for Dissolving Stereopticon
- Outlet in Floor for Effect Machine
- Outlet in Floor for Flood Lamp
- Outlet in Floor for Projector Arc
- Push Button
- Double Baseboard Receptacle
- M.P.M. Motor Outlet
- House Phone
- Wall Switch for Ceiling Lights

Wire Sizes

Low-Intensity	30 A.	No. 4
Reflector High-Intensity	75 A.	No. 2
High-Intensity	125 A.	No. 00
Super High-Intensity	200 A.	200,000 C. M.

FIG. 1. Key of symbols for projection room layouts.

TABLE II

Distance from Front Wall to Center of Projector Conduit Outlet
(See Figs. 2, 3, and 4)

Proj. Angle (Degrees)	Simplex R.C.A. Type *R* Stand	Simplex West. Elect. Type *R* Stand	Motiograph	Simplex Acme	Simplex R.C.A. *L* and *M* Base	Simplex West. Elec. *L* and *M* Base
−6	44 1/2	45	24	26 1/2	30	33
−4	45	46	25 1/2	26 1/2	30	33
−2	46	47	27	27	30	33
0	47	48	28 1/2	27 1/2	30	33
2	48	49	30	28	30	33
4	48 1/2	49 1/2	31 1/2	28 1/2	30	33
6	49	50	33	28 1/2	30	33
8	50	51	34	28 1/2	30	33
10	51	52	35 1/2	28 1/2	30	33
12	52	53	37	29	30	33
14	53	54	38	29	30	33
16	54	55	39 1/2	29	30	33
18	54	55 1/2	40 1/2	29	30	33
20	55	56	42	29	30	33
22	56	57	43	29	30	33
24	57	58	44	28 1/2	30	33
26	58	59	44 1/2	28 1/2	30	33

TABLE III

Height from Floor to Center Line of Projection Port
(See Figs. 2, 3, and 4)

Proj. Angle (Degrees)	Simplex R.C.A. Type *R* Stand	Simplex West. Elec. Type *R* Stand	Motiograph	Simplex Acme	Simplex R.C.A. *L* and *M* Base	Simplex West. Elec. *L* and *M* Base
−6	51 1/2	51 1/2	52	51	51	51
−4	50	50	50	50	50	50
−2	49 1/2	49 1/2	49	49	49	49
0	48	48	48	48	48	48
2	47 1/2	47 1/2	47	47	47	47
4	47	47	46	47	46	46
6	45 1/2	45 1/2	45	45	45	44 1/2
8	44	44	44	44	44	43 1/2
10	42	42	42	43	43	42 1/2
12	40	40	41 1/2	52 1/2	42	41
14	39	39	40	41 1/2	41	40
16	37 1/2	37 1/2	38 1/2	40 1/2	40	39
18	35 1/2	35 1/2	37	39 1/2	38 1/2	38
20	34	34	35 1/2	38 1/2	37 1/2	37
22	33	33	33 1/2	37 1/2	36 1/2	35 1/2
24	32	32	31	37	35 1/2	34 1/2
26	31 1/2	31	30	36	34	33 1/2

tance from the floor to the center line of the projector ports for different angles of projection.

In preparing this report, the Committee encountered considerable difficulty in forming suitable recommendations for the location of the projector ports. This was due to the non-uniform design of the various makes of projectors. Table IV is a tabulation of two constants for various angles of projection which, when substituted in the formula, will give the distances A and B for makes of projectors other than those included in Tables II and III.

The Committee recommends the use of means other than glass in projector ports to prevent transmission of noise from the projection room to the auditorium, such as reducing the free aperture of the port to the minimum essential for projection.

Observation Ports.—The free aperture of the observation ports shall be 12 inches wide and 14 inches high, and the distance from the floor to the center line of the openings shall be in accordance with Table V. The bottom of the port shall be splayed in accordance with Table I.

The observation ports shall be fitted with a good grade of plate glass set at an angle as shown in Fig. 6, and provided with a rubber frame between the glass and the sides of the port hole in order to reduce the transmission of sound from the projection room into the auditorium. The glass shall be hinged at the centers of the side edges so that by swinging it to a horizontal position, both sides can be cleaned from the projection room.

Other Ports.—All other ports, such as those intended for effect projectors, dissolving stereopticons, or single spot-lamps, shall be 30 inches wide and 36 inches high. The distance from the floor to the center line of the ports shall be 38 inches. The minimum spacing allowed between these ports shall be as shown upon the plans. The bottom of the ports shall be splayed in accordance with Table I. The placing of these ports to the right or the left of the projectors shall be optional and according to conditions.

Floor Covering.—Where local regulations permit, the floor of the projection room should be covered with a good grade of fire-proof material; otherwise, the cement should be painted or filled. The floor covering should be laid before the equipment is installed. The floors of rooms adjacent to the projection room should be painted with a good grade of paint for concrete.

Projection Room Painting.—The color of the projection room walls and doors shall be olive green to the height of the door lines. Acoustic material should either be painted in accordance with the instructions of the manufacturer of the material, or materials of the specified colors should be chosen: The walls above the door line and the ceiling shall be a buff color. All iron work of projection ports shall be covered with at least two coats of flat black paint. All other rooms shall be painted buff.

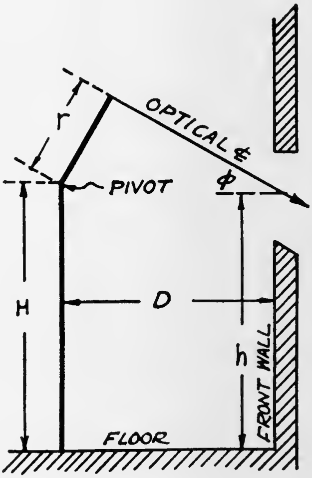
Projection Room Lighting.—An individual approved ceiling fixture

TABLE IV

Method of Locating Projector Port for Any Projector

$$h = H + rA - DB$$

Projection Angle (Degrees)	A	B
0	1.00	0.00
2	1.00	0.04
4	1.00	0.07
6	1.01	0.11
8	1.01	0.14
10	1.02	0.18
12	1.02	0.21
14	1.03	0.25
16	1.04	0.29
18	1.05	0.33
20	1.06	0.36
22	1.08	0.40
24	1.09	0.45
26	1.11	0.49
28	1.13	0.53
30	1.16	0.58



H is the height of the center of the projector pivot from the floor; r is the radial distance of the optical center line above the center of the pivot; D is the distance of the center of the pivot from the front wall of the projection room; ϕ is the angle of projection; and h is the required height of the center of the port from the floor of the projection room. Select the values of a and b corresponding to the angle of projection, and substitute in the formula.

with canopy switch shall be installed for each piece of equipment, and shall be placed in line parallel to the front wall at a distance not less than 18 inches nor more than 24 inches from the front wall. The outlet connected to the emergency lighting system shall be located in the ceiling midway between the extreme ends of the projection room and 4 feet from the back wall. Small projection rooms shall be equipped with one approved "reelite," and large projection rooms with two such lights conveniently located.

Conduits.—(*a*) Conduits shall in all cases be concealed, and all boxes shall be of the flush-mounting type. (*b*) The size of conduits for projection arcs shall be in accordance with the wire sizes indicated in Fig. 1, and in conformance with the regulations of the proper

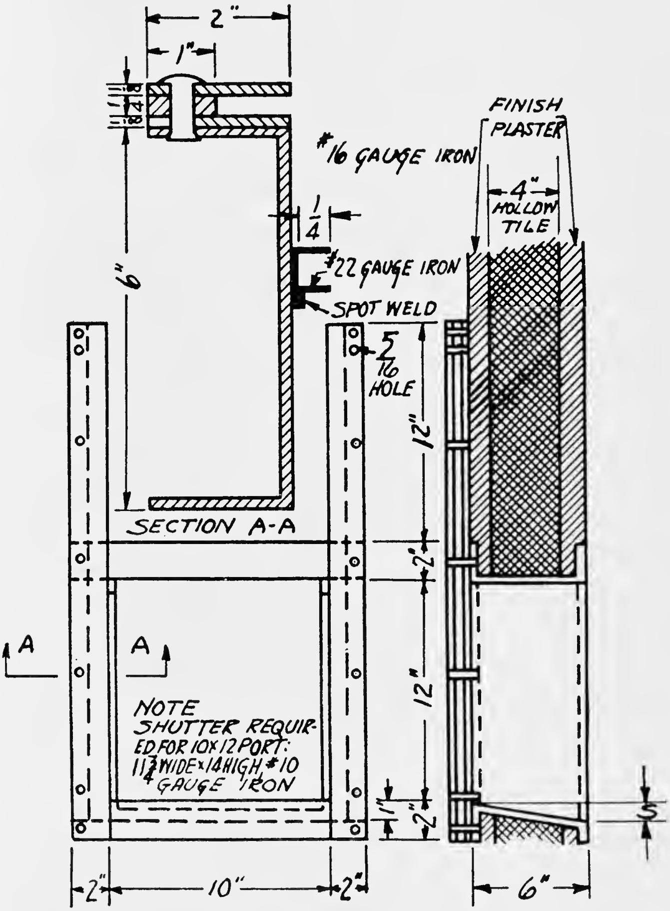


FIG. 5. Standard projection port construction.

authorities. These sizes anticipate the need for increased capacity, and should be adhered to in order to provide space for pulling in larger wires as needed. (*c*) Conduit for sound equipment shall conform to the type of sound equipment to be installed. The manufacturers of such equipment should be consulted with regard to the proper layout of the sound system before proceeding with the installation.

Projection Room Heating.—Proper provision shall be made for heating the projection room. The same facilities used for heating the theater should be extended to the projection room.

Projection Room Ventilation.—An exhaust system of ample capacity shall be provided for the projection room and other adjacent rooms used in connection with projection equipment. All arcs of whatever description shall be connected into the ducts of a separate exhaust system containing a blower type of exhaust fan.

There shall also be a separate opening or vent flue in the main projection room leading directly to the nearest outside air. Such flues shall be at least 78 square inches in cross-section and constructed of incombustible materials. When the projection room is in use, a current of air shall be maintained through the room to the outside air at a minimum rate of 50 cubic feet a minute, and sufficient to furnish a complete change of air in 10 minutes. In cases where the theater is air-conditioned, the projection room shall be connected into the main duct of this system.

TABLE V

Height of Observation Port
(See Figs. 2, 3, and 4)

Proj. Angle (Degrees)	Distance, Floor to Center of Observation Port (Inches)	Proj. Angle (Degrees)	Distance, Floor to Center of Observation Port (Inches)
−6	51	+10	43
−4	50	+12	42
−2	49	+14	41
0	48	+16	39
+2	47	+18	38
+4	46	+20	37
+6	45	+22	37
+8	44	+24	37
		+26	36

Additional Rooms.—A separate room shall be provided solely for the rheostat equipment. This room shall be provided with ventilating means as previously set forth. An additional and separate room, properly ventilated, shall be provided for the projection arc supply equipment. Where local regulations require, a properly ventilated room should be provided for rewinding.

Toilet and Washrooms.—Hot and cold water and other toilet facilities shall be installed, and located convenient to the projection room. Suitable space shall also be provided for clothes lockers.

PROJECTION ROOM EQUIPMENT

Projectors and Spacing.—Where two projectors are used, they shall be equally spaced upon either side of the center line of the auditorium.

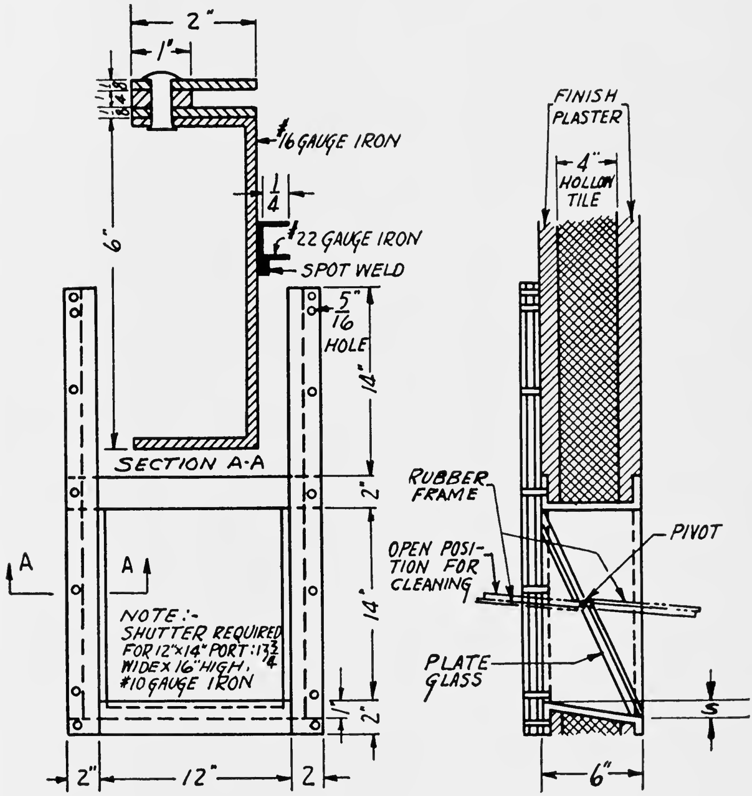


FIG. 6. Standard observation port construction.

When three projectors are used, the center projector shall be placed upon the center line of the auditorium. The distance between projectors shall be $4^1/_2$ feet, measured between lens centers, for projection distances greater than 100 feet. For projection distances less than 100 feet, the spacing shall be 4 feet.

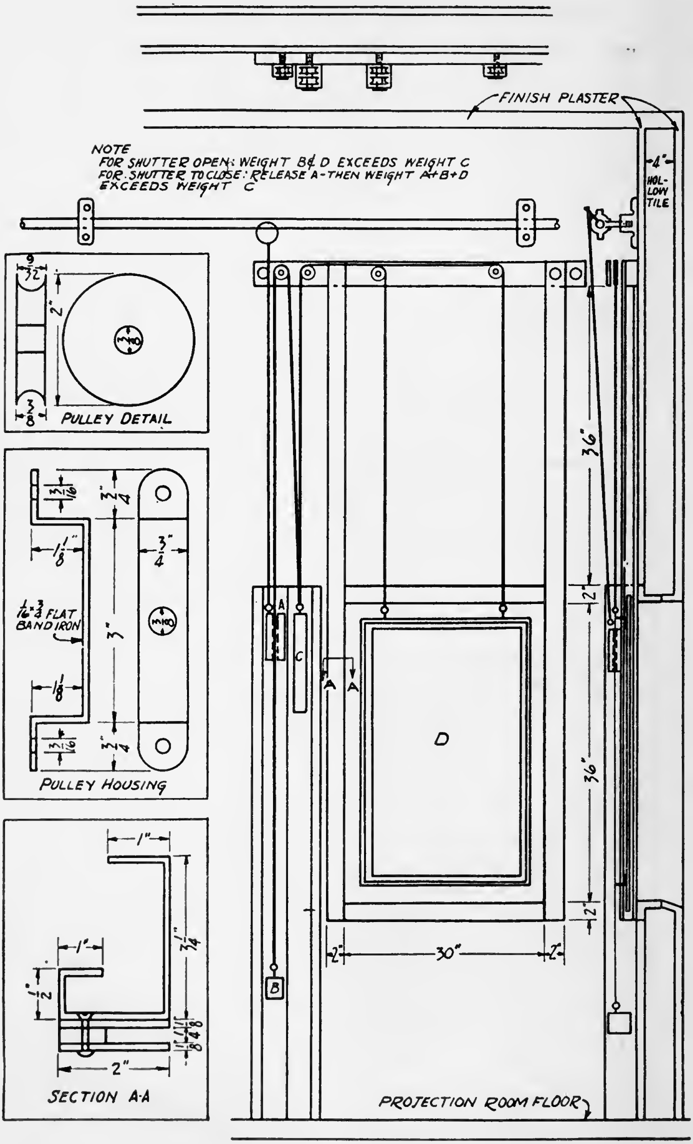


Fig. 7. Standard projection port shutters.

Projection Arc Supply and Location.—In those cases where the projection arc supply consists of machinery that generates acoustical hum or mechanical vibration, the use of acoustical or mechanical insulation will be required. Rotating machinery used for projection arc supply shall be located as remotely as possible from the auditorium and the projection room. Arc supplies other than rotating equipment may be located in the room adjacent to the projection room, taking precautions to place it at least 4 feet away from the sound equipment.

Power Supply to Equipment.—Where line-voltage variations are greater than ± 3 per cent, the power company should be requested to rectify the condition. In those cases where it is impossible to maintain a steady line supply into the theater, either manually controlled or automatic regulators should be installed.

Film Storage.—Approved film storage cabinets having a capacity sufficient to accommodate all the film in use in the theater at any one time shall be installed. The film shall be kept in such cabinets at all times except when being projected or rewound. Any film in addition to that being used for the current show or in excess of that permitted by local authorities, shall be kept in original shipping containers.

FIRE PROTECTION

Projection Port Shutters.—(Fig. 7.) These shall be constructed of iron guides not thinner than 16-gauge, built up of iron flats, 2 inches wide and $^1/_8$ inch thick, with spacers 1 inch wide and $^1/_4$ inch thick, in which the shutter may slide. The shutter shall be made of not less than 10-gauge iron, or of other approved fire-proof material. The bottom sill of shutter tracks shall be provided with leather bumpers.

One type of mechanism for the shutter system having the approval of the Committee consists of a suitable rod which may be constructed of $1^1/_2$-inch pipe mounted upon the front wall of the projection room in a series of ball-bearing brackets in such a manner that the rod may revolve freely in the bearings.

The shutter system shall be located a sufficient distance below the ceiling line to admit of easy operation. At each port, and securely fastened thereto, shall be a chain or rod of approved design attached to a metal ring fitting loosely over a pin inserted into the rod about 45 degrees upward from the horizontal, so that the revolving of the rod shall cause the pin to fall to a down-vertical position and permit the ring to slip off and drop the shutter.

Into each shutter cord or chain shall be inserted an approved fusible link. The master control cord shall be so arranged through a system of pulleys in conjunction with a counterweight that either automatic or manual operation will permit the shutters to drop. The master manual control cord shall be located at each of the entrances of the projection room. In addition, the master control cord shall be furnished with fusible links placed approximately 10 or 12 inches above and immediately upon the center line of the projector magazine. All larger shutters shall be provided with an additional counterweight (Fig. 7), to facilitate manual operation of these shutters.

Emergency Exhaust Fan.—An exhaust fan of sufficient capacity to remove all smoke and gas in case of fire shall be provided, and this fan shall be so connected to the port shutter controls that its full capacity will be automatically made available upon the dropping of the shutters. The fan and air duct shall be of fire-proof construction and located in accordance with local requirements.

Doors.—The doors shall be an approved metal or metal-clad type, swinging outward from the projection room, and shall be provided with door-checks or other approved door-closing devices.

Exits.—Exits shall be provided strictly in accordance with local authorities having jurisdiction, particularly with reference to size and location. It is recommended that never less than two exits from the projection room be provided. At least one of these exits should be of the conventional stairway type, with risers not in excess of 8 inches and a minimum tread to each step of not less than 9 inches, and of sufficient size to permit transportation of equipment.

It is recommended that the secondary exit provide a means of access to the ground, which may be *via* a roof scuttle or doorway accessible from the projection room by means of steps or a ladder.

Windows.—Where a projection room is built against the exterior wall of a structure, one or more windows should be provided in it.

Fire Extinguisher Equipment.—The local authorities having jurisdiction should be consulted regarding the proper type, number, and location of fire extinguishing equipment.

J. O. BAKER, *Chairman*

J. O. AALBERG	J. J. FINN	P. A. MCGUIRE
T. C. BARROWS	E. R. GEIB	R. MIEHLING
F. C. CAHILL, JR.	H. GRIFFIN	M. D. O'BRIEN
J. R. CAMERON	S. W. HANDLEY	H. RUBIN
G. C. EDWARDS	J. J. HOPKINS	J. S. WARD
J. K. ELDERKIN	C. F. HORSTMAN	V. A. WELMAN

REPORT OF THE SOUND COMMITTEE*

The Sound Committee this year has decided to concentrate upon four projects, the first two of which will be discussed in some detail because the Sound Committee will need the coöperation of every one if it is to accomplish anything on them. The object of the first project is to achieve greater uniformity in the sound records from the various producers. Certainly, it will be agreed that that is necessary and desirable; but at once the question arises as to what is the proper or ideal recording characteristic. The Sound Committee three years ago recommended[1] to the Standards Committee that the dividing line between recording and reproduction should be the release print—that all losses incurred up to the release print" . . . should be compensated for in the recording operation. The frequency characteristic of the reproducing apparatus should be flat except for a correction for whatever slit is used." This recommendation, however, has not been adopted, as yet, by the Standards Committee, and it is the sense of the present Sound Committee that the recommendation should be reconsidered in the light of the developments and data accumulated during the past three years.

Before any conclusions can be reached on this point it seems necessary to obtain data on the recording frequency characteristics used by the various studios at present. This, in turn, raises the question of how to obtain comparative data from the various studios. It appeared from a discussion of the question that a great deal of skill, patience, and special calibrated precision equipment are required if satisfactory results are to be obtained. To determine whether measurements made by different organizations would check, a frequency film was made and the same print was measured by five different organizations. When the results were plotted upon the same sheet of paper they revealed excessive deviations at frequencies higher than 3000 cycles and smaller ones at frequencies lower than 200 cycles. Even the results from two of the most skilled research organizations

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

in the country deviated by amounts that represented the limit in experimental error.

It was decided, therefore, that a much simpler method of obtaining comparative data from the various studios would be to establish a "Frequency Reference Standard" in the form of a carefully prepared frequency film. In such a film the actual level that is recorded is of little importance. For comparative purposes it is necessary only that the various organizations concerned measure the reproduction from this Reference Standard upon any machine and any system that they may happen to be using; and then to measure, under identical conditions, a film record made by themselves, and to report the deviation from this Reference Standard. If two organizations obtain the same deviation it is obvious that their recording characteristics will be the same; and if different, a comparison of the deviations will show the location and magnitude of the differences.

Such a film has been made for the Sound Committee through the courtesy of the RCA Manufacturing Company, and the master negative is in the hands of the Chairman of this Committee. The No. 1 print has been designated the "Primary Frequency Reference Standard," and the Eastman Kodak Company has kindly offered to measure its frequency characteristic once each year on their microdensitometer, to determine the stability of this film as a reference standard.

It is planned to hold the number of prints made from the master negative to an absolute minimum. Each succeeding print made from the master negative, beginning with the No. 2 print, will be designated a "Secondary Frequency Reference Standard," and a calibration will be provided with it which will show the deviation between it and the Primary Frequency Reference Standard. The secondary standards should not be used as test reels, but should be used only for the purpose of calibrating test reels. At intervals indicated by experience, the secondary standards can be calibrated in terms of the primary standard. Thus we shall have for the work of this Committee, a datum plane or bench-mark to which all measurements can be referred and, therefore, correlated with each other. To begin with, it was decided to make six secondary frequency reference standards. The stock was furnished through the courtesy of the Eastman Kodak Company, the printing and developing through the courtesty of De Luxe Laboratories, and the calibrating through the courtesy of Warner Brothers.

The film referred to above has the variable-width type of track.

A second similar film of the variable-density type is being made for the Committee so that the relative permanency of the two types of track as reference standards can be studied.

Within the next few months, therefore, the various studios may expect to be requested to furnish to the Sound Committee information on their recording characteristics, expressed in terms of their deviation from the primary frequency reference standard. From these data it is hoped that the Sound Committee can arrive at a recording frequency characteristic that they can recommend.

The object of the second project is to obtain, from the level standpoint, a more artistic rendition of sound in the theater. In other words, the "level balance" that the producer had in mind at the time the record was made should be preserved, and the projectionist should be enabled to pre-set his reproducing equipment, without rehearsal, so as to create the effect intended.

If all producers will determine the normal or reference setting for reproduction in their review rooms, and all theaters will do the same, it will then be possible to mark upon all release prints the deviation from this normal which would be required in any review room or theater to create the effect and loudness desired. In order to determine the normal or reference setting in review rooms or theaters, taking into account also personal tastes as to loudness, a standard test reel will have to be selected. This may be the SMPE standard test reel or a reel chosen especially for the purpose by the Committee.

Two factors determine the relative loudness, on a given equipment, of two successive reels: (*1*) the percentage of modulation used in making the negative, and (*2*) the processing of the print, in which density or transmission is the most important factor. If the producer, when previewing the No. 1 print made from the release negative, would determine the deviation from his normal setting required to create the loudness and the effect he wishes, this deviation expressed in decibels would represent the deviation from normal in any other place for all prints having the same density as the one that he previewed. If the laboratory making the rest of the release prints were given this information, as to the level in decibels above or below normal at which prints having the same density as the No. 1 print should be played, the laboratory could then determine from a table showing the variation of level with density the correct playing level for all prints whose densities differ from that of the No. 1 print. This information could then be written or punched at a suitable place upon the leader; for example, it might be incorporated as part of the 24 frames of "identification leader" of the standard leader of the Academy of Motion Picture Arts and Sciences. After noting the deviation from normal marked upon the reel, the projectionist could play the reel at the correct level in his theater by making the indicated setting on his equipment.

The object of the third project is to study the processing characteristics for sound-film used by various producers, to the end that greater uniformity may be achieved in processing methods. As the Technicians' Branch of the Academy already has a Committee working upon the problem, it is felt that the Sound Committee of the S. M. P. E. should endeavor to coöperate in any way possible with the Academy in an effort to expedite the work. We believe that when the Academy first undertakes to standardize the measurement of film densities it is attacking the problem in the correct manner. The Sound Committee is being urged to study the problem in the hope of assisting the Academy to eliminate the rather wide divergence apparently existing at the present time in the measurement of densities by the various studios.

The object of the fourth project is to evolve, if possible, a simple and inexpensive method of making rough measurements of the acoustic frequency characteristic of review rooms and theaters, to the end that review rooms and theaters may be adjusted so that a given print will sound more nearly the same when reproduced in the various places. It has been suggested that if a wobble-frequency film, fulfilling certain conditions, were available, measurements could be made quickly and inexpensively, enabling the engineer more nearly to approximate ideal reproduction conditions. This proposal was not made with the thought in mind that it would supersede the more refined and accurate work now being carried on by the acoustical experts, but would make available to those who could not afford or who did not have access to the more refined and accurate methods a means for making a first or coarse adjustment of their reproduction conditions.

In closing, the Committee wishes to commend the newsreels upon the marked success that they have attained in standardizing the loudness of their release prints.[2]

P. H. EVANS, *Chairman*
C. DREHER, *Vice-Chairman*

M. C. BATSEL	W. C. MILLER	O. SANDVIK
R. M. EVANS	K. F. MORGAN	E. I. SPONABLE
L. G. GRIGNON	W. A. MUELLER	R. O. STROCK
E. H. HANSEN	L. L. RYDER	S. W. WOLF
J. P. LIVADARY		W. WOLF

REFERENCES

[1] Report of the Sound Committee, *J. Soc. Mot. Pict. Eng.*, **XIX** (Aug., 1932), No. 2, p. 166.

[2] BATTLE, J. A.: "Improvements in Sound Quality of Newsreels," *J. Soc. Mot. Pict. Eng.*, **XXV** (Aug., 1935), No. 2, p. 154.

DISCUSSION

MR. SANDVIK: The Sound Committee feels that the question of uniform frequency characteristic of the talking motion picture, as heard in the theaters, is the most important problem that it has at hand, and we should welcome very much any information available bearing upon the problem. It is a very far-reaching problem, taking in all operations that have any relation to the sound, from the recording studio to the theater (*i. e.*, the acoustics of the theater), and all that the sound Committee can hope to do is to initiate thoughts along these lines, hoping that finally something will come out of them.

For the purpose of illustration let it be assumed that through a careful study of the theater acoustics, and other factors that enter into consideration, the most satisfactory characteristic of the frequency spectrum that should be fed into the average theater has been decided upon. Let it further be taken for granted that somewhere in the process it will be necessary to equalize; that is, to boost the high-frequency end of the spectrum with respect to the low-frequency end. The question then is, at what stage or stages in the process should the equalization take place? Or, to make it more concrete, which will result in a greater volume range, for example, to introduce equalization in the original recording system or in the final reproducing system? The answer to this question is quite evident, but the information in the literature on this general subject is very limited.

SYMPOSIUM ON NEW MOTION PICTURE APPARATUS

During the Spring Convention at Hollywood, Calif., May 20–24, 1935, a symposium on new motion picture apparatus was held, in which various manufacturers of equipment described and demonstrated their new products and developments. Some of this equipment is described in the following; the remainder will be published in subsequent issues of the Journal.

OZAPHANE FILM AND THE CINELUX PROJECTOR*

A. M. CHEFTEL**

The exhibition of motion picture film in suburban areas in France and in the colonial possessions is carried on under circumstances requiring the greatest possible economy in theater equipment, release print cost, and distribution expenses.

It is believed that sufficiently economical operation is made possible through the use of the very thin, low-cost, slow-burning Ozaphane film for release prints. Ozaphane film is made from a cellulosic sheet material 0.04–0.05 millimeter (about 0.002 inch) thick, containing the material from which a photographic image is formed by the diazotype process. Thus, an additional image-carrying layer is unnecessary, and the weight and thickness of the material is a minimum. A reel that holds 300 meters (984 ft.) of regular motion picture film will hold 1000 meters (3281 ft.) of Ozaphane. A 3000-meter (9842-ft.) subject would weigh more than 20 kilograms (44 lb.) when made upon regular film, but only 7 kilograms ($15^1/_2$ lb.) if Ozaphane were used.

In the diazotype process, the material from which the image is to be formed may be invisible in the cellulosic vehicle until development, which forms a colored compound. The colored substance is formed when two suitable chemical substances in the film react in an alkaline medium, which is usually provided by the use of ammonia gas. Premature reaction is prevented by the slight acidity of the medium. When light is permitted to fall upon the undeveloped film, one of the substances is altered in such a way as to prevent the later ammonia development from forming a colored compound. Thus, if Ozaphane film is printed from a positive, a positive image results. A direct process of this type offers some promise of simplifying distribution through the possibility of making duplicate copies from an Ozaphane exhibition print.

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* Communicated.

** Paris, France.

In addition to its use in motion picture work, Ozaphane film is expected to supplant the disk record as a medium for sound reproduction. For this purpose it is proposed to use a track 0.5 millimeter (0.0197 inch) wide, scanned at a rate of 0.45 meter (1.476 ft.) per second. By placing nine such tracks side by side upon a film 9.5 millimeters (0.374 inch) wide, a 65-meter (213-ft.) length will provide about 22 minutes' playing time.

THE CINELUX PROJECTOR CD-2

A portable motion picture projector-sound reproducer has been designed for use with Ozaphane film. It consists of three units contained in two trunks for trans-

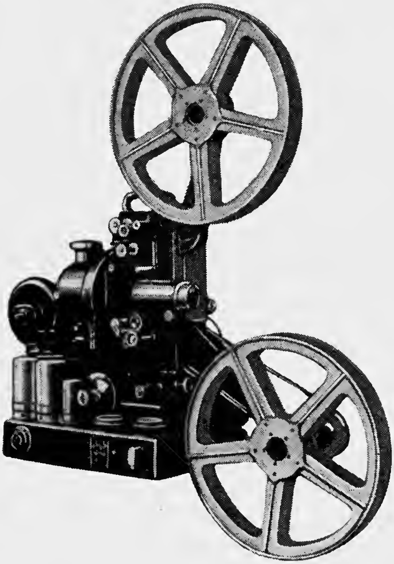

FIG. 1. Front elevation of Cinelux projector, showing film path.

portation. In use the projector is mounted above the amplifier, and the loud speaker is placed near the projection screen. The most unusual feature of the apparatus is the film-moving system, which utilizes friction driving rollers instead of sprockets or claws.

The film path is arranged as follows, starting at the top of the machine (Fig. 1): feed roll, upper drive roller, loop control roller, picture gate, intermittent, lower drive roller, sound scanning station roller, damping roller, and friction take-up. The film is moved by the upper drive roller at a speed just sufficient to maintain a loop above the picture projection gate. Regulation of the speed of film travel over this drive roller is effected by means of a control roller located within the upper loop, in such a way as to maintain a loop of sufficient size at all times. Velvet pads hold the film in position in the gate. At a short distance beyond the gate is the lower drive roller which moves the film continuously at a constant rate and is the pacemaker for the rest of the machine. Between this roller and the gate is the intermittent of the beater roller type, which causes the pull-down by intermittently enlarging the loop between the gate and the lower drive roller.

Beyond the lower drive roller is a film-driven roller over which the film runs

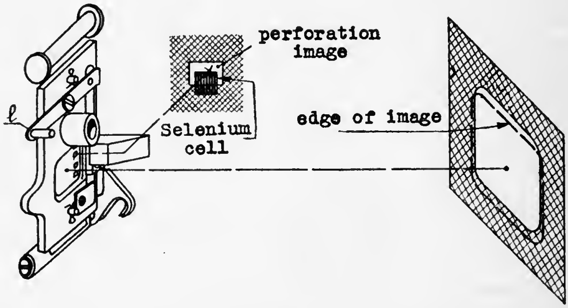

FIG. 2. Diagram showing arrangement of automatic framing system; lever *l* adjusts the image upon the screen.

for sound scanning. Between this point and the slippage-driven take-up is a vibration-absorbing roller.

Framing is maintained automatically by means of the perforation images printed upon the Ozaphane film from the master positive, which has standard perforations. The projection aperture (Fig. 2) is cut away at one side to provide illumination of the area bearing the perforations. Light transmitted by this area passes through a prism and lens to an adjustable mask at the front of a light-sensitive cell. The cell operates in conjunction with an amplifying system to energize a magnetic brake which, in turn, causes the intermittent to be advanced or retarded accordingly as the framing tends to change.

A HIGH-SPEED CAMERA

C. T. BURKE*

The study of mechanical transients occurring at very high speeds requires a camera capable of much higher picture rates than the conventional slow-motion camera. This problem has been attacked from several angles, but the methods of approach have followed along two avenues—the utilization of a moving optical system to preserve a stationary relationship between the film and the image, and the utilization of a brief and brilliant flash of light to establish the exposure.

* General Radio Co., Cambridge, Mass.

The latter approach enormously simplified the camera design problem. The mechanical design of a camera capable of taking pictures at rates as high as 5000 per second presents serious problems in the design of all parts of the camera to give reliable operation at such rates. The elimination of any moving shutter part is, therefore, a distinct gain. The stroboscopic-light method of exposure makes possible the elimination of shutters, intermittent motions, or means for moving the image with the film.

The camera is reduced to a means for carrying the film past an aperture of proper dimensions at the desired speed. The number of moving parts is reduced to film reels and drive motors. To be sure, the simplification of the camera is at the expense of an additional complication in the lighting system, but a consideration of all factors indicates that the stroboscope method offers the best approach to the problem of ultra high-speed photography.

The structure of the camera is shown in Fig. 3. The moving parts consist of the sprocket and two spools, the drive motors, and the commutator which controls the stroboscopic flash rate and serves to space the frames upon the film properly for projection (Fig. 4).

The principal problem in the design of the drive sprocket and reels was the elimination of inertia and the reduction of friction, since there is some fire hazard involved in passing film through the camera at very high speeds. The matter of inertia is of great importance because of the necessity of bringing the camera quickly to speed.

The film is pressed against the sprocket by an aluminum roller, and a metal plow is provided under the sprocket to prevent the film from being carried around by the sprocket teeth and being broken. The plow does not touch the film in normal operation, but immediately corrects any tendency to stick, and also prevents the film from winding around the sprocket in case of breakage.

No mechanical connection is provided between the driving sprocket and the take-up reel. The take-up reel is driven by a series motor of sufficient torque to keep the film taut but not to break it. The difference required in the speed by the changing diameter of the reel as the film is taken up is thus automatically cared for by the slowing down of the motor. Extremely high acceleration can be provided for, since it is possible to operate the motors at over-voltage. The time required to run 100 feet of film through the camera is only a second or two, and no damage results to the motors from such momentary overloading. The acceleration under these conditions is remarkably rapid. Full and constant speed is attained within less than ten per cent of the film length.

A standard lens mount focuses the image behind the aperture, which is fitted with a *V*-edged gate. Focusing is facilitated by a diametric opening in the sprocket and an eye-piece in the back of the camera.

It will be observed that distortion in the image will result in consequence of the curvature of the sprocket. This distortion can be minimized by the use of a sufficiently large sprocket diameter. In the camera described, the sprocket diameter is 4.75 inches, carrying twenty standard 35-mm. frames upon its periphery. The center of the picture is 0.0295 inch closer to the lens plane than the extreme upper and lower edges of the frame. This difference does not cause serious distortion with the subjects and lens systems normally used. When using 16-mm. film the distortion is, of course, proportionately reduced.

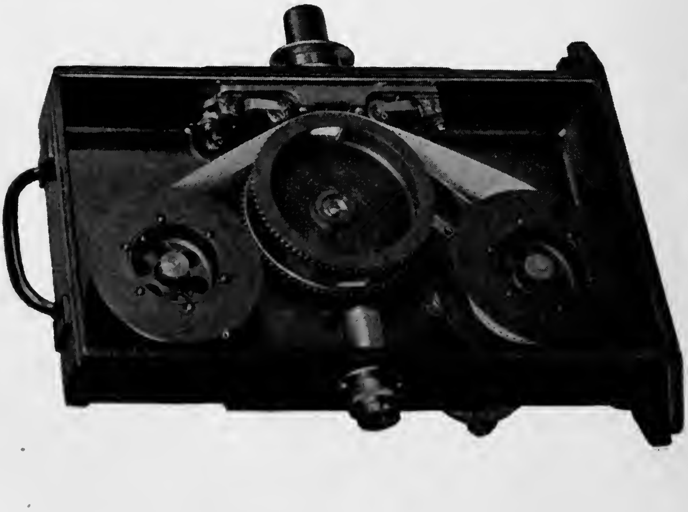

FIG. 3. Internal structure of the high-speed camera.

FIG. 4. Complete assembly of high-speed camera, showing driving motors and commutator.

Since the film moves through the camera continuously without shutters, the distribution of exposures upon the film is determined by the rate of flash of the stroboscope light in relation to the film speed. If the film is to be projected, the images must be spaced properly along the film. In order to accomplish this a commutator is mounted upon the sprocket shaft to provide electrical impulses for setting off the stroboscopic flash at equal intervals. A film thus exposed can be projected in standard projection equipment. The commutator presents a rather serious mechanical problem. The segments must be located with extreme precision. Any irregularity in their placement will appear as flicker in the projected picture. The film speed is so great that a minute angular displacement of the commutator segment will result in rather serious flicker difficulty.

This camera has important applications in the study of high-speed mechanisms and various mechanical transients. Picture rates (using 16-mm. film) as high as 5000 per second have been attained. These films may be reprojected, giving an extraordinary slowing down of the motion observed.

THE WALL MOTION PICTURE CAMERA

H. GRIFFIN*

The Wall camera (Fig. 5) was originally developed in 1926 and 1927 for newsreel work and has recently been redesigned for use either in the studio or in the field. The camera can be equipped with either light-valve, flashing lamp, or galvanometer. It is driven by a direct-drive, 12-volt, d-c. motor of approximately $^1/_{20}$ hp. The motor can be of the interlocking type, if desired, to run with a 12-volt motor of the same type upon a sound recorder. The camera can also be furnished with a synchronous motor for synchronizing with a sound recorder, if desired. Each motor has but one bearing fitted at the outer end of the armature shaft. The inner end of the armature shaft is direct coupled to the shutter shaft, providing a direct form of drive. The outer end of the shutter shaft constitutes the inner bearing for the armature shaft.

The sprocket is run by the shutter shaft through a worm and gear of the hunting-tooth type and of the proper ratio to use a 31-tooth sprocket. The reason for this is that if the film, which is perforated four holes at a time, should be unevenly spaced, the hunting tooth of the sprocket would minimize whatever error occurred. The teeth of the sprocket are made narrower on the sound side than standard, so as to eliminate interference with the sound-track.

The film trucks are made to give a $^1/_4$-inch opening for threading, and are provided with safety pins at the outer ends so that the door can not be closed unless they are in position.

The intermittent is driven from the sprocket shaft through high-helix-angle gears to minimize any inequality of motion imparted by the gearing. This intermittent is of the claw and locking-pin type, using three cams and running in

*International Projector Corp., New York, N. Y.

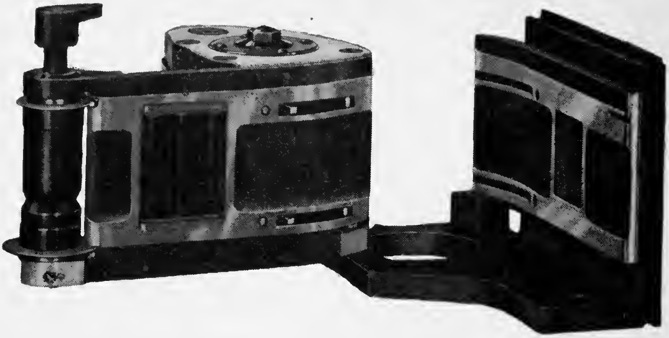

FIG. 6. Intermittent movement, pilot pin, and gate assembly.

FIG. 5. Close-up of the Wall camera.

closely fitted ways. The aperture plate is made of stainless steel, hardened, ground, and lapped to a mirror finish. A spring-actuated pressure pad with three bakelite rolls is the only pressure contact exerted upon the film in its passage through the intermittent. The aperture and back plate have a 0.002-inch clearance over the film. The pull-down cam of the intermittent has a dwell of approximately 202 degrees, which makes the shutter opening approximately 190 degrees. The particular method of installing the intermittent in the camera provides a further dwell of 33 degrees, making a total shutter opening of 225 degrees.

The shutter is provided with an adjustable blade operated through right- and left-hand spirals upon the shutter shaft. These spirals are so made that, if desired, they will produce a complete fade-out with a 180-degree shutter. In the case of a 225-degree shutter opening, enough of the spiral is used to make the shutter adjustable from 90 to 225 degrees. The intermittent can be opened for threading, and by the turn of a wing-screw can be removed from the camera. It is provided with a case that covers the cams and has a removable opening in the top. A special grease is used which will adhere to the cams for several months without renewal.

The turret is provided with openings for four lenses and locks in a hardened and ground *V*-shaped slot upon the periphery of the turret. The locking device is provided with a coiled spring to eliminate the shock of indexing. It is also provided with a knurled adjusting nut to shift the lenses about the axes of the turret for angle shots. The lenses are attached to the turret with a bayonet lock, and are so made that the barrel of the lens does not turn over when focusing the lens. The graduation of the lenses can be read from the operating position. Unless otherwise specified, Bausch & Lomb lenses of the following sizes are used: 40- or 50-mm., *f*/2.3; 75-mm. and 100-mm., *f*/2.3; and 152-mm., *f*/2.7. The recently developed 25-mm., *f*/2.3 Bausch & Lomb lens can also be supplied.

The focusing device is of the shift-over type; that is, the camera proper slides over upon the base so that the focusing tube is directly back of the photographic lens. When the operator wishes to follow an object while photographing it, he does so by using the same focusing device with a wide-angle lens mounted directly ahead of the focusing tube and having a glass with the various aperture sizes etched thereon to give the exact position of the photographed object. The camera is provided with a footage counter and a tachometer for registering the speed of the camera. It is also provided with a handle suitably placed so that the weights of the camera, motor, and lenses balance. All parts of the camera except the intermittent are oiled by three oilers at the back of the camera. The weight of the camera, motor, and lenses is forty-four pounds. When the camera is furnished with the flashing lamp, it is supplied with a lamp holder, quartz, and quartz shoe accurately positioned with respect to the film, the sound being registered directly upon the sprocket. When furnished with a light-valve or galvanometer, the units are so made as to be interchangeable in position with the flashing lamp.

The magazine is equipped with ball bearings throughout, has a removable light-trap to facilitate cleaning, and is operated manually by a knob upon the door of the camera. The spools are collapsible and are easily removable from the roll of film. The weight of the camera, tripod, loaded magazines, motor, and lenses is considerably less than eighty pounds.

TRIPOD

The tripod is made with a flat top when used with the standard camera, and with a dove-tail slide when used with the special camera. When made with the flat top, the hold-down screw is in the center of the top and is operated by means of a knurled knob from the side of the head. The tilt is approximately 40 degrees either side of the center. The head is operated in the usual manner by pressure exerted upon the handle.

The action of the tripod differs from that of most other devices of this kind inasmuch as the driving member for both the pan and the tilt is a worm-gear driving a worm upon which the damping friction is applied, the principle being that to obtain a steady movement the friction must be applied close to the center of the worm, and while the fine adjustment necessary when friction is applied over a large surface is eliminated.

FALL, 1935, CONVENTION

WASHINGTON, D. C.
WARDMAN PARK HOTEL
OCTOBER 21–24, INCLUSIVE

Headquarters

The headquarters of the Convention will be the Wardman Park Hotel, where excellent accommodations and Convention facilities are assured. Registration will begin at 9 A.M., Monday, October 21st. A special suite will be provided for the ladies. Rates for S. M. P. E. delegates, European plan, will be as follows:

One person, room and bath	$3.00
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	5.00
Rates for connecting parlors	5.00

A modern fire-proof garage is located on the Hotel property, and a special 75 cents per day rate has been arranged for.

Technical Sessions

An attractive program of technical papers and presentations is being arranged by the Papers Committee. Sessions will be held in the *Little Theater* of the Hotel, off the west lobby, as follows: Monday to Thursday mornings, inclusive; and Monday, Tuesday, and Thursday afternoons.

Film Programs

Exhibitions of newly released motion picture features and short subjects will be held in the *Little Theater* on Monday and Tuesday evenings. Passes to various motion picture theaters in Washington will be available to the members registering for the duration of the convention.

Apparatus Exhibit

An exhibit of newly developed motion picture apparatus will be held in the east lobby of the Hotel, to which all manufacturers of equipment are invited to contribute. The apparatus to be exhibited must either be new or contain new features of interest from a technical point of view. Information concerning the exhibit and reservations for space should be made in writing to the Chairman of the Exhibits Committee, Mr. O. F. Neu, addressed to the General Office of the Society at the Hotel Pennsylvania, New York, N. Y. No charge will be made for space.

Informal Get-Together Luncheon

The usual luncheon will be held at noon on October 21st in the *Continental Room* of the Hotel. An address of welcome will be delivered by the Honorable Sol Bloom, member of Congress from New York. Other speakers will be announced later.

Semi-Annual Banquet

The semi-annual banquet of the Society will be held in the *Continental Room* of the Hotel on Wednesday October 23rd at 7:30 P.M. Addresses will be delivered by eminent members of the industry followed by dancing and entertainment. The presentation of the scroll of honorary membership to Thomas Armat, of Washington, D. C., awarded last May at Hollywood, will be made, and, in addition, the recipients of the Journal Award and the Progress Medal of the Society will be announced and the presentations made.

Points of Interest

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

Recreation

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

PROGRAM

Monday, Oct. 21st

9:30 A.M.	Registration
10:00 A.M.	Society business
	Technical papers program
12:30 P.M.	Informal get-together luncheon
2:00 P.M.	Technical papers program
8:00 P.M.	Exhibition of newly released motion pictures

Tuesday, Oct. 22nd

10:00 A.M.	Technical papers program
2:00 P.M.	Technical papers program
8:00 P.M.	Exhibition of newly released motion pictures

Wednesday, Oct. 23rd

10:00 A.M.	Technical papers program
12:30 P.M.	Free afternoon, for recreation or special trips and visits
7:30 P.M.	Semi-annual banquet

Thursday, Oct. 24th

10:00 A.M.	Technical papers program
2:00 P.M.	Technical papers program
6:00 P.M.	Adjournment of the Convention

SOCIETY ANNOUNCEMENTS

BOARD OF GOVERNORS

At a meeting held at the Hotel Pennsylvania, New York, N. Y., September 13th, further work was done in drafting *Administrative Practices,* a compendium of all the Board actions in effect and not specifically prescribed in the Constitution and By-Laws. *Administrative Practices* will be kept up to date from year to year, and will thus constitute a complete code of currently operative policies for the guidance of each successive Board. Included are the regulations pertaining to the various Awards of the Society, Honorary Membership, Standardization procedure, *etc.*

OFFICERS FOR 1936

Ballots for voting for officers of the Society for 1936 were mailed recently to the voting membership. The nominations were as follows:

H. G. Tasker, *President*
E. Huse, *Executive V.-P.*
L. A. Jones, *Engineering V.-P.*
O. M. Glunt, *Financial V.-P.*
J. H. Kurlander, *Secretary*
T. E. Shea, *Treasurer*
A. S. Dickinson, *Governor*
H. Griffin, *Governor*
A. C. Hardy, *Governor*

The President, Executive Vice-President, Secretary, and Treasurer hold office for one year; the other Vice-Presidents and the three Governors hold office for two years.

Present members of the Board whose terms do not expire until December 31, 1936, are:

A. N. Goldsmith, *Past-President*
J. I. Crabtree, *Editorial V.-P.*
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Results of the election will be announced at the Fall Convention at Washington, D. C., October 21st, and the successful candidates will assume office on January 1, 1936.

SECTIONAL COMMITTEE ON MOTION PICTURES UNDER THE ASA

As announced previously, no definite technologic decisions were reached at the Paris Congress, although an agreement was achieved as to the manner in which 16-mm. standardization was to be handled. The Deutschen Normenausschuss, a member of the International Standards Association (ISA) was appointed ISA Secretariat for the project, and questionnaires have been mailed to the nineteen national standardizing bodies, in as many countries, who are members of the ISA.

The items of the Questionnaire are as follows:

(1) Have you a Committee for the standardization of 16-mm. sound-film? (*Yes* or *No*.)

(2) If not, are you going to institute such a Committee? (*Yes* or *No*.)

(3) Which Associations of your country deal with the question?

(4) Which of these Associations are collaborating with you?

(5) Do you agree with Recommendation *B1*, as to the distance between the sound and the picture? (*Yes* or *No*.) If not, please state the reasons.

(*Recommendation B1: The distance between the sound and the corresponding picture should be 26 pictures. The existing standards of 25 (SMPE) and 27 (DIN) pictures, respectively, should be changed to the standard of 26 as soon as a revision becomes possible.*)

(6) Do you agree with Recommendation *B2* as to the position of the emulsion in the projector? (*Yes* or *No*.) If not, please state the reasons.

(*Recommendation B2: (a) Film obtained by reversal—emulsion toward the lens. (b) 16-Mm. positive film obtained by contact printing from a 16-mm. negative—emulsion toward the source of light. (c) 16-Mm. positive film obtained by optical reduction from 35-mm. films may be placed with the emulsion side either to the lens or to the light-source. (d) In order to permit projection of 16-mm. sound-films, whether obtained by the reversal process, optical reduction, contact printing, or color processes, it is recommended that the sound-head be provided with a device allowing refocusing of the sound objective, according to whether the emulsion is on one side or the other.*

(7) Which position of the sound-track do you propose (*i. e.*, SMPE standard—left; or DIN-ICE standard—right)?

(8) Which Associations of your country have agreed with your proposal?

(9) Are you prepared to accept the *opposite* position of the sound-track, if this represents the votes of a majority of nations? (*Yes* or *No*.) If not, please state the reasons.

(10) What is the amount of capital invested in your country in (*a*) 16-mm. sound-film apparatus sold and at present in production; (*b*) 16-mm. sound-films sold and at present in production—*e. g.*, in archives, *etc.;* (*c*) development work and manufacturers' equipment—tools, *etc.*

This questionnaire will be acted upon shortly by the Sectional Committee, and then forwarded to the American Standards Association for transmittal to the ISA and the Secretariat.

SOCIETY SUPPLIES

Reprints of *Standards of the SMPE and Recommended Practice* may be obtained from the General Office of the Society at the price of twenty-five cents each.

Copies of *Aims and Accomplishments*, an index of the *Transactions* from October, 1916, to June, 1930, containing summaries of all the articles, and author and classified indexes, may be obtained from the General Office at the price of one dollar each. Only a limited number of copies remains.

Certificates of Membership may be obtained from the General Office by all members for the price of one dollar. Lapel buttons of the Society's insignia are also available at the same price.

Black fabrikoid binders, lettered in gold, designed to hold a year's supply of the

JOURNAL, may be obtained from the General Office for two dollars each. The purchaser's name and the volume number may be lettered in gold upon the back-bone of the binder at an additional charge of fifty cents each.

Requests for any of these supplies should be directed to the General Office of the Society at the Hotel Pennsylvania, New York, N. Y., accompanied by the appropriate remittance.

The Society regrets to announce the death of one of its members:

ABDULLA FAZALBHOY

July 15, 1935

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXV NOVEMBER, 1935 Number 5

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JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

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THE PHOTOGRAPHIC EFFECTIVENESS OF CARBON ARC STUDIO LIGHT-SOURCES*

F. T. BOWDITCH AND A. C. DOWNES**

Summary.—*The work done in connection with the photographic effectiveness of National motion picture studio carbons has been extended to include the Sun Arc carbons and $^1/_2$ x 12-inch Rotary Spot carbons.*

Energy distribution curves of the two latter types of carbon at various currents are given, and the beneficial effects of increased current upon the photographic effectiveness of these two types of light-sources are emphasized. The desirability of the higher currents in using these sources is very clearly demonstrated. Included are the effects of the use of a gelatin filter frequently used with the Sun Arcs and Rotary Spot carbons.

The value of a light-source for illuminating a photographic subject depends upon its spectral distribution; that is, upon the proportions of violet, blue, green, yellow, orange, and red light in the radiant energy emitted by the source; and upon the spectral or color-sensitivity of the photographic film or plate upon which the picture is recorded. Previous communications[1,2] have given the spectral distribution and photographic effect of certain carbon arc light-sources which have been or are being used in motion picture and other photographic studios for various types of photography and photo-engraving. Additional information on other light-sources used primarily in the motion picture studios is given here.

The previous papers dealing with carbon arc light-sources for photography have dealt with flame arcs which may be used with either direct or alternating current. The additional light-sources described in this paper are of the high-intensity type. The distinguishing features of these two distinctly different types of arcs have been described previously in this JOURNAL[3]. The high-intensity light-sources used in the studios are the so-called sun arcs and rotary spots, which can be operated only on direct current. The spectral distributions of these light-sources are somewhat similar, but differ quite materially in their photographic effectiveness.

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** Research Laboratories, National Carbon Co., Cleveland, Ohio.

Fig. 1 shows the spectral energy distribution of 16-mm. high-intensity sun arc carbons operated at 130, 140, and 150 amperes. From these curves it will be readily appreciated that the form of the energy distribution of the high-intensity sun arc does not vary ma-

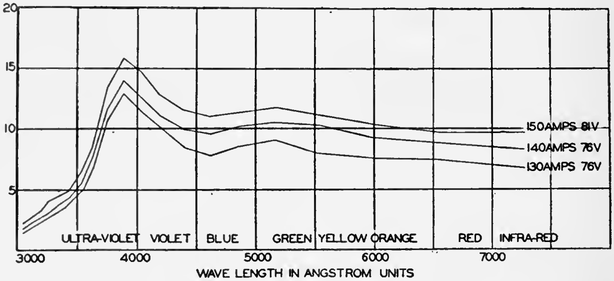

FIG 1. Spectral energy distribution of motion picture sun arcs; positive crater radiation only: 16-mm. H. I. positive, 11-mm. H. I. negative. One square = 250 microwatts per sq. cm. at 10 feet.

terially with the current, but the differences that do exist are sufficient to cause the photographic effectiveness, as will be shown later, to be affected to some degree by the current.

Fig. 2 shows the spectral energy distribution curves of $^1/_2$ by 12-inch rotary spot carbons at 70, 80, 90, and 110 amperes. These

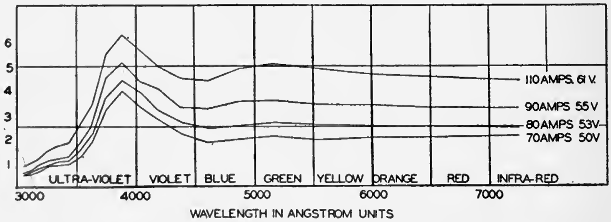

FIG. 2. Spectral energy distribution of Ashcraft rotary spot arc; positive crater radiation only: $^1/_2$ by 12 rotary spot positive, $^3/_8$ CC Orotip negative. One square = 125 microwatts per sq. cm. at 10 feet.

curves also have essentially the same form, but here again the photographic effectiveness is materially affected by the current.

In Fig. 3 are reproduced the spectral energy distribution curves of 8-mm. motion picture studio carbons given in a previous paper.[2]

Table I lists the actual amounts of energy in sunlight at three

TABLE I

Radiant Energy in Microwatts per Square Centimeter from Carbon Arc Studio Light-Sources

Lamps and Carbons	Power		Distance from Source (feet)	Photo-graphically Effective 3400–7000 Å. μw/cm.	(per cent)	Penetrating Infrared 7000–14,000 Å. μw/cm.	(per cent)	Long-Wave Infrared 14,000–50,000 Å. μw/cm.	(per cent)	Total Energy (μw/cm².)
Sunlight	May–June			43,010	42.7	37,570	37.3	20,230	20.0	100,810
	October–November			36,720	40.5	35,890	39.6	18,100	19.9	90,710
	December–January			33,840	38.3	36,750	41.7	17,650	20.0	88,240
	Amps.	*Volts*								
Sun Arcs	150	82	10	3,900	36.8	3,080	29.1	3,620	34.1	10,600
16-Mm. H. I. Carbons										
	140	78	10	3,500	35.1	2,980	29.9	3,500	35.0	9,980
	130	76	10	2,940	32.7	2,590	28.8	3,460	38.5	8,990
Rotary Spots	110	61	10	1,730	31.9	1,630	30.2	2,050	38.0	5,410
1/2 × 12 Rotary Spot Carbons										
	90	55	10	1,230	30.2	1,250	30.8	1,590	39.0	4,070
	80	53	10	1,020	28.5	1,050	29.6	1,490	41.9	3,560
	70	50	10	760	26.8	840	29.7	1,230	43.5	2,830
Side Arcs	40	37.5	3.28	4,010	36.4	2,740	24.9	4,260	38.7	11,010
8-mM. Nat. M. P. Studio Carbons										

seasons of the year, and of the three types of arc lamps used in motion picture studios as just described. The table gives the total energy for each of these sources between 3400 Å, the cut-off of the glass camera

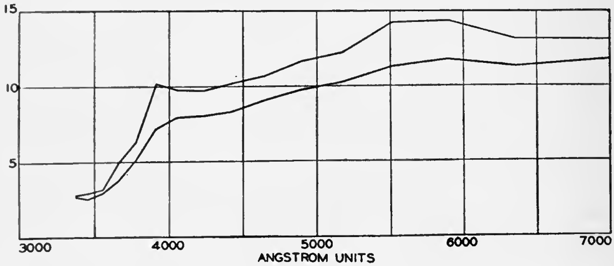

FIG. 3. Spectral energy distribution, 8-mm. National CC motion picture studio carbons; 35 and 40 amps., 37.5 volts d-c. One square = 250 microwatts per sq. cm. at 1 meter.

lens in the ultraviolet, and 50,000 Å, the limit of sunlight and of the transmission of glass in the infrared portion of the spectrum. In addition to the total radiant energy, the table shows the actual amounts and percentages in three spectral bands, *viz.*, the photographically effective, from 3400 to 7000Å (including visible light from

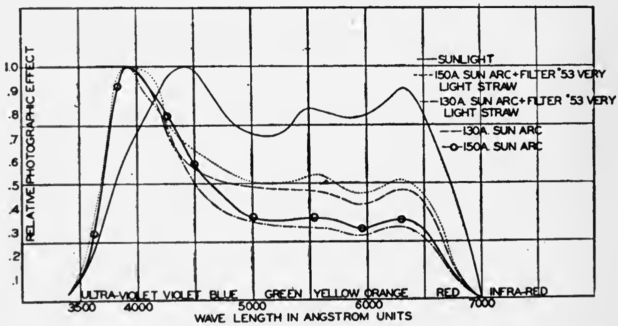

FIG. 4. Relative photographic effects of 16-mm. H. I. carbon sun arcs on Supersensitive panchromatic film.

4000 to 7000 Å); the penetrating infrared from 7000 to 14,000 Å, and the long-wave infrared from 14,000 to 50,000 Å.

The photographically effective band is the only one of any value for ordinary photography, and the other two bands are usually referred to as heat. The most efficient photographic light-source is, therefore, the one having the highest percentage of its energy in the photographically effective band from 3400 to 7000Å.

Curves of photographic effect, taking into account the spectral

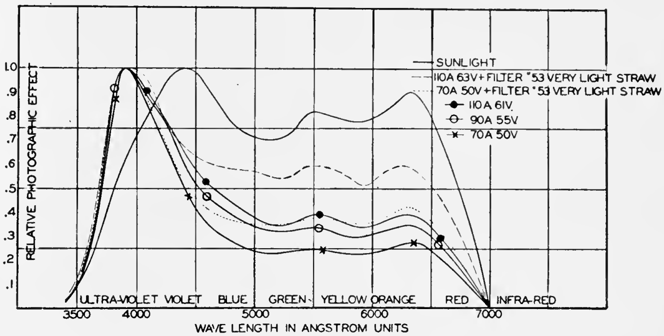

FIG. 5. Relative photographic effect of 1/2 by 12 rotary spot carbons on Supersensitive panchromatic film.

energy distribution of the light-source, the spectral sensitivity of Eastman supersensitive panchromatic film, and the transmission of the camera lenses, have been calculated by a method described by Jones.[4] The results of these calculations in the case of the high-

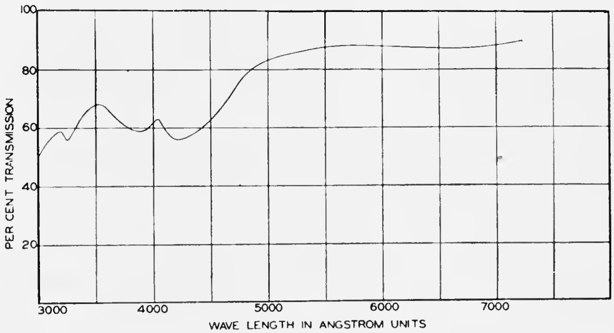

FIG. 6. Light transmission of gelatin filter No. *53 Very Light Straw* (Brigham Gelatin Co.).

intensity carbons used in the sun arcs are shown in Fig. 4. Included in this illustration is the photographic effect of sunlight, for comparison with the carbon arcs. The curves show that the photographic effect of the sun arc at 130 amperes is not quite as great as at 150 amperes. The effect of operating the lamp at 140 amperes, however, is essentially the same as that of operating at 150 amperes, except that the total amount of light is greater at the higher current.

Since these sun arcs are frequently used with filters, particularly in color motion picture photography, there are included in Fig. 4 the relative photographic effects of the 130-ampere arc plus the Brigham Gelatin Company's gelatin filter No. *53, Very Light Straw.* The effect of this filter is to reduce the violet and the blue, and to accentuate the orange and the red effectiveness of the light-source, as a comparison of the curves will show.

In Fig. 5 are shown the similar curves of photographic effectiveness

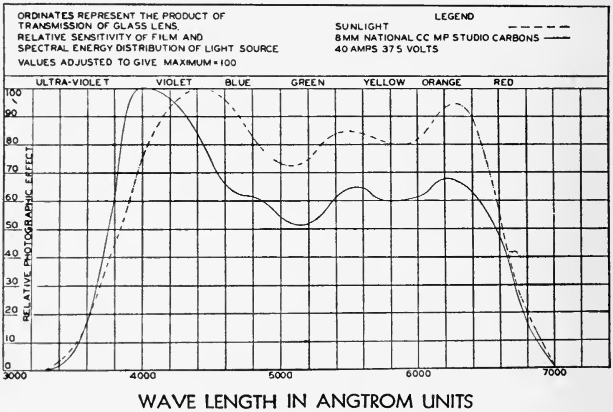

FIG. 7. Photographic effect in relation to wavelength, for Supersensitive panchromatic film.

for rotary spot carbons at 70, 90, and 110 amperes. The photographic effects at 70 and 110 amperes are shown both with and without the filter No. *53, Very Light Straw.* The curve for 90 amperes is without the filter. The curves show that the effect of increasing the current upon the photographic effect of the $^1/_2$ by 12 rotary spot carbons is considerably greater than in the case of the sun arc carbons.

The work at 110 amperes was done only to emphasize the result of increasing the current upon the photographic effectiveness, and should not be understood as a recommendation to burn $^1/_2$ by 12 rotary spot carbons at this high current. It is hoped that these figures will encourage the studio technicians to operate their various carbon arc lamps at the highest practicable current in each case, which is about 150 amperes for 16-mm. carbons in the sun arcs, and 90 to 95 amperes for the $^1/_2$ by 12 rotary spot carbons.

Particular attention should be given to the fact that the photographic effect of rotary spot carbons at 110 amperes with no filter is better than that of the same carbons at 70 amperes with the No. *53* filter.

Fig. 6 shows the percentage transmission of the Brigham Gelatin Company's gelatin filter No. *53 Very Light Straw.* While such a filter results in at least partial correction of the greater photographic effect of the blue and violet, or short-wave energy, it should be remembered that it actually reduces the quantity of light available. Fig. 7 is a

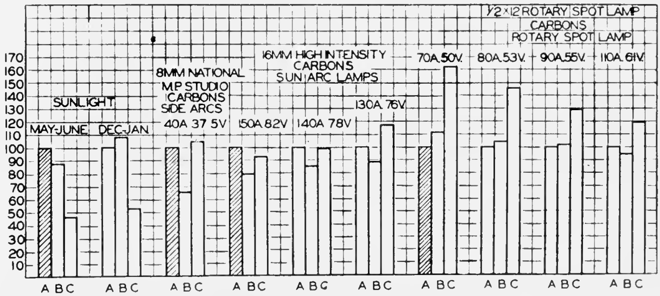

FIG. 8. Relative quantities of penetrating and long-wave infrared radiation, for equal quantities of photographically effective radiation.

A = 3400–7000 Å photographically effective
B = 7000–14,000 Å penetrating infrared
C = 14,000–50,000 Å long-wave infrared

reproduction of the curve of photographic effect of the 8-mm. National motion picture studio carbons given in the article previously cited.[2]

The spectral energy distribution curves that have been given cover only the near ultraviolet and the visible parts of the spectrum, since these include the only wavelengths that are effective in reproducing the photographic image upon supersensitive panchromatic films or plates. It should not be forgotten, however, that all light-sources have the greater proportion of their radiant energy in the penetrating and long-wave infrared regions. These portions of the spectrum differ in their characteristics, particularly by their ability to pass through water or human flesh, but are usually classed together as heat.

Fig. 8 shows the relative amounts of penetrating and long-wave infrared radiations emitted for equal amounts of photographically effective radiations, including the visible spectrum plus a small quantity of near-ultraviolet radiation. In this illustration, for each of the light-sources, the quantity of photographically effective radiation from 3400 to 7000 Å has been fixed at 100, and the quantities of the penetrating and long-wave infrared bands are plotted as percentages of the photographically effective region.

In the cases of the 16-mm. high-intensity carbons used in the sun arcs, and the $^1/_2$-inch carbons used in the rotary spots, the effect of increased current is very noticeable in decreasing the relative amounts of penetrating and long-wave infrared radiations. It is therefore apparent, from the data presented in this paper, that much is to be gained by running the high-intensity arcs at the highest possible current within the rating of the carbons. Not only is the photographic efficiency of the light much improved, but the infrared radiation per unit of photographic light, which has no useful effect, is materially reduced.

REFERENCES

[1] Joy, D. B., and Downes, A. C.: "Characteristic of Flame Arcs for Studio Lighting," *Trans. Soc. Mot. Pict. Eng.*, **XII** (1928), No. 34, p. 502.

[2] Joy, D. B., Bowditch, F. T., and Downes, A. C.: "A New White Flame Carbon for Photographic Light," *J. Soc. Mot. Pict. Eng.*, **XXII** (Jan., 1934), No. 1, p. 58.

[3] Joy, D. B., and Downes, A. C.: "A New Alternating-Current Projection Arc," *J. Soc. Mot. Pict. Eng.*, **XXI** (Aug., 1933), No. 2, p. 116.

[4] Jones, L. A.: "Use of Artificial Illuminants in Motion Picture Studios," *Trans. Soc. Mot. Pict. Eng.*, **V** (1921), No. 13, p. 74.

THE RADIANT ENERGY DELIVERED ON MOTION PICTURE SETS FROM CARBON ARC STUDIO LIGHT-SOURCES*

F. T. BOWDITCH AND A. C. DOWNES**

Summary.—*The spectral energy distributions are given of Sunlight, National motion picture studio carbons, Sun Arcs, and Rotary Spot carbons under the conditions found in the studios. From the spectral energy distributions, the amounts of actual energy received by an actor from one of these light-sources at various distances, and the numbers of carbon arc lighting units required to equal the intensity of sunlight have been calculated.*

A chart is included which shows the relative amounts of photographically effective, penetrating infrared and long-wave infrared radiations emitted by the various arc units.

The substitution of artificial for natural lighting in the production of most of the scenes used in modern motion pictures has often raised the question as to how the artificial light-sources used in the studios compare with natural sunlight as to quality (spectral composition), particularly in respect to the division between visible light or photographically effective radiant energy and the penetrating and long-wave infrared, commonly classified together as "heat." This article discusses these questions for the various types of carbon arcs used for photographic purposes.

Motion picture studios use three types of carbon arc lighting units, the "sun arcs," burning 16-mm., high-intensity carbons at 130 to 150 amperes; the "rotary spots," burning $^1/_2$ by 12 rotary spot carbons at 70 to 80 amperes; and the "side arcs," burning 8-mm. National M. P. studio carbons at 35 to 40 amperes. "Domes" and "scoops" are, for the purposes of this article, included in the "side arc" classification. The "sun arcs" and "rotary spots" are "high-intensity" arcs, and the "side arcs" are ordinary "flaming arcs." The distinguishing features of these two types of arcs have been described in previous communications.[1] The motion picture studios use only direct cur-

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** Research Laboratory, National Carbon Co., Cleveland, Ohio.

rent, and while the high-intensity arcs of the type used in the "sun arcs" and "rotary spots" operate only on direct current, the "flaming arcs," such as are used in the "side arcs," operate satisfactorily on alternating current with no great loss in output of radiant energy.

The spectral characteristics of these different types of arcs can best be shown by means of the curves. Fig. 1 shows (*a*) the spectral distribution of the radiant energy in natural June sunlight, essentially like that of Southern California; (*b*) the radiant energy from a 150-ampere, high-intensity carbon sun arc at a distance of 10 feet; (*c*) the radiant energy of a 70-ampere carbon arc rotary spot at 10 feet; and (*d*) that of a National motion picture studio carbon at 3.28 feet (one

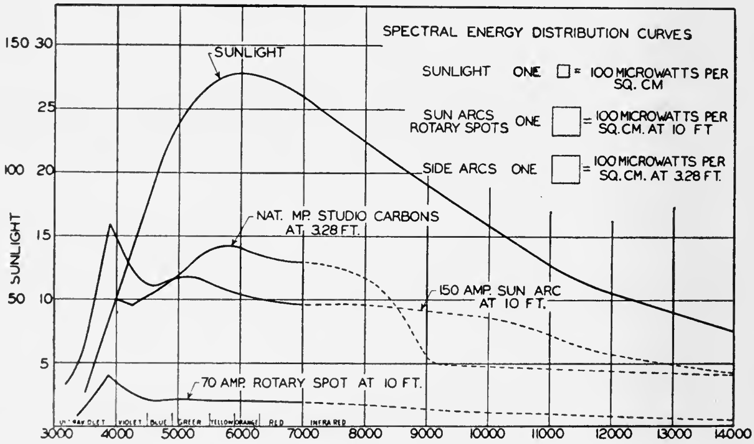

Fig. 1. Spectral characteristics of various types of arcs.

meter). A spectral range of about 3400 Å, the ultraviolet cut-off of glass, to 14,000 Å, the limit of penetrating infrared radiant energy, is covered. Examination of these curves shows that the quality of the radiant energy from the three types of carbon arcs is very similar to that of natural sunlight.

At other currents, the spectral characteristics of the arcs differ from those shown in Fig. 1 only in respect to the level of the curve, and do not differ in form, excepting that with increasing current there is a tendency for the percentage of visible or photographically effective radiation to increase at the expense of the penetrating and long-wave infrared portions of the spectrum.

These curves of spectral energy distribution can be used to calculate the total of the visible light or photographically effective radiant energy, and that of the penetrating infrared radiations. To obtain the complete story, however, it is necessary to add to the data obtained from the curves the non-penetrating or long-wave infrared radiation beyond 14,000 Å, which is also emitted by sources of radiant energy and manifested as heat.

In Fig. 2 are shown the amounts of radiant energy delivered upon a motion picture set by the carbon arc light-sources of Fig. 1. This

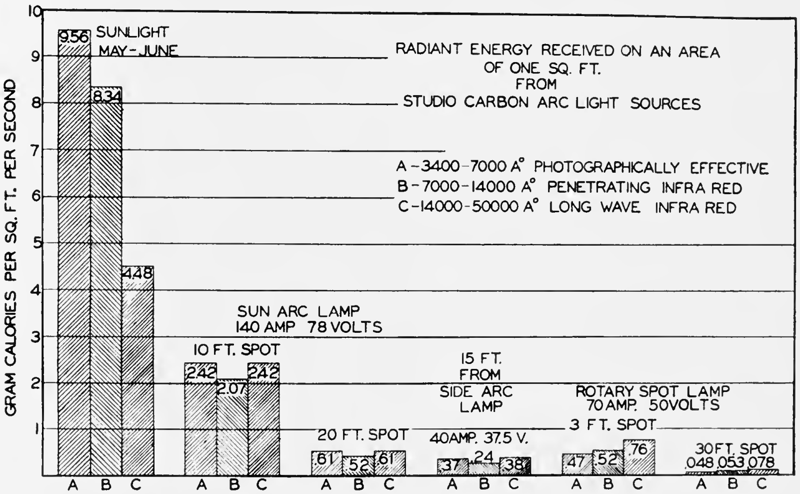

FIG. 2. Radiant energy delivered upon sets by the carbon arc light-sources of Fig. 1.

energy is shown in three divisions, as follows: (*A*) the photographically effective, from 3400 to 7000 Å (including visible light from 4000 to 7000 Å); (*B*) the penetrating infrared, from 7000 to 14,000 Å; and (*C*) the long-wave, non-penetrating infrared, from 14,000 to 50,000 Å. These divisions are chosen because each has a characteristic behavior in its effect upon studio photographic materials and upon human sensibilities. The amounts of energy in these bands, which is the radiant energy upon the motion picture set, are given in gram calories per square foot per second.

The effect of band *A*, the photographically effective and visible light, upon photographic emulsions and upon the human eye is familiar. The effects of the other two spectral bands are perhaps not so well known, and it should be noted that the demarcation between them is not sharp, as the limits selected here would indicate. The penetrating infrared, band *B*, which is defined as extending from 7000 to 14,000 Å, possesses the property of passing through water and also human flesh. The property of penetrating human flesh is not, however, restricted to the non-visible infrared, but extends some distance into the red portion of the visible spectrum, as is easily demonstrated by holding a lighted incandescent lamp in the closed hand.

TABLE I

Lamp Units Required to Equal Intensity of Sunlight

Source	Amperes	To Equal Photographically Effective Energy of Sunlight		Total Energy of Sunlight	
		10-Ft. Spot	20-Ft. Spot	10-Ft. Spot	20-Ft. Spot
Sun Arcs	150	3.5	14	3.0	12
	140	4	16	3.25	13
	130	4.6	18+	3.6	14+
		3-Ft. Spot	30-Ft. Spot	3-Ft. Spot	30-Ft. Spot
Rotary Spots	110	9	88	7	66
	90	13	123	9	87
	80	15	150	10+	100
	70	20	200	13	125
		60° Solid Angle at 15 Feet			
Side Arcs	40	26		23	

The long-wave infrared, band *C*, evidences itself in exactly the same way as heat from a fireplace. It does not penetrate water, but is absorbed by it.

The extreme limits of these three spectral bands are fixed for our purposes by the properties of the glass used in the lamp houses and in the camera lenses. Glass of the kinds used for such purposes cuts off radiations of wavelengths less than 3400 Å units in the ultraviolet, and of wavelengths greater than 50,000 Å in the infrared. The radiant energy from the sun when it reaches the earth's surface contains no wavelengths shorter than about 2950 Å, and none longer than 50,000 Å.

For the purposes of motion picture photography the only band of any value is *A*, the photographically effective, and the two infrared

TABLE II

Energy in Gram Calories per Square Foot per Second on Motion Picture Sets from Studio Carbon Arc Lamps

Lamp and Carbons	Amps.	Volts	Size of Spot (feet)	Photo-graphically Effective 3400–7000 Å	Penetrating Infrared 7000–14,000 Å	Long Wave Infrared 14,000–50,000 Å	Total Energy
Sunlight May–June				9.563	8.343	4.479	22.39
October–November				8.164	7.984	3.996	20.15
Sun Arc	150	82	10	2.714	2.143	2.500	7.357
16-Mm. H. I. Carbons			20	0.679	0.536	0.625	1.839
	140	78	10	2.42	2.07	2.42	6.910
			20	0.605	0.518	0.605	1.728
	130	76	10	2.075	1.773	2.388	6.226
			20	0.52	0.44	0.60	1.56
Rotary Spot	70	50	3	0.469	0.520	0.761	1.750
1/2 × 12 (2135–2)			30	0.048	0.053	0.078	0.1792
	80	53	3	0.626	0.650	0.921	2.197
			30	0.064	0.067	0.094	0.2251
	90	55	3	0.758	0.774	0.961	2.513
			30	0.078	0.079	0.100	0.2574
	110	61	3	1.062	1.006	1.268	3.336
			30	0.109	0.103	0.130	0.3418
Side Arc 8-Mm. National M. P. Studio Carbons	40	37.5	15 60° angle	0.368	0.244	0.380	0.992

bands should therefore be kept as low in intensity as possible. The carbon arc sources shown here have amounts of the infrared per unit of useful radiation as small as, or smaller than, any other artificial sources of illumination.

Fig. 2 shows that with the exception of the 10-foot spot from the sun arcs, the radiant energy received by an actor working under these light-sources is only a small fraction of the energy of direct sunlight. This is true not only of the total energy but also of any of the three bands into which the radiant energy has been divided. Even in the case of the most powerful sun arcs, in a 10-foot spot, the total radiation is only a third that of sunlight.

Table I shows the number of units of these various carbon arc studio lighting units that would be required to give intensities, both total and photographically effective, equal to that of June sunlight. For example, the table shows that thirteen 70-ampere rotary spot lamps would have to be concentrated upon a 3-foot spot to equal the total radiant energy from the sun, and that twenty of them would have to be concentrated upon the same spot to equal the photographically effective energy from the sun.

Table II shows the amounts of energy in gram calories per square foot per second which these carbon arc sources give under various conditions of current and voltage.

These data show that it would require a very large number of artificial light-sources to approximate the heating effects of sunshine in Southern California. The various types of arcs expose the actor to a total radiation varying in intensity from a maximum of one-third, in the case of the sun arc, to less than one-hundredth that of June sunlight per lamp.

REFERENCE

[1] JOY, D. B., AND DOWNES, A. C.: "A New Alternating Current Projection Arc," *J. Soc. Mot. Pict. Eng.*, **XXI** (Aug., 1933), No. 2, p. 116.

MODERN INSTRUMENTS FOR ACOUSTICAL STUDIES*

E. C. WENTE**

Summary.—*Up to the time of the development of the telephone current amplifier, measurements in sound were for the most part made with instruments operating on mechanical principles. At the present time almost all such measurements are made by means of microphones, amplifiers, and other specially designed electrical instruments. This paper gives a descriptive survey of various recently developed electrical devices used in acoustical studies and a brief discussion of their limitations and their field of application.*

Instruments for acoustical research should demand particular consideration upon the part of the motion picture engineer if for no other reason than the fact that it was the development of such devices that made possible the change from the silent to the sound pictures. The condenser microphone, in the form in which it was almost exclusively used for the production of the first commercially successful sound pictures, was originally developed for the study of sound-waves and extensively used for this purpose before it found any commercial application. The light-valve and the oscillograph, as used for the first variable-width sound pictures, were both originally conceived and developed as instruments to be used for scientific investigations in acoustics.

The application of special instruments for the analytical study of sound began during the last century. One of the first and outstanding of these instruments, although never used extensively, was the phonautograph of Scott (1857). This instrument consisted essentially of a diaphragm, to the center of which was attached a stylus resting upon a moving strip of smoked paper. When the diaphragm was set in motion under the action of sound-waves, a wavy line was traced upon the paper, giving a graphical picture of the pressure variations of the sound-wave. This device is of special interest as it appears to have been the first instrument to comprise a diaphragm of the general form found in most present-day acoustical instruments and

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in two of the outstanding inventions of the last century, the telephone and the phonograph. The phonautograph, when compared with Edison's first phonograph, shows how a purely scientific instrument can be the precursor of a great invention.

During the last century one of the chief problems in acoustical measurements was to devise instruments capable of a measurable response to the exceedingly small pressures that obtain in ordinary sound-waves. Laboratory and commercial instruments generally had to depend upon resonance or sound concentrators for their sensitivity, both of which, according to present standards, introduce large amounts of distortion. About twenty years ago, however, came the development of the telephone amplifier through the invention of the audion by deForest. In conjunction with a microphone, such an amplifier could translate the small power of a sound-wave into corresponding electrical power great enough to operate electrical meters or recorders of various kinds. It was no longer necessary to resort to devices that introduced distortion in order to attain the necessary sensitivity. Soon after these amplifiers became available, microphones were therefore devised for the study of sound-waves of ordinary intensities which introduced distortion of a much lower order of magnitude than the acoustic instruments previously available. Instruments in which a microphone is an essential element have so come to dominate the field of acoustic measurements that we may disregard all others in our present discussion.

In one sense the microphone is really the only acoustic instrument used in most sound measurements, for after the sound-wave has been translated into a corresponding electrical current we need only apply the tools of the electrical engineer for measurement or analysis of this current to determine desired characteristics of the sound-wave. We shall, therefore, first give some consideration to the microphone, and follow this with a discussion of some recently developed electrical instruments that are particularly useful in the study of acoustical problems.

Microphones.—A sound-wave is characterized by periodic changes of pressure, temperature, density, and particle velocity. A device that translates any one of these characteristics into a corresponding electrical current is a microphone. Microphones of each of these types have been proposed by various investigators. Pressure, temperature, and density are scalar quantities proportional to each other at any point in a sound field, so that microphones responding to any one of these characteristics may be conveniently grouped under the general heading of *pressure microphones*. However, velocity is a vector quantity, the magnitude of which is not always proportional to the pressure in the sound-wave. So we shall expect to find characteristic differences in the response of pressure and velocity microphones, depending upon where and how they are placed in a sound field. Which of these two classes or what combination of the two is to be preferred depends upon the nature of the problem under investigation.

If the microphones are assumed to be small compared with the wavelength, so that they will not distort the sound field by diffraction, then the response of a pressure microphone will be independent of the direction of propagation of the sound-wave; whereas, that of the

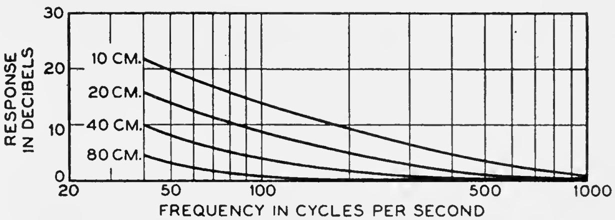

FIG. 1. Response *vs.* frequency characteristic of a velocity microphone, for various distances from a source of constant strength.

velocity microphone will be proportional to the cosine of the angle between this direction and a line drawn normal to the face of the microphone. Hence, if measurements are to be made of sound coming from a known direction, the velocity microphone can often be so oriented as to discriminate against interfering sound-waves. The application of this feature in various kinds of acoustic measurements has been discussed in a recent paper by Wolff and Massa.[1] On the other hand, results of measurements in complex sound fields can often be more easily interpreted when obtained with a pressure microphone, because of its non-directional characteristics.

The reactions, in respect to the sound field, of pressure and of velocity microphones differ in another important respect because of the fact that in the sound field of a simple source the pressure varies inversely with the distance from the source at all frequencies; but the velocity increases more rapidly at low than at high frequencies as the distance from the source is decreased. If, then, the source emits sound of complex wave-form, the pressure microphone will deliver a voltage of identical form, regardless of its position in the sound field; but the velocity microphone will generate a voltage with a greater proportion of low-frequency components at near than at far points. The magnitude of this change is indicated by the response *vs.* frequency characteristics, shown in Fig. 1, for various distances from a source of constant strength, a flat characteristic being assumed for the instrument when placed at a great distance from the source. This variation, while of no great practical consequence when the instrument is used at moderate distances, must be taken into account in measurements made near the source, and exacts a careful control of placement.

It has been pointed out that with the advent of amplifiers, sensitivity in a microphone became of secondary importance. It is not, however, a matter to be disregarded entirely, because there is a practical lower limit to the voltage that can be amplified, and consequently for a microphone of a given sensitivity there is a lower limit to the sound intensity at which the microphone can be usefully employed. This ultimate limit to amplification is set by the noise voltage generated by the thermal agitation of the electrons in the input resistance of the amplifier.[2] The most sensitive high-quality microphone so far described is of the moving-coil type, similar to the Western Electric Company's *618* microphone. It is, therefore, of interest to see over what range of intensity sound can be successfully translated by this instrument. A potential of about 10^{-4} volt is developed per bar of sound pressure, and its electrical resistance is approximately 20 ohms. The voltage due to thermal agitation of the 20-ohm resistance over a 15,000-cycle band is equal to 7×10^{-8}. Assuming that the microphone can be usefully employed down to potentials equal to the thermal potential, we find that the lowest measurable sound pressure is 7×10^{-4} bar. Lower values of pressure can be measured if the transmitted frequency band is decreased, because the noise power is directly proportional to the width of this band. The two lower curves of Fig. 2 show graphically the pressures in a plane wave that can be measured at various frequencies for a 15,000- and a 200-cycle band, account being taken of the variation in sensitivity of the instrument with frequency. The shaded area gives the range of hearing. It is seen that even with this relatively sensitive microphone in the region where the ear is most sensitive, the sound pressures must be some 15 decibels above the threshold of audibility if the instrument is operated over the wider band. This microphone, when placed in a plane sound field, will translate approximately 1 per cent of the sound falling upon the diaphragm into electrical power. It is interesting to note that if this efficiency were raised to 100 per cent, the lowest pressures that could be measured in this region would be just about equal to what the ear can hear. As the sound pressure is raised to higher levels, the microphone will generate harmonic voltages of an increasing amount. The upper curve of the diagram shows the pressures at which the harmonic components are 30 decibels below the fundamental. Above this level the harmonic components begin to increase rapidly. Over

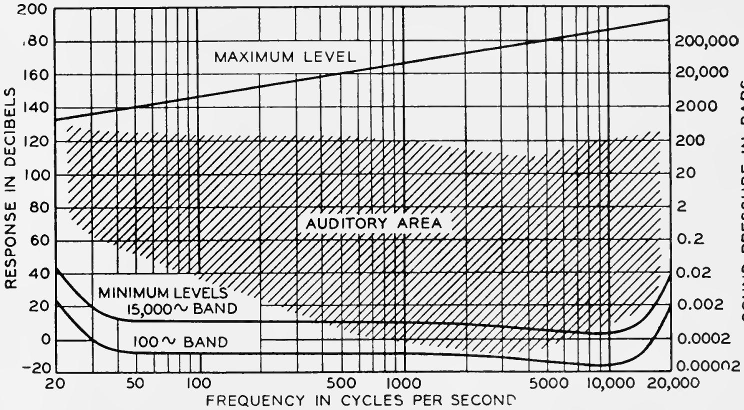

FIG. 2. Showing the pressures in a plane wave that can be measured at various frequencies, for 15,000- and 200-cycle transmitted bands.

most of the frequency range the operating pressures are considerably above the feeling level for the ear, which is represented by the upper boundary of the shaded area. However, many sounds encountered in civilized life that we may wish to study lie above the feeling level.

Rapid Record Oscillograph.—If we wish to make a detailed study of the properties of the sound-wave not having a steady character, theoretically the most perfect method available for the purpose is to use an oscillograph, which translates the time pattern of the microphone current into a corresponding space pattern. If the oscillograph is to give a true graphical representation of the instantaneous pressures in the sound-wave, *i. e.*, an accurate picture of the waveform, it is necessary not only that its sensitivity be the same at all frequencies, but that it preserve the phase relationships as well, a condition that need not be satisfied in a record to be used solely for the reproduction of sound. In the past, conclusions have frequently been erroneously drawn regarding the characteristics of certain types of sound-waves upon the basis of records obtained with oscillographs not free from phase distortion. The appearance of the record can be completely altered by a shift in the relative phases of the components. In acoustical problems, when we wish to study the effect of various

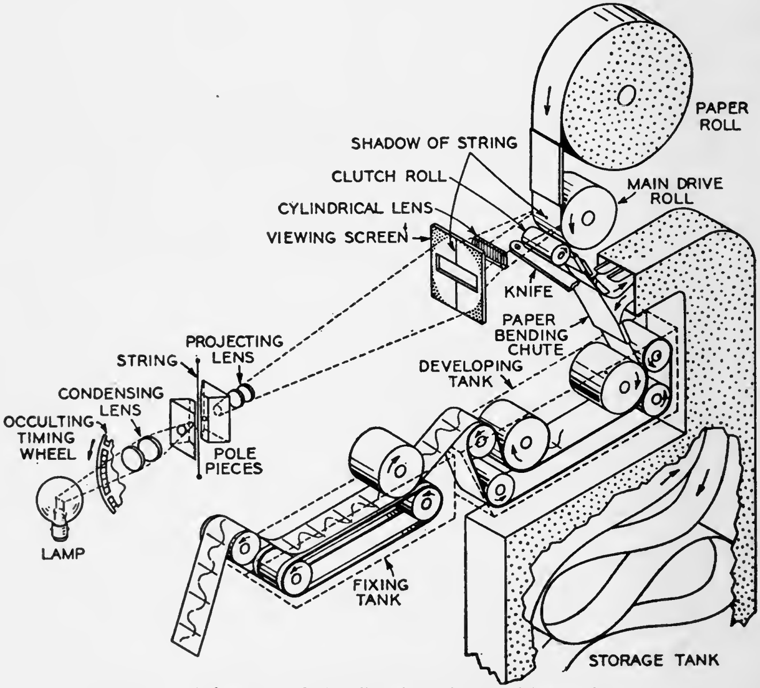

FIG. 3. Diagram of the Curtis string oscillograph.

conditions upon the sound-wave, it is a great convenience, and sometimes essential, that the record be available for inspection as soon as possible after the sound has been recorded. An instrument satisfying these conditions is the Curtis string oscillograph,[3] the operation of which is shown diagrammatically in Fig. 3. This instrument is free from both frequency and phase distortion up to about 8000 cps. A strip of photographically sensitive paper is passed by the point of exposure into a reservoir from which it is fed through processing baths. The record is available for inspection about one minute after exposure.

This instrument has been found to be extremely useful in many kinds of acoustic investigations.

When the sound to be studied is steady, the wave-form may be observed with a cathode ray oscillograph, which is available in many forms. By the use of a sweep circuit of the type described by Bedell and Reich,[4] the repeated cycle may be automatically stabilized into a stationary pattern.

Harmonic Analyzers for Steady Currents.—In many acoustic measurements it is not so important to know the exact form of a sound-wave as its harmonic components. It is, of course, possible to determine these components from an oscillogram by well-known mathematical or instrumental methods. These methods, except where only a few components are desired, are slow and laborious. Components that are small compared with the largest components

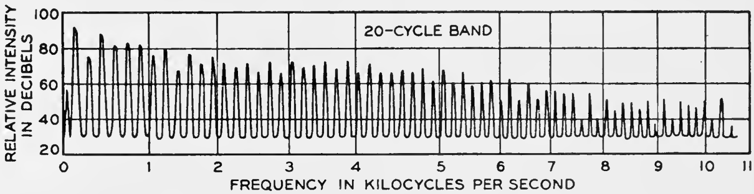

FIG. 4. Analysis of a steady complex sound.

can usually not be determined with great accuracy from oscillograms. When the current to be analyzed has a steady character, one of a number of so-called current analyzers may be used. These have been developed in several different forms, but have the common feature of comprising a narrow band-pass circuit, either mechanical or electrical, the mid-frequency of which is variable continuously or in small steps over the frequency range. The analysis is made by varying the frequency of this transmitting circuit and reading the corresponding transmitted currents upon a meter, or registering them with an appropriate recorder. The narrower the frequency band of the transmitting circuit the greater the degree to which closely spaced components may be distinguished. The wider band is, however, to be preferred where detailed resolution is not required, as the analysis may be made at a proportionately greater speed. An analyzer of this type, in which the width of the transmitted frequency band may be set to either 20 or 200 cycles, was described by Wolf and Sette.[5] The filters in this analyzer have sharp discriminations at the edges of the transmitting band, so that even closely spaced components may be measured with a high order of precision.

Fig. 4 shows the type and form of the results that may be obtained with this analyzer when used in conjunction with a level recorder. The particular record shows the harmonic components in the current of an audiometer of the buzzer type. It gives the relative intensities of about 70 components, the amplitudes of which cover a range of more than 50 decibels. This type of instrument is also useful in the study of the statistical distribution with respect to frequency of the components in a sound that is not steady in character. Fig. 5, for example, shows the result of an analysis of the sound emitted by a small electric drill.

High-Speed Analyzer.—Analyzers of the type just described are

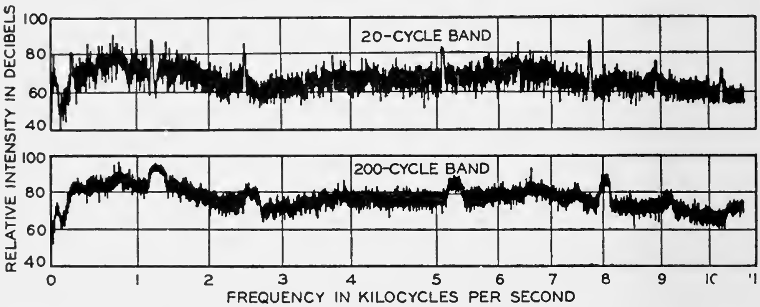

FIG. 5. Analysis of the sound emitted by a small electric drill.

particularly suitable for the analysis of steady-state currents. Many sounds, however, assume a steady-state value for only a short period. Unless a statistical value is desired, the analysis must then be made by sweeping through the frequency range during this period. Other kinds of sounds, such as speech or music, vary in their harmonic composition almost continuously. At first thought we should conclude that such changes in composition might be followed by sweeping the transmitting frequency band back and forth rapidly, and recording the transmission throughout each sweep cycle with a high-speed recorder. It is possible to proceed a certain distance in this direction; but no matter what type of transmitting circuit is used, it will have a finite time-constant; *i. e.*, a finite time is required for the current to reach a certain fraction of its steady-state value when the circuit is set to a given frequency. Similarly, a finite time interval is required for the current to die down to a certain fraction of the steady-state value when the frequency is changed. For this reason, as the rate of shift of the frequency band is increased, the precision with which the harmonic components are determined is decreased. Only a very

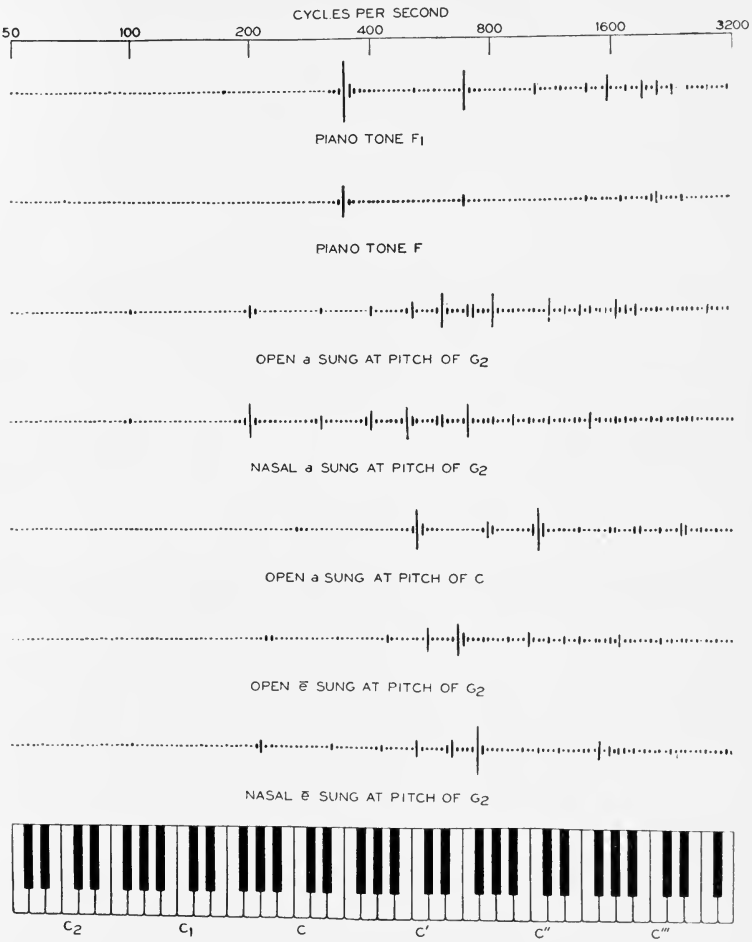

FIG. 6. Records of typical sound obtained with the Hickman analyzer.

rough analysis of the waves of ordinary speech or music will be possible by this method. The speed of the analyzer can be greatly increased without sacrificing resolution by employing, instead of a single transmitting element of variable transmission frequency, a large number of elements closely spaced in frequency and all operative simultaneously, for in this case the current needs to be maintained only sufficiently long for the slowest element to approach its steady-state value.

An analyzer built up from electrical filters of the required number would be both expensive and bulky. A simple instrument of this type, having mechanical resonance elements simultaneously operative, has been developed by Hickman.[6] A series of tuned reeds with their resonance frequencies spaced at equal pitch intervals are simultaneously electromagnetically driven by the current to be analyzed. These reeds are especially designed so that each one will be set in resonant vibration at only one particular frequency. A mirror is attached to each reed from which light is reflected and brought to focus upon a screen in the form of a short fine line. The

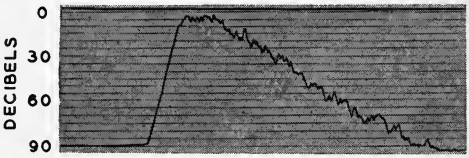

FIG. 7. Curve obtained with the sound decay high-speed level recorder.

broadening of this line as the mirror vibrates is proportional to the amplitude of motion of the reed, which, in turn, is proportional to the strength of the component in the driving current having a frequency approximately equal to the resonance frequency of the reed. The amplitude of the various components may be thus observed simultaneously upon the screen or the changes in the composition with time may be recorded by a motion picture camera. Fig. 6 shows the form in which records of some typical sounds are obtained with this instrument.

Another novel form of high-speed analyzer has recently been described by Meyer.[7] By a method well known in communication engineering, the frequencies of the various harmonic components of the current are increased by equal amounts. After this the current is translated into sound by a special high-frequency loud speaker. The components of the radiated sound are then all of short wavelength, which are reflected from a grating consisting of a row of rods equally spaced along a concave surface. Analogously to light reflected from a concave ruled grating, the components of the sound are brought to a focus at different points along a focal surface. Along this surface a small high-frequency microphone is moved back and forth rapidly. The current generated by the microphone along its path is then recorded. From the record so obtained the relative strength of the various components is determined.

High-Speed Level Recorder.—In some important types of sound measurements we are not interested in a detailed analysis of the sound-wave but merely in the variation with time of the average level

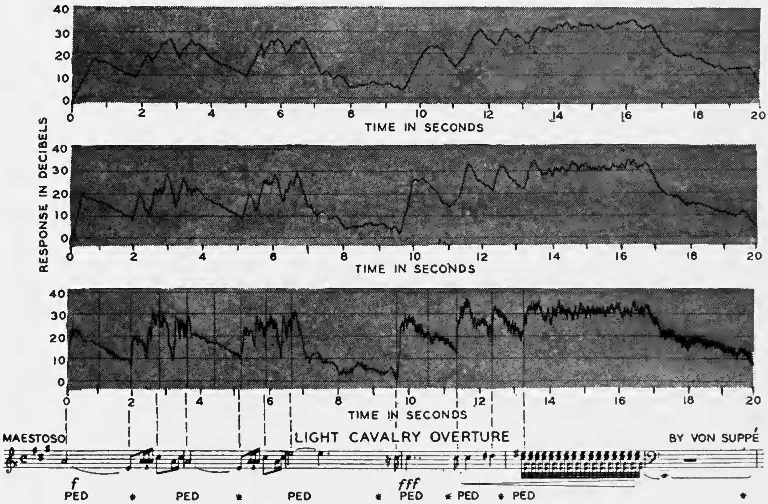

FIG. 8. Variations of level of sound from a piano, obtained with the high-speed level recorder.

of the sound, as in the measurement of the rate of decay in a room or the flow of energy in speech, music, or noise. In some cases this average is preferably taken over long and, in others over short, time intervals. For long-time averages, a thermocouple or rectifier and an ammeter may be used, but for short-time averages an instrument is required that can follow changes of intensity at a higher rate. Frequently, also, the range of intensity over which we desire to make measurements of this character is very wide. Reverberation measurements are preferably made over a range of at least 60 decibels, and the level range of orchestral music covers about 75 decibels. Several instruments designed for such purposes have been described recently.[8] In the instrument described by Wente, Bedell, and

Swartzel the level is recorded by a stylus upon waxed paper. The recorder can be adjusted to give either a short or a long time average. At the highest operating speed it is capable of following changes of intensity at the rate of 840 decibels per second, and fluctuations in intensity of about 100 per second. The instrument may be adjusted so that the full scale covers a range of 30, 60, or 90 decibels.

Fig. 7 shows the type of curve obtained with this recorder in the measurement of the rate of decay of sound in rooms. Fig. 8 illus-

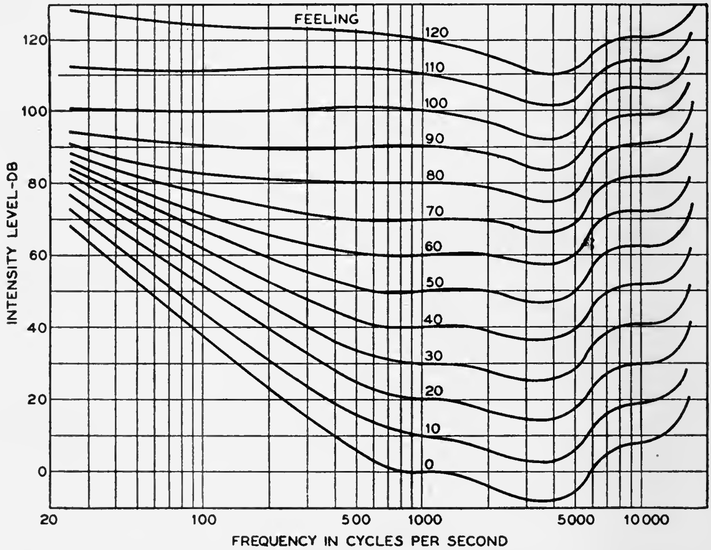

FIG. 9. Relation between aural stimulus and sensation, the various curves giving the intensity levels of pure tones of equal loudness.

trates its use as a recording volume indicator. It shows the variations in level during the playing of a phrase upon the piano. The curves from top to bottom were obtained with the recorder set to operate at increasingly higher speeds. From records of this type the dynamics of the performance of a musical selection and the range of level can be accurately checked and studied.

Measurement of Pitch.—For acoustical studies, where it is of no particular importance to know the wave-form, but interest lies in the variation of pitch with time, as in the study of the *vibrato* in musical tones, or in the inflections of the speaking voice, several types of instruments have been devised. Perhaps of these the most widely known is the *tonoscope*, developed by Seashore and his associates, which operates on the stroboscopic principle. This instrument has rows of uniformly spaced dots upon a rotating cylinder, the number of dots increasing in successive rows. A neon light is made to flicker in synchronism with the fundamental of the tone under investigation. The particular row which under the light appears stationary gives the pitch of the tone at any instant. By the aid of a suitable camera, the time variations of pitch may be recorded photographically, giving a so-called strobophotograph.

A frequency recorder operating on a different principle has been described by Hunt. By a special circuit arrangement, employing gas-filled discharge tubes in combination with a spark recorder, the pitch of a tone can be recorded upon paper. The scale is linear up to 8000 cycles. This instrument is capable of following changes in pitch at a high rate.

Loudness and Its Measurement.—The preceding discussion was restricted to the purely objective or the physical aspects of sound. Often we are finally interested in not the physical nature of sound but its subjective characteristics as perceived by our ears. The relationship between stimulus and sensation is very complex, as may be observed from the curves shown in Fig. 9. The various curves give the intensity level of pure tones of equal loudness. The threshold of audibility varies widely with frequency, and the relationship between sensation level and intensity level is not the same at the various frequencies and levels; for instance, at a loudness level of 40 decibels above threshold, a change of 5 decibels in the stimulus at 100 cycles produces the same change in sensation as a change of 10 decibels at 1000 cycles. For complex tones the relationships are often more complex, although Fletcher and Munson have developed formulas whereby the loudness level of a steady sound can in most cases be computed from the intensity level of its components. In spite of the above apparently complex relationships, so-called noise or sound meters have been developed that indicate upon a scale the subjective intensity. These meters have proved themselves particularly useful in the measurement and study of noise.

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FLUTTER IN SOUND RECORDS*

T. E. SHEA, W. A. MacNAIR, AND V. SUBRIZI**

Summary.—*Frequency modulation of a sound signal is caused by non-uniformity in the record speed during the recording or reproducing process. This source of flutter is discussed and was demonstrated at the May, 1935, Convention.*

The paper includes a discussion of the physical nature of frequency modulation, the physiological effects of frequency modulation, the methods of producing known amounts of artificial flutter, and the methods of measuring flutter.

There are various forms of distortion which may degrade the quality of sound signals. Many of these types of distortion are well known, and their effects readily identified by ear by the experienced engineer. For example, the effect of a limited volume range is characterized by a high noise level. Also the effect of a limited frequency range has been demonstrated many times,[†] and engineers quickly detect the lack of crispness and naturalness of certain types of sounds when the higher frequencies are suppressed. Furthermore, the effect of non-linear response of a portion of the electrical circuit, or "overload," is well known.

Some other forms of distortion are more obscure, and perhaps are not readily detected by as many persons. Frequency modulation[††] of a sound signal produces some very interesting and sometimes not readily identifiable auditory sensations. Distortion of this type is caused in sound records by the non-uniform speed of the record during the recording or reproducing processes. An analysis of the distortion leads to the location of the mechanical cause of the non-uniform speed, and consequently leads to improved record-driving mechanisms.

The methods of quantitative analysis of these speed variations

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† *E. g.*, at the meeting of the Atlantic Coast Section, Jan. 30, 1934, at New York, by H. Fletcher.

†† Where the word "flutter" is used, its meaning will be restricted to the distortion due to frequency modulation.

will be described, and the physical nature and some of the physiological effects of the distortion caused by them will be discussed and demonstrated.

PHYSICAL NATURE OF FREQUENCY MODULATION

Frequency modulation[1] consists of a cyclic change in the frequency of a recurrent wave, the cyclic amplitudes of the wave remaining unchanged. It is equivalent to a distortion of the time-axis scale of a recurrent wave or a periodic variation of the time-delay of the

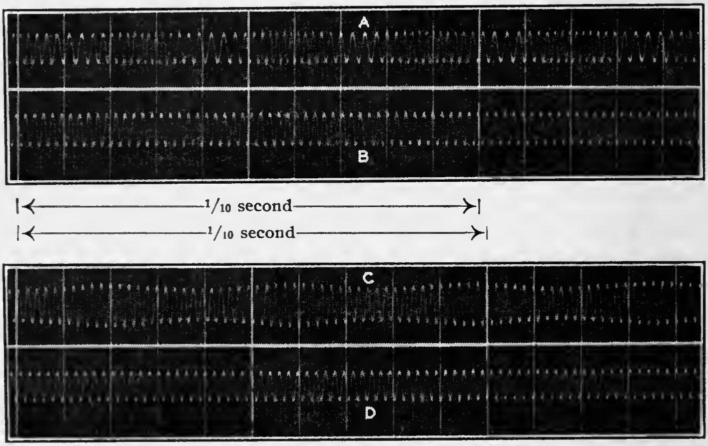

FIG. 1. Frequency-modulated and amplitude-modulated oscillator tones.
(*A*) Frequency-modulated oscillator tone.
(*B*) Constant-frequency oscillator tone.
(*C*) Amplitude-modulated oscillator tone.
(*D*) Constant-frequency oscillator tone.

signal. If one puts a constant-frequency record into a reproducing machine that has a periodic speed variation, the output signal has the form shown in an exaggerated way in Fig. 1. In the oscillogram marked *A* there are periodic changes in frequency. At the time when the wave cycles were near together, the reproducing machine was running above average speed; and at the time when the waves were spread out, the reproducing machine was running at lower than average speed. This periodic speed change of the reproducing machine, which gives a signal of the type illustrated here, is "flutter." The flutter in the signal is, technically, "frequency modulation," because the frequency of the signal periodically swings above and below normal. For comparison, oscillogram B, of a constant frequency tone, is included. In contrast, an amplitude-modulated wave is shown in oscillogram C, which is the familiar type of modulation used on the radio broadcasting channels.

Frequency modulation may be very complex in character. Where, however, a single-frequency tone is considered and the cyclic change in frequency is itself sinusoidal, the amount and character of the distortion are described by three factors:

(1) The frequency of the normal tone (f_o).
(2) The extent of the cyclic change in this frequency ($\pm \Delta f_o$).
(3) The frequency of the cyclic change (f_m).

The extent of the cyclic change is usually expressed in percentage form ($\Delta f_o / f_o \times 100$); this may be called the *amplitude* of the distortion. The frequency f_m may be called the rate of the distortion. We shall use the terms "amplitude" and "rate" to express the character of various frequency modulations.

Frequency modulation of the sinusoidal type may be shown to be physically equivalent to (*1*) the production of side-frequencies, spaced at uniform discrete intervals; and (*2*) a reduction in the amplitude of the normal or "carrier" tone. The frequency interval between the sideband components is equal to the rate of the modulation, and the magnitudes of the various components depend upon the value of the ratio ($\Delta f_o / f_m$). Various analyses of frequency modulation have been published.[2]

The instantaneous amplitude of any undistorted sinusoidal wave of frequency f_o may be written:

$$y = A \sin \omega_o t \tag{1}$$

where the condition $\omega_o = 2\pi f_o$ is dependent upon the maintenance of uniform frequency. If the frequency varies, ω_o must be regarded as a variable; *i. e.*,

$$y = A \sin \int_o^t \omega dt \tag{2}$$

If the variation in the frequency is sinusoidal then:

$$\omega = \omega_o + \Delta\omega_o \sin \omega_m t \tag{3}$$

where $\omega_m = 2\pi f_m$.

Substituting (3) in (2),

$$y = A \sin \int_o^t (\omega_o + \Delta\omega_o \sin \omega\ t)dt$$

$$= A \sin \left[\omega_o t - \frac{\Delta\omega_o}{\omega_m} \cos \omega_m t \right]_o^t$$

$$= A \sin \left[\omega_o t + \frac{\Delta\omega_o}{\omega_m} - \frac{\Delta\omega_o}{\omega_m} \cos \omega_m t \right] \qquad (4)$$

The second term within the brackets of (4), namely, $\Delta\omega_o/\omega_m$, is a constant phase-angle, and for simplicity may be dropped out; whence

$$y = A \sin (\omega_o t - \alpha \cos \omega_m t) \qquad (5)$$

and

$$y = A\ [\sin \omega_o t \cos (\alpha \cos \omega_m t) - \cos \omega_o t \sin (\alpha \cos \omega_m t)] \qquad (6)$$

The well-known Fourier developments for cos (x cos y) and sin (x cos y) are:[3]

$$\cos (x \cos y) = J_o(x) - 2J_2(x) \cos 2y + 2J_4(x) \cos 4y - \ldots \qquad (7)$$

$$\sin (x \cos y) = 2J_1(x) \cos y - 2J_3(x) \cos 3\ y + \ldots \qquad (8)$$

in which the J's are the well-known Bessel's coefficients. Expanding (6) in accordance with (7) and (8),

$$y = A\ [\sin \omega_o t\{J_o(\alpha) - 2J_2(\alpha) \cos 2\omega_m t + 2J_4(\alpha) \cos 4\omega_m t - \ldots\} - \cos \omega_o t\{2J_1(\alpha) \cos \omega_m t - 2J_3(\alpha) \cos 3\omega_m t + \ldots\}] \qquad (9)$$

which may be written

$y = AJ_o(\alpha) \sin \omega_o t$	carrier	
$- AJ_1(\alpha)[\cos(\omega_o + \omega_m)t]$	1st upper side-frequency	
$- AJ_1(\alpha)[\cos(\omega_o - \omega_m)t]$	1st lower side-frequency	
$- AJ_2(\alpha)[\sin(\omega_o + 2\omega_m)t]$	2nd upper side-frequency	(10)
$- AJ_2(\alpha)[\sin(\omega_o - 2\omega_m)t]$	2nd lower side-frequency	
$+ AJ_3(\alpha)[\cos(\omega_o + 3\omega_m)t]$	3rd upper side-frequency	
$+ AJ_3(\alpha)[\cos(\omega_o - 3\omega_m)t]$	3rd lower side-frequency	
$+ \ldots\ldots\ldots\ldots$		

The magnitudes of the carrier and the various side-frequencies relative to that of the original undistorted wave are given by the coefficients $J_o(\alpha)$, *etc.* The locations of the side-frequencies are given by the values of $\omega_o \pm \omega_m$, *etc.*

From tables of Bessel's functions, we may plot the values of the J's as a function of α as in Fig. 2. Some typical examples illustrate the use of Fig. 2. Thus, if a 2000-cycle tone is modulated 5 per cent (from 2100 cycles to 1900 cycles) 20 times per second, $\alpha = \Delta f_o/f_m$

= 100/20 = 5.0, the relative magnitudes of the carrier and the successive orders of side-frequencies are (Fig. 3, lower half):

0.17, 0.32, 0.04, 0.36, 0.39, *etc.*

The components are spaced 20 cycles apart. The carrier is small

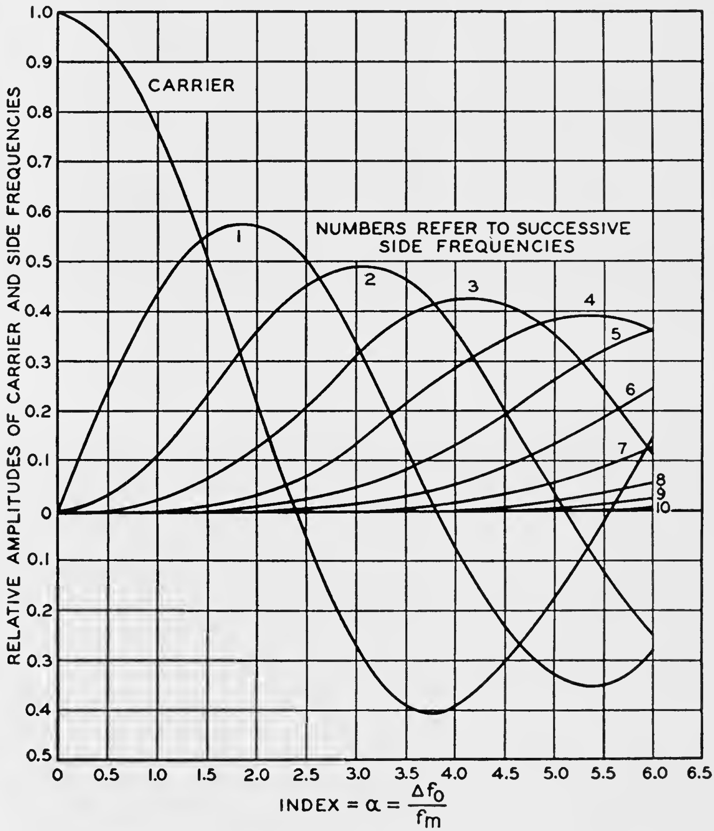

FIG. 2. Relation between carrier and side-frequencies in frequency-modulated tones.

in this case, but a number of the side-frequencies are substantial in magnitude. Obviously, there are values of α for which either the carrier or any specific order of side-frequencies may be wiped out. On the other hand, where α is small (due either to a small departure from average frequency or rapidity in this fluctuation), the side-band components are small and relatively unimportant, while the carrier has nearly its original magnitude. If $\alpha = 0.25$ (upper half of Fig. 3), the carrier has a value of 0.98 and only the first-order components, with a value of 0.13, are of appreciable magnitude.

Physically, then, distortion due to frequency modulation is remarkably like non-linear distortion in that extraneous frequencies are produced having a systematic relation to the fundamental or

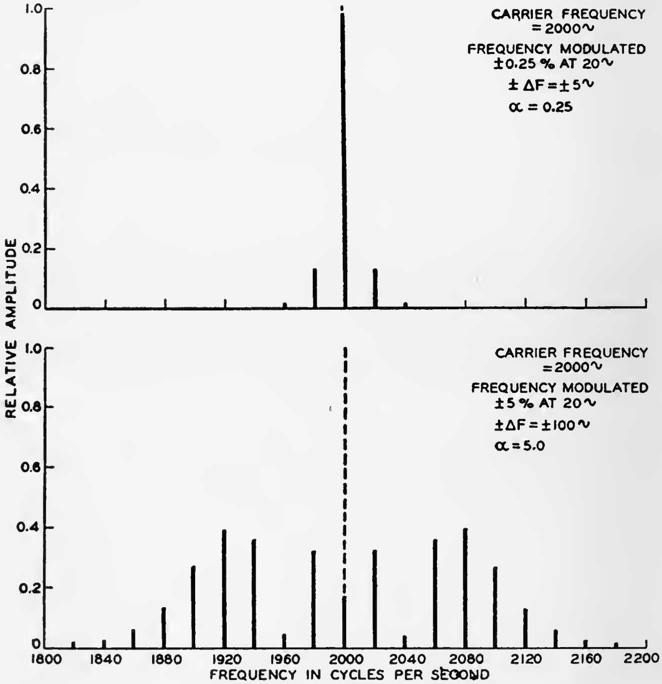

FIG. 3. Acoustic spectra of certain flutter tones.

normal tone. The physiological effects of this distortion will be discussed below.

PHYSIOLOGICAL EFFECTS OF FREQUENCY MODULATION

It is a part of this paper to demonstrate the aural effects of frequency modulation of sound signals. The effects produced, of course, will vary with amplitude and rate of the modulation, but will also vary greatly with the acoustical listening conditions.

Hanson[4] has demonstrated that a pure tone generated in a comparatively "dead" room sounds the same as the same tone generated in a "live" room. If, however, the signal is frequency-modulated, then the character of the sounds picked up in the two rooms is quite different. Oscillographic analysis of the sounds as picked up by a microphone shows that the sound from the "dead" room is nearly the same as the signal supplied to the loud speaker; that is, of uniform amplitude, but modulated frequency. The signal picked up from the "live" room, however, exhibits very marked amplitude fluctuations of complicated character, indicating that the "live" room has operated upon the frequency-modulated signal in such a way as definitely to change its character. This is illustrated in Fig. 4, in which the signal from the "dead" room is of nearly uniform amplitude, but the signal from the "live" room shows large fluctuations

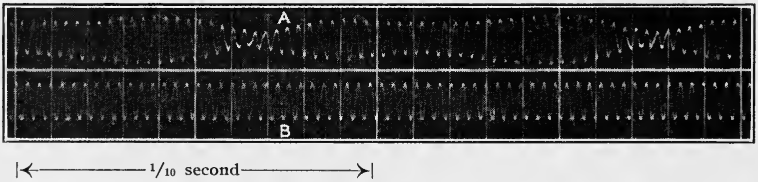

FIG. 4. Frequency-modulated tone in "live" and "dead" rooms.
(A) Frequency-modulated tone in "live" room.
(B) Frequency-modulated tone in "dead" room.

in the amplitude of the signal. It is to be expected, therefore, that the frequency-modulated signal will sound quite differently when heard in a "live" room than in a "dead" one.

Under any given listening condition there is a marked difference in the aural sensation produced by a 1000-cycle tone modulated at rates of about 40 cycles and above, and by the same tone modulated at about 20 cycles and below. At the latter rates of modulation one hears a tone that sweeps up and down in pitch across the frequency band. That is, one hears the modulated signal in the form that would be the natural interpretation of equation (5) and the discussion leading up to it. For rates of modulation of about 40 cycles and above, however, one hears a group of frequencies that are not harmonically related to one another and which impart a harsh quality to the tone. In this case, one hears the modulated signal in the form that would be the natural interpretation of equation (10). Now, it has been shown that, analytically, equations (5) and (10) are merely two ways of writing the same thing. It is interesting that (5) appears to be a more natural interpretation for low rates and (10) for higher rates of modulation.

In producing musical tones musicians often use artistic frequency modulation to improve the musical quality of their performance. An important component part of the *vibrato* is a frequency modulation at a rate of about 6 cps., with an amplitude of plus and minus several per cent.

That the auditory effects of a frequency-modulated signal and an amplitude-modulated signal may be very similar under certain conditions is shown in Fig. 5. Oscillogram *A* shows a frequency-modulated signal, the modulation being so small that it can not be

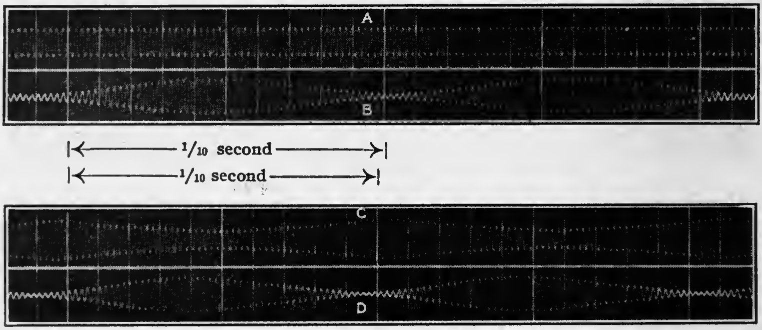

FIG. 5. Frequency modulation and amplitude modulation in a live room.
(*A*) Frequency-modulated input to loud speaker.
(*B*) Microphone output.
(*C*) Amplitude-modulated input to loud speaker.
(*D*) Microphone output.

seen as such; and oscillogram *C* shows a signal that is amplitude-modulated at the same rate. Each of these signals was supplied to a loud speaker in a live room, and oscillograms *B* and *D* show the signals picked up by a microphone in the room. In this case a live room has modified both types of signals so that they are practically identical.

METHODS OF PRODUCING KNOWN AMOUNTS OF ARTIFICIAL FLUTTER

There are a number of methods for producing known amounts of artificial flutter. In the case of constant-frequency signals, a simple way is to vary the tuned circuit capacity in one of the high-frequency circuits of a heterodyne oscillator by means of a rotating variable air condenser with plates so shaped and driven at such rates as to give the desired modulation.

In the cases of speech and music, the problem is more difficult. Here, one way is to produce the undistorted signal in the form of a plane acoustic wave, and swing a pick-up microphone to and fro along the direction of travel of the sound. Where the signal is generated by a loud speaker, the latter may be vibrated instead of the microphone, if more convenient. The resulting signal will then be frequency-modulated at the rate of the vibrating microphone or speaker, and at an amplitude that may be calculated. Obviously, room reflections may provide serious complications to this method, especially if used for modulating an original sound signal that may be coming from several different directions at once, and therefore

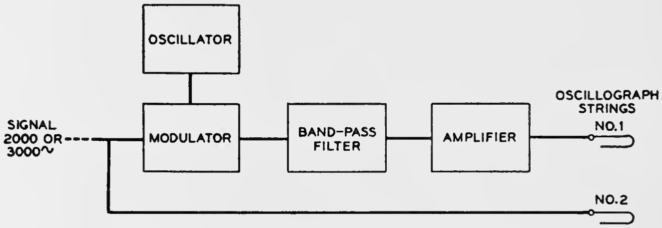

FIG. 6. Schematic arrangement of a flutter-measuring circuit.

be subjected to varying amounts of modulation depending upon its angle of incidence with the vibrating microphone. The method is better suited to distorting the signal from a loud speaker because the speaker may be mounted in a sufficiently dead room in such a manner that the effect of reflections may be made negligible.

Generally speaking, it is easier to modulate a signal that is already stored in the form of a record. In this case it is necessary only to introduce, mechanically, the desired speed variations in the record. An alternative is to drive the record at a uniform speed and to vibrate the pick-up device so that the scanning point moves along the record at a non-uniform speed. For demonstration purposes the desired effect has been attained by operating upon a film record played back in a re-recording machine. The film speed relative to the scanning light was varied by means of a motor-driven cam, the speed and eccentricity of which determined the rate and amplitude, respectively, of the resulting frequency modulation.

METHODS OF MEASURING FLUTTER

In the practical analysis of the flutter caused by speed variations in a reproducing machine, the signal from a constant-frequency record run in the machine is analyzed for frequency modulation. This is done by changing the frequency modulation into amplitude modulation, and demodulating this modified signal in some common form of detecting circuit.

A very useful form of analyzing circuit and one that is at present

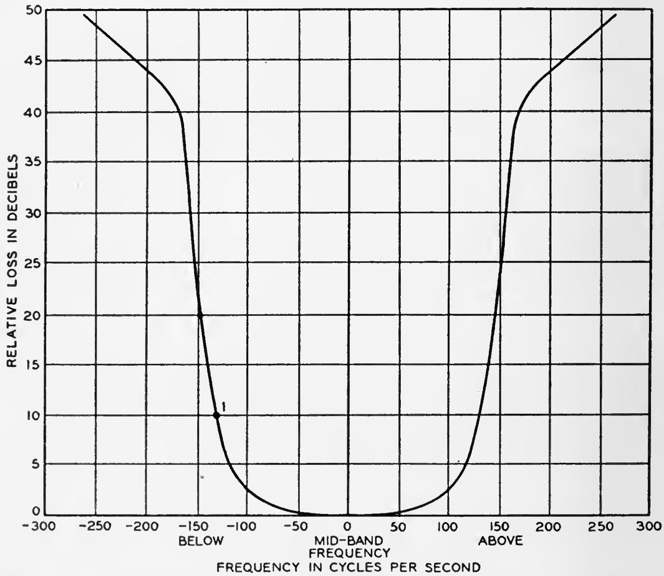

FIG. 7. Attenuation-frequency characteristics of the band-pass filter.

in use at Bell Telephone Laboratories is shown in schematic form in Fig. 6. A 2000- or 3000-cycle signal (with side-bands) from the machine under test is modulated by an oscillator tone. The difference-frequency passes through a band-pass filter at the point marked *1* upon the frequency characteristic shown in Fig. 7. Here the lower side-bands are attenuated and the upper side-bands amplified relatively to the carrier frequency, resulting in an amplitude-modulated wave that is amplified and recorded by one string of a rapid-record oscillograph.[5] To insure that any amplitude change that might occur in the original signal will be observed, another string of the oscillograph is used simultaneously to record this signal directly.

Because of the complicated character of a frequency-modulated signal it is laborious to calculate the response of such a circuit to frequency modulation of various amplitudes and rates. This is especially true since in many cases more than the first-order terms must be taken into consideration. It is a more practicable expedient to calibrate the equipment, using known amplitudes and rates of artificial flutter.

DEMONSTRATIONS ACCOMPANYING THE PRESENTATION OF THIS PAPER

An extensive demonstration accompanied the presentation of this paper at the Spring, 1935, Meeting at Hollywood, Calif., May 20–25, 1935. The mathematical portion of the paper was not presented, but, instead, the side-band nature of frequency modulation was demonstrated.

The demonstrations were designed to illustrate the many interesting and varied acoustical phenomena that occur in connection with sound flutter, and were built up from simple physical phenomena with which most motion picture engineers are acquainted. It was not intended to include material relative to commercial tolerances in flutter. In order that the phenomena involved could be clearly perceived by the audience, the amounts of flutter demonstrated generally exceeded greatly what is permissible in commercial practice.

(*1*) *Visual vs. Auditory Perception of Flutter.*—Oscillograms and fluttered tones were used to show that flutter could be perceived visually in oscillograms only when extreme in amount.

(*2*) *Side-Band Nature of Flutter.*—The production of discrete side-tones was shown by slides and demonstrated by means of a search analyzer.

(*3*) *The Influence of Room Acoustics upon the Perception of Flutter.*

(*4*) *Method of Measuring Flutter in Sound Tones.*

(*5*) *Flutter in Single-Frequency Tones.*—(*a*) The rate of flutter and (*b*) the amplitude of flutter were varied in a 1000-cycle tone to show the accompanying changes in the character of the distortion heard.

(*6*) *Flutter an Important Part of Artistic Vibrato.*

(*7*) *Flutter in Speech and Music.*—(*a*) The rate of flutter and (*b*) the amplitude of flutter were varied in excerpts of typical speech and music records to show the accompanying changes in the character of the distortion heard.

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[2] VAN DER POL: *loc. cit.*

SHOWER, E. G., AND BIDDULPH, R.: "Differential Pitch Sensitivity of the Ear," *J. Acoust. Soc. of Amer.*, **3** (Oct., 1931), No. 2, Part 1, p. 275.

[3] WATSON, G. N.: "Theory of Bessel Functions," *Cambridge Univ. Press* (1922), p. 22.

[4] HANSON, R. L.: "Liveness of Rooms," *J. Acoust. Soc. of Amer.*, **3** (Jan., 1932), No. 3, p. 318. (Fig. 3 is taken from this paper.)

[5] CURTIS, A. M., SHEA, T. E., AND RUMPEL, C. H.: "The Rapid-Record Oscillograph in Sound Picture Studies," *J. Soc. Mot. Pict. Eng.*, **XVIII** (Jan., 1932), No. 1, p. 39.

[6] KELLOGG, E. W.: "A New Recorder for Variable-Area Recording," *J. Soc. Mot. Pict. Eng.*, **XV** (Nov., 1930), No. 5, p. 653.

DISCUSSION

MR. SHEARER: There is hardly any need for me to emphasize that the care and trouble taken in preparing these records was no small task. I dare say it took a group of men many weeks, if not months, to prepare the material, and we certainly have to thank Mr. MacNair, his associates, and company for producing this excellent introduction to the Society of these recording troubles by their true names.

I have always maintained that the tone purity of recording is of more importance than the correct frequency characteristic. We have been a little too prone to regard good sound as something that merely has the correct frequency characteristic. We see how readily extremely small amounts of flutter, three-quarters of one per cent, one per cent, three per cent, at various frequencies can utterly ruin the sound record; and when we consider that these distortions can enter into the original recording, in the printing to some extent and under extreme circumstances, and also in the reproduction of sound, we can see that a sound runs many chances of having this extreme kind of distortion introduced into it. If the sound arrives at the theater with less flutter than half of one per cent, it really is quite remarkable.

I believe that flutter trouble is much more noticeable than a small departure from a true frequency characteristic. I should like to re-emphasize the fact that the various *rates* of flutter that we heard have a varying effect upon the amount of distortion that is apparent. I get the impression that the rates at 96 cps., or thereabouts, are more damaging than the rates above that, although, of course, the content of the record has something to do with exactly what rate has the most effect upon it.

In dealing with flutter introduced purposely into the record, such as the *vibrato* in singing, we obtain some idea of how critical a singer's *vibrato* is toward producing a pleasant tone. I believe we notice *vibrato* errors in singing more than any other defect in the quality of their voices.

MR. KELLOGG: I feel that I am a veteran as to experience in listening to the effects of speed variations, or "wows," upon music and speech. My first such experience occurred in 1919, when working with Chester Rice on what we hoped might be a system of secret telephony, which consisted in distorting speech beyond recognition by recording it upon a wire and then taking it off with a moving pick-up. Our rate of motion back and forth with the pick-up was probably not more than twice per second, so it was a fairly slow "wow," but it amounted to 25 or 30 per cent. What amazed and at that time discouraged us in the work was that, no matter what we did, we could not seem to make speech entirely unintelligible. It is the wonderful "toughness" of speech in that respect that has made radio and talking movies.

We called our distorter our "wow-wow" machine, because that term seemed to describe the way things sounded that we put through it. So far as I know, that was the first use of the term to designate a speed variation.

A few years later I had a change of heart. Instead of trying to produce "wows," I began trying to eliminate them. I worked hard on the problem and discussed it at some length at the Washington Convention in 1930.[6]

This admirable demonstration supplies what I have wanted to hear for years; namely, "wows" of known magnitude introduced in order to study the effects of various kinds and amounts upon quality.

There are two or three questions: A *vibrato* in a single voice is unquestionably regarded by many as pleasant. It is provided in musical instruments, such as organs, and is produced when desired by violinists, although the amplitude of the "wows" so introduced is, I believe, less than that found in many vocal renditions. I wonder whether, in the case of a number of tones or voices sounding together, it makes any difference whether the "wows" are all in phase, as occurs when they are introduced into recorded music by speed fluctuations in a machine, or in random relation, as occurs with separate voices or instruments. I wonder also, whether the live-room or the dead-room test provides the more reliable indication of what is tolerable in "wows" or speed fluctuations. I confess to have found it difficult to establish any definite relationship between the fluctuations that are noticeable on steady tones in a live room, and those that are found to be distinctly objectionable in musical reproduction. In musical reproduction it is amazing how much one can stand for, not without some loss of quality, but before people begin to complain. Have you made any tests that would indicate whether head-phone tests, or dead-room or live-room tests are better guides to how much one can stand before the sound begins to sound "sour"?

MR. MACNAIR: There has been some argument in the Acoustical Society recently as to exactly what *vibrato* was, and I was careful to state that frequency modulation was only one part of it. It seems to be well established that a small amount of amplitude modulation always accompanies the frequency modulation, and just why the 6-cycle modulation sounds best, I do not know. It probably has to do with the ease with which that frequency can be produced, because with instruments like the violin it is often slower than that. I do not know the answer as regards what happens when a chorus of people sing, each one having his own modulation.

As to the question in regard to what one hears in a live or dead room, there are perhaps several answers. In the demonstration we tried to show that the frequency modulation certainly sounded different in a dead room from what it did in a live room. Whether the tests should be carried out in a dead room or in live room, I believe, depends upon the circumstances.

A PORTABLE FLUTTER-MEASURING INSTRUMENT*

R. R. SCOVILLE**

Summary.—*A portable flutter-measuring equipment is described which may be used to measure the uniformity of motion of recording and reproducing machinery. The instrument filters out noise components, magnifies the frequency modulation, converts it to amplitude modulation, and finally demodulates it to obtain an indication of the frequency variation present in the original signal.*

In flutter-correction work adjustments are made on the reproducer under the guidance of the measuring set. The cumulative effects of change of pressure or position of the guide shoes, alignment of sprockets or bearings, although individually small, are often considerable. To study flutter in recording machines 3000-cycle records are made, which are subsequently reproduced on known flutter-free machines and measured with the instrument.

Frequency modulation or flutter is caused by non-uniform motion in sound recording and reproducing machinery. Until recently the practical reduction of flutter in the studio and in the theater has been a troublesome problem. This is due to the extremely small amplitude of the variations involved and to the difficulty in detecting the mechanical cause of the trouble. But with the development of a portable instrument sufficiently sensitive to measure these complex frequency variations, a new and much needed technic for correcting flutter has been made available for field use.

Fig. 1 shows the external appearance of the equipment. The instrument is of the direct-reading type, with a range of sensitivity between ±0.02 and ±3.0 per cent. This has been found to be satisfactory for all conditions of frequency variation encountered in practice. The readings of the instrument represent the per cent change above and below the mean frequency being measured, and are independent of the rate of the variation, except for flutter rates below two per second, and except also as affected by the optional use of filters which aid in the determination of the flutter rate.

The equipment consists of two cases weighing about 35 pounds

* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** Electrical Research Products, Inc., Los Angeles, Calif.

each. It is energized from a 110-volt, 50–60 cycle a-c. line, and no batteries or additional equipment are needed. For general flutter measurement work, the output of a theater reproducing system is connected directly to the measuring instrument. When exact determinations of the flutter frequencies are required, an oscillograph may be connected to the instrument for analysis work, but this is seldom required.

The principles underlying the production and measurement of frequency modulation, particularly as applied to recording and re-

FIG. 1. Flutter-measuring instrument set up for operation.

production, have been published elsewhere.[1] The instrument to be described herein operates in the following manner: A flutter-free 3000-cycle record is reproduced on the machine to be measured, and the output is connected to the flutter-measuring equipment. The instrument circuits first filter out noise and extraneous frequencies which would otherwise interfere in the measurement. The wave is then heterodyned by a variable-frequency oscillator in such manner that a difference-frequency of predetermined value is obtained. Consequently the mean input frequency need be only approximately 3000 cycles. The resultant wave of definite mean frequency and amplitude is then impressed upon a frequency-discriminating network which converts the frequency-modulated wave to one having amplitude modulation. The transformation is such that the percentage of amplitude modulation obtained is proportional to the percentage of frequency modulation *and independent of the rate* of this modulation.

After further amplification, the amplitude-modulated wave is impressed upon a demodulator, which recovers the envelope frequency and measures it. Since the envelope amplitude is related to the percentage of frequency variation and is of the same rate as that of the original speed variation, it is made to operate a meter calibrated directly in percentage of frequency variation. Headphones or an oscillograph may be plugged into the instrument to determine what flutter rates are present. A segregation of the flutter frequencies present is made possible by the use of a filter incorporated in the instrument, by means of which readings may be made of either the low-frequency (1 to 20 cps.) or the high-frequency components (20 to 130 cps.). These respective bands may also be connected to an external oscillograph for more detailed analysis, if desired.

Despite the intricate transformations performed in the flutter-measuring instrument, the manual operations required to obtain a reading are simple and logical. The signal is adjusted to a designated amplitude, and the calibrating dial is manipulated to compensate for deviations of the mean input frequency, until the meter directly above the dial (Fig. 1) indicates the designated value. After setting the meter-scale dial (lower left, Fig. 1) to the correct position, depending upon the amount of flutter in the source, the percentage of frequency variation is indicated upon the meter shown in the lower case of the instrument (Fig. 1). The meter-scale dial provides for full-scale meter indication for percentage of frequency variations of ± 0.1, ± 0.3, ± 1.0, and ± 3.0 per cent. Having determined the total percentage of frequency variation in the source, the classification of the variation as to rate is made by throwing over the low-pass filter key where flutter components having rates up to 20 cps. are measured. Similar measurements are made in the high-range position, of components from 20 to 130 cps. This feature is of special value in locating sources of flutter for purposes of making adjustments.

Approximate determination of the rate of variation of the flutter pattern is made by listening with telephone receivers introduced at appropriate points in the circuit. If the rate is low, the flutter may be readily distinguished and counted in reference to time; whereas, if it is high, a note of the corresponding frequency may be heard by connecting into the demodulator circuit. Either a cathode ray or an oscillograph of the recording type may be plugged in, if desired, to analyze the flutter pattern. Figs. 2 and 3 are oscillograms of the output of the flutter-measuring instrument. Fig. 2 was made using the low-pass filter, which excluded flutter frequencies greater than about 25 per second. A frequency of about 20 per second is very noticeable, together with a component having a rate between 2 and 3 per second. The 20-cps. rate was found to correspond to the rotational speed of one of the drive shafts, while the second was the result of unbalance of the flywheel. Fig. 3 shows the flutter components present in the higher range. In this case the dominant fre-

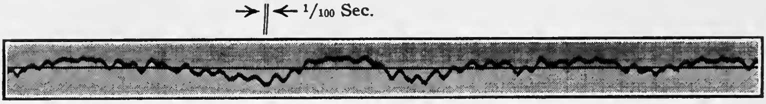

FIG. 2. Low-frequency flutter pattern, with a prominent 20-per second component, and an additional variation occurring 2–3 times per second.

FIG. 3. High-frequency flutter pattern showing the 25–150 per second components. Note the prominent 96 per second variation.

quency is found to be 96 cps. which is the rate at which the sprocket teeth engage the film.

In flutter correction work, adjustments are made on the reproducer under the guidance of the flutter-measuring instrument. Fig. 4 shows the instrument set up in a projection booth and adjustments being made on the machine. The procedure varies with the nature of the equipment involved; but, in general, adjustments are made while the machine is operating by observing the indications of the flutter-measuring instrument. The application of finger pressure at certain points in the film path may reduce the flutter and indicate to the operator the need of certain mechanical adjustments. Change of sprockets often produces a considerable improvement. The relative alignment or eccentricity of sprockets or rollers, defective gears, and unbalance of the flywheel system, may all be contributing flutter factors. The measuring equipment, by informing the operator of small improvements made during the adjustments, each of which might by itself be inaudible, makes possible a cumulative improvement that may be of very observable magnitude.

In a recent case of flutter correction, measurement of the machine

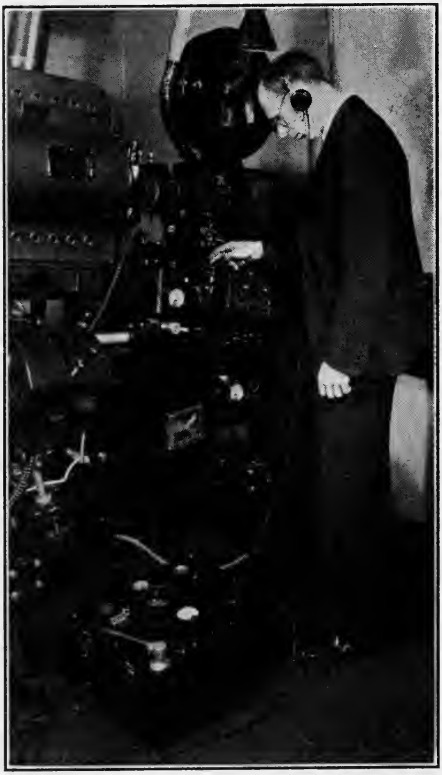

FIG. 4. Operation of flutter-measuring instrument in the projection room of a theater.

disclosed a frequency variation of approximately 96 cps., due to sprocket hole pull, of ±0.9 per cent and a low-frequency reading of ±0.25 per cent, mainly at six cps. The rates mentioned were identified by a head-phone test, but could have been more precisely analyzed by an oscillograph. The pressure of the guide shoes in the vicinity of the sound sprocket was changed, and the reading dropped to ±0.7 per cent. The sound sprocket was removed, inspected, and found to be undercut due to wear. Replacement resulted in a reduction to ±0.5 per cent, or approximately half the original value. Although this was not regarded as entirely satisfactory, attention was shifted to the low-frequency variation. Measurement showed the sound sprocket to have excessive eccentricity. This was corrected. The low-frequency reading dropped from ±0.25 to ±0.18. Similar treatment of a second sprocket near the filtered drive decreased the reading further to ±0.15 per cent. Next, the alignment of all sprockets and rollers adjacent to the scanning point was carefully checked,

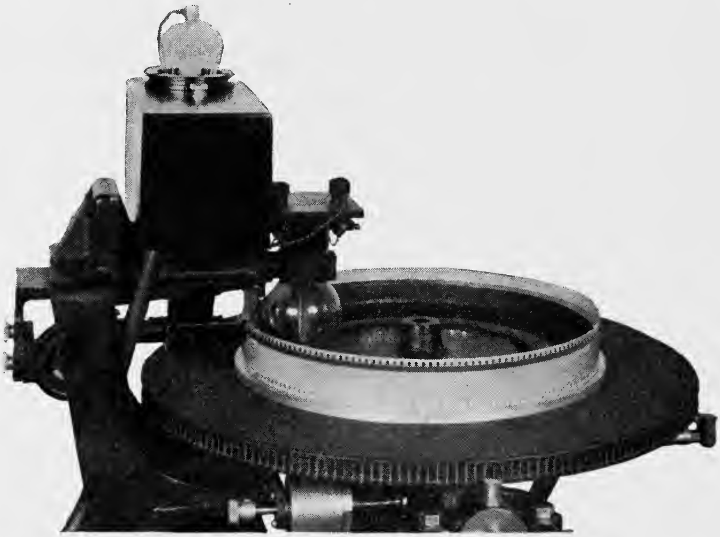

FIG. 5. Reproducer for flutter measurements of test recordings.

and changes made as required. The reading then dropped to ±0.12, which was one-half the original amount. Switching over to the high-frequency measuring range disclosed a reduced reading, and after further adjustment of the guide shoe the indication dropped to ±0.32 per cent, or about one-third the original variation. It was noticed, however, that slight finger pressure upon one side of the film caused the reading to drop appreciably. The guide shoe assembly was removed and provision made to shift the angle of the guide shoe axis relative to the film. On reinstalling and adjusting to the optimum position, the reading on the high-frequency range was found to have dropped from the original value of ±0.9 per cent to ±0.25 per cent, which was regarded as satisfactory. After some further work on the machine, the low-frequency reading came down to a minimum of ±0.08 per cent, which was approximately one-third the original value. Listening tests confirmed the over-all improvements shown by the measurements, although each individual improvement was too small to be noticeable.

In extensive field tests recently conducted, the average high-frequency type of flutter was reduced to half its original value by means of the technic herein described. At the same time the average low-frequency flutter was reduced to two-thirds. None of the reductions were of such a nature that the unaided ear could have effected the improvement, which in the aggregate was considerable.

In flutter correction work upon recording machines, the procedure is somewhat different from that just outlined. Several test recordings are made and subsequently reproduced by a relatively flutter-free reproducer, so that the measured flutter is substantially that recorded upon the film, rather than that introduced by the reproducer. Measurements are made with each sample and the relative readings are compared. Fig. 5 shows a practically flutter-free reproducer used in measuring film recordings. It consists of a drum mounted upon the turntable of a high-quality disk recording machine, and a scanning means for reproducing film wound around the drum. This method, originally proposed and used by Bell Telephone Laboratories, has given very satisfactory results. At present, the flutter produced in film recording machines is considerably less than that found in average projection machines; consequently the measurements of recorded flutter are more delicate than those for film reproduction.

Marked improvements in sound quality almost invariably follow the intelligent application of this technic. The flutter-measuring instrument, by indicating the approximate nature of the frequency variations present, suggests the method of correction. Practical results have shown that some form of measuring instrument is an almost indispensable tool for correcting flutter.

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LIGHTING FOR TECHNICOLOR MOTION PICTURES*

C. W. HANDLEY**

Summary.—*Some of the studio illuminating equipment used for lighting in Technicolor productions is described, together with brief discussions of the spectral characteristics of the various units. Included are the broadside, supplementary lighting units, the Sunlight arc, the Sun Spot and Solar Spot, diffusing mediums and color filters, and arc silencing devices and methods.*

The introduction of the Technicolor three-color process of color photography into the motion picture studios brought forth the need for improved studio lighting equipment. All known color processes involve filtering or breaking up the light entering the camera into the primary colors, and recording each color upon a separate emulsion. Obviously, in a three-color process, a lower intensity of illumination falls upon each of the three negatives than upon the single negative used in black-and-white photography, because the latter receives all the rays passing through the camera lens. It is therefore necessary that the stage illumination be of higher intensity than required for black-and-white photography in order to attain corresponding photographic speed. Furthermore, since the color-sensitivity of the three negatives and the color-balance of the process as a whole is designed to render accurate color tones under daylight illumination, it is highly desirable that the light-source used in the studio should have a spectral energy distribution conforming closely to that of natural sunlight.

It is true that the same photographic effect can be attained with a light-source differing in quality from that of sunlight by using suitable filters. This, however, involves the absorption of a portion of the light reflected from the set, and a consequent reduction of photographic speed. The fact must always be recognized that filters never add light of any color. They merely reduce the intensity of the colors they are designed to suppress. Any increase of temperature on the set over that experienced in black-and-white productions

* Presented at the Spring, 1935, Meeting at Hollywood, Calif.
** National Carbon Co., Los Angeles, Calif.

is highly undesirable. It is accordingly evident that changes in lighting equipment must be of a character to provide an increase of photographic light of daylight quality without exceeding the amount of radiant heat projected upon the stage by the lighting equipment used for black-and-white photography.

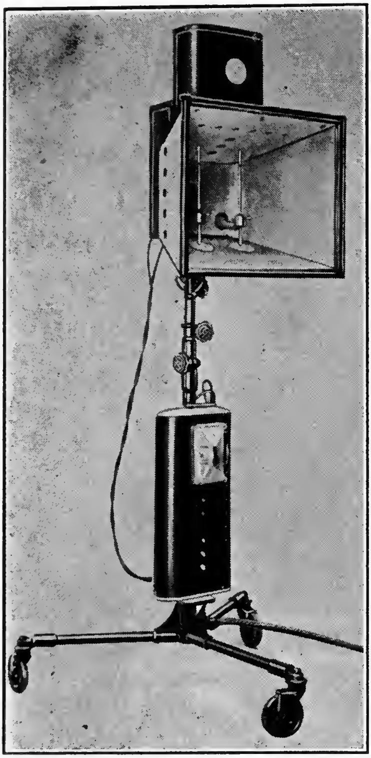

FIG. 1. *MR-29* twin-arc broadside lamp.

THE BROADSIDE

The white-flame carbon arc has long been recognized as a light-source of high photographic efficiency and as one providing photographic effects essentially equivalent to those of sunlight. The old type of broadside lamp, burning $^1/_2$ by 12-inch white-flame carbons at 40 or 45 amperes were extensively used in the days of silent pictures. The mechanism of these lamps is of such design, however, that it is practically impossible to adjust it so that it will operate with the quietness necessary when used in proximity to sound recording equipment. Furthermore, higher intensities of illumination than these units are capable of supplying are required to meet the needs of the Technicolor process satisfactorily with a reasonable number of lamps upon the set. Since the broadside, used for floor lighting, and the scoop, for overhead lighting, provide the broad level of general illumination for the set as a whole, they constitute the most important elements of the lighting equipment. It is these units that establish the general color-tone of the scene in Technicolor photography.

The research laboratory of the National Carbon Company undertook the development of a new carbon to fulfill the specific needs of this new photographic process. The result of the research was a metal-coated carbon 8 millimeters in diameter, designed for operation at 40 amperes. Its characteristics have been described in detail by Joy, Bowditch, and Downes.[1] Due, in part, to the high current-density at which these carbons are operated, their light departs somewhat from the normal characteristics of the white-flame carbon arc and takes on more of the character of the high-intensity arc. In fact, through the photographically effective range, the relative intensity of

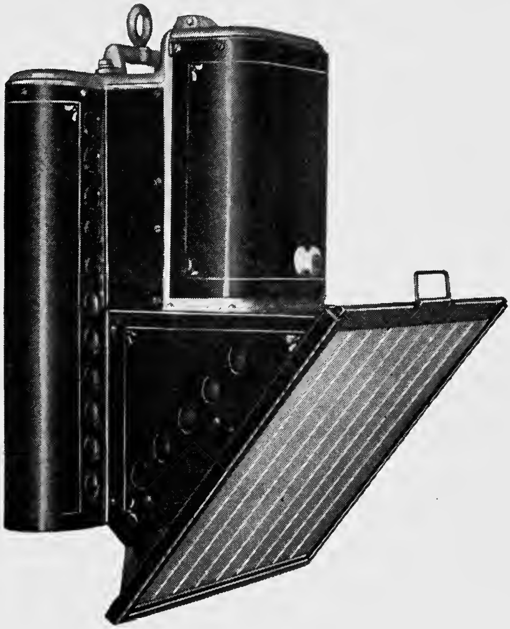

FIG. 2. *MR-27* scoop.

radiation at various wavelengths is almost indentical to that of the 13.6-mm. high-intensity projector carbon arc operated at 125 amperes.

The development of a suitable lamp for use with these carbons was then accomplished through coöperation with an established lamp manufacturer. Two lamps were designed and made available to the motion picture studio: the twin-arc broadside lamp, *MR-29*, shown in Fig. 1, and the twin-arc scoop, *MR-27*, shown in Fig. 2. A detailed discussion of the development of these lamps has been given by Mole[2] together with a statement of the specifications that had to be fulfilled in adapting them to color photography. These units burning the new

National motion picture studio carbons deliver somewhat more than the required 200 foot-candles at 15 feet; give an even distribution of light, constant in quality and intensity; provide a spectral energy distribution very similar to that of sunlight; and fully fulfill the requirements of silence imposed by the sound technicians. They have proved highly efficient for black-and-white photography, and practically a necessity for color photography. A comparison of the spectral energy distribution of the light from these lamps with that of

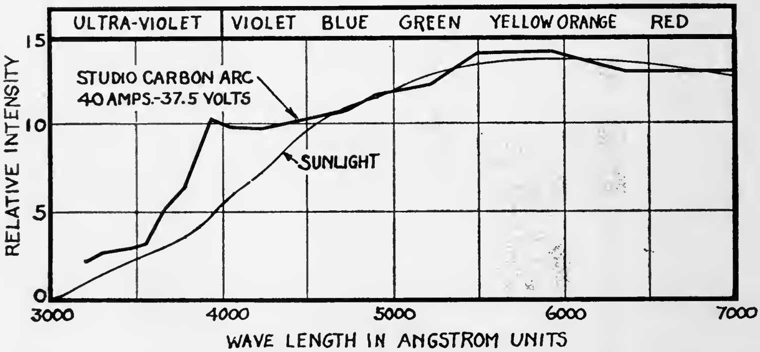

FIG. 3. Spectral energy distribution of studio carbon arc and sunlight.

natural sunlight is given in Fig. 3. A distinct advantage of this light, as pointed out by Joy, Bowditch, and Downes,[1] is that more than 40 per cent of the radiant energy emitted is photographically effective.

SUPPLEMENTARY LIGHTING UNITS

While broadsides and scoops provide the general level of set illumination and are highly satisfactory for the front and side lighting, their use without supplementary equipment would result in flat and uninteresting photographic effects. Accordingly, very powerful lighting units are placed in elevated and other strategic positions when strong shafts of light are required to pierce the even intensity of illumination supplied by the broadsides and the scoops. These larger units are used also for increasing the intensity of light in any given area, thereby separating points of special interest from the remainder of the set. The units used for this supplementary lighting are the spotlights and sun arcs, powerful carbon arc lamps that utilize the high-intensity principle first applied to searchlights and later extensively adopted for motion picture projection.

THE 80-AMPERE ROTARY ARC SPOTLIGHT

The 80-ampere rotary arc spotlight is used for back-lighting and to increase the intensity of illumination at any point where projected light is required, where the increase desired does not demand the power of a sun arc. It is in regular use in most of the studios and has been adapted to sound by the use of fiber gears which reduce mechanical noise. Some of them are fitted with snap-switches to cut out the control motor when the unit is close to the microphone. They are operated at 75–80 amperes with 50–55 volts at the arc. The operating element of an 80-ampere rotary spotlight is shown in Fig. 4.

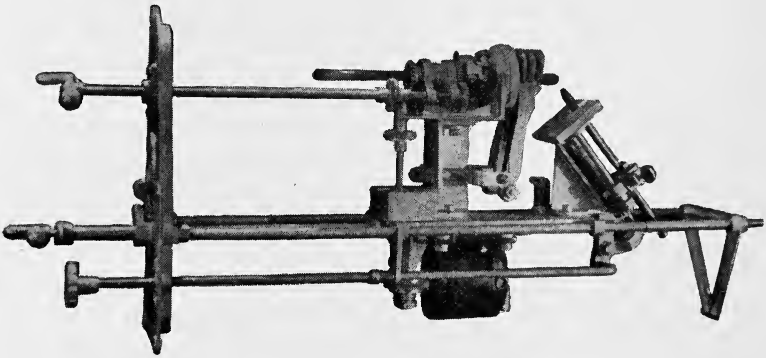

FIG. 4. Element of 80-ampere rotary arc spotlight.

To insure full efficiency and uniform photographic effect, reasonable attention should be given to the maintenance of these lamps and to preserving correct conditions of operation. A recent examination of several of them in operation revealed considerable variation in the quality and quantity of light emitted. This resulted from various causes, all easily removed or prevented. A badly pitted and soiled condenser was found to cut out as much as 40 per cent of the total light output. A variation of $^1/_2$ inch in the arc-gap (not uncommon in practice) changed the spectral energy distribution sufficiently to be noticeable in the Technicolor negative. In order to arrive at a standard for this type of unit in one instance, a lamp was fitted with a clean condenser free from pit marks, the best arc length (approximately $^1/_2$ inch) was maintained, a spot three feet in diameter was focused upon a white wall thirty feet from the unit, and the direct light was measured with a standard Weston photometer fitted with a filter that reduced the intensity to within the limits of the instrument.

The figures so obtained are used in checking other units of this type.

The spectral energy distribution of the 80-ampere rotary spotlight is higher at the blue end of the spectrum than that of the broadside lamp. A satisfactory color balance is maintained by the use of straw-colored gelatin in front of the condenser. Although this filter is very light, it reduces by more than 20 per cent the photographically effective radiation of the lamp. The need for the development of a new lamp, to give the desired spectral energy distribution without the use of a filter, is therefore indicated. In all probability such a lamp should have a different carbon trim from that now being used in rotary spotlights.

FIG. 5. 36-inch Sun arc.

THE SUNLIGHT ARC

Two sizes of Sunlight arc are in common use, the mirror diameters of which are, respectively, 24 inches and 36 inches. They are designated as 24-inch Sun arcs and 36-inch Sun arcs. A 36-inch Sun arc is shown in Fig. 5. These lamps are used where the highest intensity of projected light is required, as in back-lighting when the action calls for a high level of foreground illumination; where well-defined shadows are desired; where a clearly defined streak of light cuts through the general illumination; and for producing high intensities of general illumination of great penetration. In the latter case diverging doors composed of strips of cylindrical lenses are often used in front of the lamp houses.

The spectral energy distribution of the light from this lamp is similar to that from the rotary spotlight, and, likewise, requires the use of a light straw filter to establish accurate color balance. There is

TABLE I

Lighting Equipment Used by Technicolor

Lamp	Type	Trim	Use	Amperes	Arc Volts
MR-29 Broadside	Twin vertical trim solenoid feed	8-mm. × 12 studio carbons positive and negative	Floor lighting	40	35–40
MR-27 Scoop			Overhead lighting	40	35–40
80-Amp. Rotary Arc Spotlight	Rotating positive high-intensity arc motor feed	$^1/_2$ × 12 80-amp. rotary spot positive; $^5/_{16}$ or $^3/_8$ × 9 CC negative	Back-lighting Spotlighting	75–80	50–55
24″ Sun Arc	Rotating positive high-intensity arc motor feed	16-mm. × 18″ or 20″ HI; WF positive; 11-mm. × 10 plain-cored negative	Back-lighting Spotlighting	135–150	68–72
36″ Sun Arc	Rotating positive high-intensity arc motor feed	16-mm. × 18″ or 20″ HI; WF positive; 11-mm. × 10 plain-cored negative	Back-lighting Spotlighting	135–150	68–72
36″ Sun Spot	Motion picture studio photoflood	10-kw. photoflood tungsten lamp	Effect lighting	87	115
MR Junior Spotlight		2000-watt *G48* tungsten lamp	Effect lighting	17.4	115

accordingly evident need for further development of this type of unit to eliminate the necessity of using a filter.

THE 36-INCH SUN SPOT

The 36-inch Sun spot is similar in appearance and design to the 36-inch Sun arc except that it uses as a light-source a 10-kw. special tungsten lamp. It is used where a color contrast is desired and where warmer tones predominate; as behind windows, where the effect of the increased red radiation creates the illusion of the yellow-orange of afternoon sunlight.

JUNIOR SOLAR SPOT

The Junior Solar spot is a newly developed unit fitted with a special prismatic front lens and a spherical mirror. It is equipped with a 2000-watt, *G-48* tungsten lamp which may be moved to a flood position or to a focus where it delivers a highly concentrated beam. The type of trim, as well as the arc current and voltage used by the different types of lighting units, is shown in Table I.

DIFFUSING MEDIUMS AND LAMP COLOR FILTERS

As previously stated, some of the high-intensity Sun arcs and 80-ampere, rotary-arc spotlights are fitted with straw-colored gelatin filters to cut out an excessive amount of blue. In addition to these, gelatin hangers of various colors are available so that the spectral energy distribution of any lamp may be changed at will to suit the requirements of the scene. Frosted gelatin hangers are used to soften the light from certain lamps. The Sun arcs have, as auxiliary equipment, diverging doors for use in spreading the beam on its horizontal transverse axis. The broadsides are fitted with "Factorlite" glass screens. These are sand-blasted on one side and molded on the other, making excellent diffusing mediums.

ARC-SILENCING DEVICES AND METHODS

Methods of silencing arc lights have been perfected by the studios. In 1930, W. Quinlan, Chief Engineer of the Fox Studios, produced and equipped that studio with complete sound filtering devices. These units consist of high-capacity electrolytic condensers connected across the bus-bars of the generator, and individual choke-coils mounted as an integral part of each lamp.[3] Other studios use high-capacity condensers of the dry type, and individual choke-coils for the various types of units. L. Kolb, Chief Electrical Engineer of M-G-M Studios, has developed larger choke-coils rated at 1000 amperes, which are mounted upon rollers and may be used at the power house. These developments, together with the previously mentioned development of the new motion picture studio carbon arc, make possible the use of 100 per cent carbon arc illumination of the motion picture stage without the slightest interference with sound recording.

REFERENCES

[1] JOY, D. B., BOWDITCH, F. T., AND DOWNES, A. C.: "A New White-Flame Carbon for Photographic Light," *J. Soc. Mot. Pict. Eng.*, **XXII** (Jan., 1934), No. 1, p. 58.

[2] MOLE, P.: "A New Development in Carbon Arc Lighting," *J. Soc. Mot. Pict. Eng.*, **XXII** (Jan., 1934), No. 1, p. 51.

[3] Report No. 2, Producers and Technicians Committee, *Acad. Mot. Pict. Arts & Sciences* (May 7, 1930).

ERRATUM

In the paper entitled "The Technical Aspects of the High-Fidelity Reproducer," by E. D. Cook, published in the October, 1935, issue, equation (10) on p. 304 should read

$$\mu = \mu_0(1 + \beta t)^{-\eta}$$

REPORT OF THE STUDIO LIGHTING COMMITTEE*

Several years ago a comprehensive program of making available to the industry complete information on illuminants, equipments, and practices in studio lighting was planned. Owing to the extent of the subject, it was deemed advisable to present this material in four reports, each covering a particular phase of studio lighting.

The first report was to deal with illuminants, their characteristics, available sizes, *etc.;* the second to discuss the various lighting equipments; the third, power supplies and distribution methods; and the fourth, lighting practices. To carry out this program it was necessary that the Committee be kept intact through two administrations of the Society, and it was the thought that all this material might eventually be published as a single booklet, a sort of handbook on studio lighting.

The first two of the reports were presented before the Society and published in the JOURNAL.[1,2] Unfortunately, because of changes of the Committee personnel, reports covering the third and fourth parts of the program were never presented. The present Committee, which includes in its personnel four of the original Committee that formulated the program, believed it a good plan to bring sections one and two up to date, as well as to present the third part covering studio power supplies and distribution methods.

(1) IMPROVEMENTS IN LIGHT-SOURCES

Arcs.—One of the most outstanding arc developments for studio lighting since the presentation of the original report has been the high-intensity, white-flame carbons. These carbons, 8 millimeters in diameter, are designed for use in general lighting equipments such as broadsides and scoops. They are copper-coated, and operated at 35–40 amperes, or at two and one-half times the current density at which the older $^1/_2$-inch carbons were operated, thus giving approximately 25 per cent more light for the same wattage. More complete data on these carbons has been given by Joy, Bowditch, and Downes.[3]

* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

Further improvements in arc carbons for studio lighting have been in the nature of refinements. A $^1/_2 \times$ 12-inch cored positive carbon for the 80-ampere rotary has been made available, with better performance features. A $^5/_{16}$-inch diameter copper-coated negative carbon is now recommended in place of the $^3/_8$-inch negative; also, the $^3/_8$-inch negative replaces the $^7/_{16}$-inch negative.

Mazda Lamps.—The original report described characteristic incandescent lamps operating at filament temperatures up to about 3100°K. Since that time, lamps have been made available with filament temperatures up to 3450°K. This is interesting in view of the fact that tungsten melts at 3655°. The advantage of this higher temperature is that the blue-violet radiation is increased 270 per cent, whereas the red radiation is increased 155 per cent. In other words, the lamps known as the Movieflood and the Photoflood give nearly twice as much blue-violet light for the same amount of red, and at increased efficiency. They are particularly advantageous for color photography. Complete data on these lamps were given in the JOURNAL by Farnham.[4]

A new bipost has replaced the mogul screw base on the 2000-watt *G48* bulb lamp and the prong base of the 5000-watt *G64* bulb lamp. This new base is much more rugged and positions the light-source with greater precision in the optical axis of the projectors.

A group of incandescent lamps ranging in wattage from 1000 to 5000 watts and capable of burning base upward, have been made available. These lamps employ the bipost base, and are particularly adapted for use in the new elliptical reflector spots. Their long tubular bulbs, with the light-source close to the end, result in minimum shadowing of the reflector by the bulb, and the base-up burning feature causes the bulb-blackening to occur outside the limits of the reflector (Fig. 1).

There has been considerable development in gaseous conductor sources, and a sodium vapor, as well as a high-intensity mercury lamp, has been made commercially available. However, both these sources possess both light and performance characteristics that render them unsuitable for motion picture studio lighting in their present form.[5]

(2) DEVELOPMENTS IN LIGHTING EQUIPMENT

The second report, which discussed studio lighting equipment, described a number of units for both general and modeling lighting, practically all of which are in general use today. There has been a very definite trend away from the one- and two-lamp broadsides, and toward the use of the "rifle" unit, because of the latter's much higher efficiency. Overhead suspension arrangements have been developed to permit the rifle reflector to be hung by its yoke above the set, thus gaining greater illumination intensities than were possible from the trough reflectors primarily designed for this service.

Contemporarily with the development of the 8-mm., high-intensity, white-flame carbon was the designing of an improved twin-arc broadside lamp to take full advantage of the new carbons. The particular feature of this lamp is the addition of a voltage-operated coil connected across the arc, whose flux opposes that of the current coil. This results in a very much steadier lamp, with constant electrode spacing. Further refinements include the use of a chromium reflector and ball bearings in the carbon feed-mechanism, as well as a more rugged and compact type of ballast resistance. A sand-blasted glass diffusing screen is used with this lamp in place of the old inefficient "silks." This unit is also available in the "scoop" form, as well. Additional data were given in a paper by P. Mole.[6]

FIG. 1. Base-up burning incandescent lamp, used in certain types of reflector spots.

An important development in incandescent lighting equipment has been the elliptical reflector spotlamp. This unit makes use of the ability of an elliptical reflector to pick up a large solid angle of light-flux from a source at one focal point and concentrate it at the other focus. About half the complete ellipsoid is used, and an iris diaphragm is placed just in front of the opening of the objective lens of large diameter, which is placed just beyond the point at which the light-rays cross, and images the diaphragm upon the area illuminated. The spot of light produced is uniform and sharply defined, and is adjustable in diameter. Four adjustable straight-edged shutters near the iris make spots of a variety of shapes and sizes possible. The gain in illumination over the conventional lens spot is about 200 per cent both at the narrow and wide beam spreads[7] (Fig. 2).

There is now available a small incandescent unit called the "Handilamp," which usually uses the 1000-watt tubular bulb lamp, either clear or frosted. It combines compactness and light weight, and is frequently mounted upon or close to the camera blimp to provide a

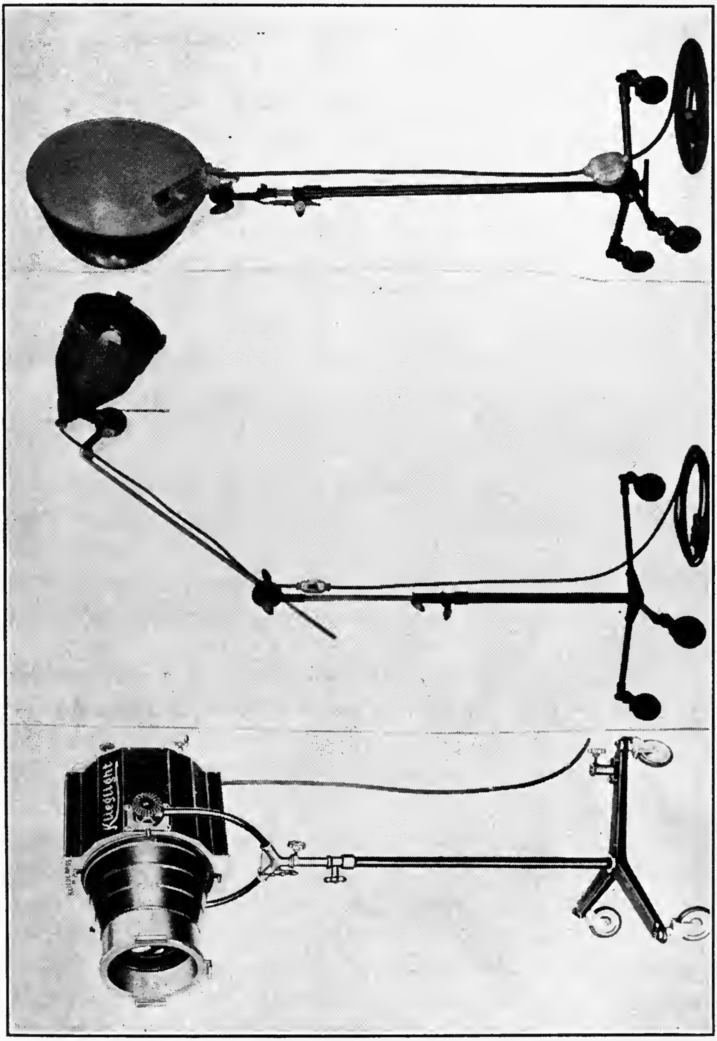

FIG. 2, Elliptical reflector spotlamp.

FIG. 3. "Handilamp", frequently mounted directly upon the camera blimp.

FIG. 4. "Cinelite," designed especially for the *No. 4* photoflood lamp.

high intensity of illumination over a localized area, generally in "close-ups." A fluted chromium- or even silver-plated reflector, about 10 inches in diameter, is used. The flutes in the reflector spread the beam more in one direction than in the other, and the amount of spread is controlled by moving the lamp in and out of the reflector (Fig. 3).

The No. *4* photoflood lamp developed originally for still photography, has found its way into the motion picture studios, and has prompted the designing of an unusually efficient reflector unit, shown in Fig. 4. The diffuse-finish aluminum reflector combines high reflection efficiency with a large light pick-up. This equipment is especially advantageous for use upon location or with expeditions where weight and size of equipment, as well as available power supply, are important factors. One of these units consuming 1000 watts is capable of giving illumination intensity equal to that furnished by 2500 watts in the usual types of lamps.

A new development in lens type spots that has great promise is the so-called Junior spotlamp. This unit substitutes the conventional plano-convex condenser with a Fresnel lens. Thus, it is possible to operate the light-source much closer to the condenser and increase the light intercepted by the lens several-fold. A spot employing the 2000-watt *G48* bulb lamp has recently been marketed, and equipments for both the 5000-watt lamp and the high-intensity arc are under development.[8]

The general adoption of supersensitive panchromatic film brought with it an unexpected, though interesting, problem. The great sensitivity of this emulsion makes it particularly susceptible to recording irregularities of illumination at low intensities, with the result that "spill" light from the equipment mounted overhead and shining upon the upper walls of the sets appears quite conspicuously in the picture. This has led to the general use of spillshields on the 18- and 24-inch sunspots.

"Skylight," or "Pan," is another unit that has grown up from a make-shift. It consists of a shallow diffuse reflector about 24 inches in diameter, provided with a socket for the 5000-watt lamp and a suitable connecting cable. It is usually suspended high upon the set, to provide uniform illumination of sky backings or cycloramas. The contour of the reflector and its finish are such as to afford a fairly uniform light distribution through a wide angle, thus permitting the unit to be placed relatively close to the surface being lighted.

The advent of motion picture photography in color has brought with it the necessity of frequently controlling the color of the light to produce certain effects. At present this is being done with colored gelatins. Gelatins have the disadvantage of fading, and it would be desirable to have many of the more frequently used colors as glass filters. The glass must either have a wire mesh embedded in it, or be used behind a wire screen to prevent its falling to pieces in event of breakage.

To obtain the practically perfect white light necessary for the Technicolor three-color process, there has been produced by the Corning Glass Works a suitable glass filter known as *No. 570*, which, when used with incandescent lamps operating at 33 lumens per watt, results in a light, the color of which meets the requirements of the process satisfactorily.

The original equipment report called attention to hum filters in

FIG. 5. Remotely operated switchboard, affording greater flexibility of lighting control.

capacities up to 300 amperes; recently, filters of 1000-ampere rating have been manufactured. Greater use is being made of portable, remote controlled switchboards. These afford greater flexibility in operating the lighting equipment and make possible many effects not otherwise easy to produce. Fig. 5. shows one type, capable of controlling separately, or by master-control, four circuits of 400 amperes each. A length of 100 feet of control cable terminating in a five-gang switch is shown on top.

(3) POWER SUPPLY AND DISTRIBUTION METHODS

Practically all the studios making theatrical pictures employ direct current obtained from motor-generators. It is interesting to note, however, that extensions in the power facilities of several studios have been made by the use of transformer banks supplying 125–250 volts a-c. direct to the lighting equipment. One or two of the eastern studios located on d-c. central station distribution lines also use this source to supplement the power obtained from their own substations. A few very small studios also on d-c. systems obtain their power solely from the central stations.

This almost universal use of direct current results from the fact that the d-c. arc is more efficient, quieter, and better adapted to light-projecting equipment than the a-c. arc, and nearly all the present studio power installations were made at the time the arc source was in more general use. If called upon to re-equip the studios completely, many electrical staffs would be in favor of employing alternating current even to the point of placing transformer banks in each stage, because incandescent lamps operate equally well with either direct or alternating current. The initial investment in copper and rotating machinery, as well as the operating and maintenance costs of such a power supply, would be very much less. Small or medium-power portable motor-generator sets would be brought to the stage when necessary to employ arc equipment.

With the advent of sound recording, direct current was at one time regarded necessary, since it was feared that trouble might be experienced from hum pick-up into the sound channels. Adequate shielding of both the wiring and equipment has, however, removed the possibility of trouble from this source.

Permanently installed generators for studio service are of 125–250 volts' rating and from 300–500-kilowatt capacity. They are usually flat-compounded, but in a few instances over-compounded. Both induction and synchronous motor drives are used. The more recent installations employ synchronous motors. It is general to use a single motor with a d-c. generator at each end of the shaft and upon the same base. Hand-regulation of the d-c. voltage is universal, and an effort is made to provide 120 volts at the sets.

Portable generators mounted either upon trucks or trailers are used to supply power when on location, or are frequently used to supplement the regular substation on very large sets or in case of a heavy shooting schedule. The generators are of the 3-wire type, rated at 125–250 volts, 100–300 kw., where motor drive is used, and 25–200-kw. capacity for gas-engine drive. The motors for portable motor-generator sets used by the West Coast producers are wound so as to be capable of operating on either 2200 or 4400 volts, three-phase, by suitable change of connection. They can generally be used on either 50 or 60 cycles.

The gasoline-engine driven portable generator outfits are, of course, necessary when on location where high-voltage lines are not available. Oftentimes small gas-engine generator sets of 25-kw. capacity or even less are taken about on the lot to operate a few "booster" lights, this practice being simpler than endeavoring to run wires from the studio substation or "high line."

Owing to the pronounced change of speed with load, an inherent characteristic of the gas-engine, trouble has been experienced because of sudden rises in the generator voltage to 140–150 volts when part of the load is suddenly switched off, and before the governor controlling the engine throttle valve has had time to operate. This results in a sudden change in the light output of the remaining lamps or may cause some to fail prematurely. To overcome this difficulty, a quick-acting voltage-operated regulator has had to be developed for holding the generator voltage in check until the throttle valve operates. The necessity for absolute quietness in connection with sound picture photography has brought additional problems in the design of the "gas wagon." Not only are special mufflers necessary but the entire engine and generator must be enclosed in a sound-proof housing. A very complete description of several gas engine-generator sets has been given by Mole.[9] One studio has made up a portable transformer wagon, analogous in its application to the portable motor-generator set. The transformers are so wired as to receive 2200 or 4400 volts on the primary side, and deliver 120–240 volts at the secondary.

DISTRIBUTION

It is quite general practice in the studio substations to employ a double bus system of 125–250 volts. Double-throw switches permit any or all of the generators to be connected to either bus. In a similar manner, the circuits to any of the stages may be connected to either of the buses. Such an arrangement has the advantage of isolating part of the system in case of trouble. It also makes possible different voltages at various locations, as, for example, a higher voltage for those stages at a greater distance, where the line drop is greater.

Three-wire, 120–240-volt feeders are carried from the main switchboard to the several distribution points in underground conduit. Within the stages either of two wiring arrangements may be employed: One, regarded as the newer type and shown schematically in Fig. 6, brings the feeders into the upper part of the stages, where they connect to several remotely controlled switchboards. Four-hole plugging boxes are usually permanently connected, each to a switch on this overhead switchboard, by a 100-foot length of 3-wire cable. When not in use, the plugging box and its cable are fastened overhead. When put into use the box is lowered to either the parallel or the stage floor and the lighting units plugged in. These switchboards also have short copper bus-bars connected directly to the line and to which No. *2*, 3-wire extension cables may be connected. These cables are, in turn, connected to spiders or coupling blocks. Heavy-current devices, such as sun arcs and rotaries, are then attached to the

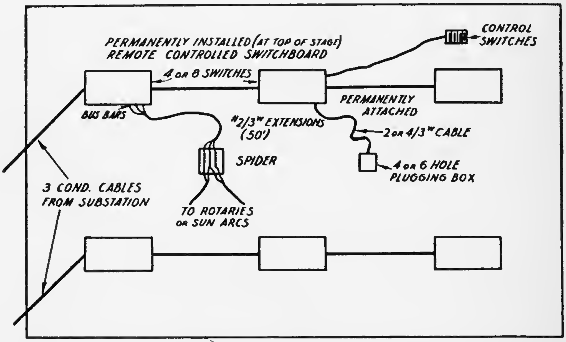

FIG. 6. Schematic diagram for permanently installed, remotely controlled overhead switchboards.

coupling blocks. The switches of these remotely controlled boards are operated by small tumbler switches at the end of a 100-foot flexible conductor, which may be placed at any part of the set.

The second and older method of power distribution on the stages, outlined in Fig. 7, consists in placing a number of outlets along the walls of the stages near the floor, to which the feeders from the substation are attached. These outlets comprise a large-capacity switch known as the "bull" switch, terminating in three heavy, short bus-bars, *0000* feeders being carried from this point to the portable switchboard. This may be operated by an attendant at the board or remotely controlled. The plugging boxes for the various lighting units are usually attached directly to this board, although in some instances, when greater length of cable is required, an extension may be introduced terminating in a splicing block, to which the plugging box cable is attached. The heavy-current units, such as the sun arcs or rotaries, are also clamped to the spiders or splicing blocks. The spiders to which these heavy-current devices are attached are kept "hot"; that is, their extension cables by-pass the switches on the portable switchboard. The units are operated by the switches attached directly to the equipments. This is done because there is always an operator at each unit.

When remotely controlled boards are used an operator stands near the cameraman with the small control switch box at hand so as to be able to operate the lights as directed by the cameraman. In the case of the heavy-current arc units operated by an attendant, the gaffer signals by yelling "Hit No. 5," or "Kill No. 8."

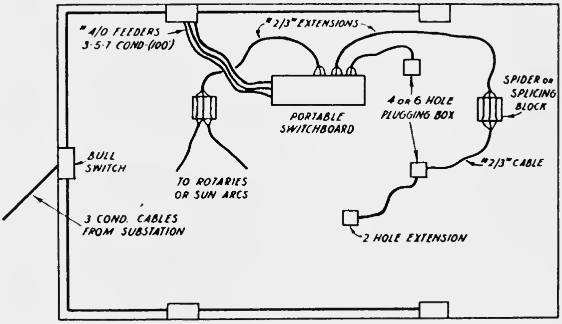

FIG. 7. Schematic diagram for portable switchboards.

There are advantages and disadvantages to both systems. The first arrangement, with its remotely controlled boards permanently installed at the tops of the stages, greatly lessens the amount of cable, particularly upon the floor, where it is very much in the way. On the other hand, it does represent considerable investment, much of which is idle.

A few electrical departments have adopted the practice of marking each cable end as well as connecting points at the switchboards—red for positive, blue for negative, and white for neutral—to facilitate making correct connections, particularly because the arc equipment requires that the current flow be in the proper direction. This practice, however, is not general, although it would be well if it were.

R. E. FARNHAM, *Chairman*

W. C. KUNZMANN	V. E. MILLER	C. STRUSS
J. H. KURLANDER	M. W. PALMER	F. WALLER
	E. C. RICHARDSON	

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THE USE OF FILMS AND MOTION PICTURE EQUIPMENT IN SCHOOLS*

MARION EVANS**

Summary.—*The educational motion picture has come as a safeguard against the extreme verbalism in education of a few years ago, which often led to serious misconceptions by the pupil of facts that can now be presented as true, unbiased reproductions of life itself. In judging the attributes of a good teaching film certain definite criteria should be followed, as regards content, emotional force, interest, manner of presenting the subject matter, etc.*

Edison challenged the educational world fifteen years ago with the prophecy that "soon the motion picture film would take the place of the text-book in the classroom." This statement created a great deal of controversial discussion on the part of educators, some of whom maintained that pictures never could take the place of the text-book but should always be regarded as supplementary or secondary to the book. This limited view was due to the fact that Edison's prophecy came at a time that was characterized as a brief period of extreme verbalism in education. Teachers then were worshipping the text as the Moslem did his Koran as the one and only means of enlightenment. Lessons consisted of reading, alternated by "chalk and talk" lessons by the teacher and parrot-like recitations in which the students repeated forced memorized facts that often had little or no meaning. Those were the days when the teacher taught geography by having the class repeat for a week in unison such phrases as, "The equator is an imaginary line running around the earth" and then was very much surprised when Johnnie wrote in his written examination, "The equator is a menagerie lion running around the earth." Johnnie did not have any idea what an imaginary line was; but he did know what a menagerie lion was, so the lion became a part of the word picture that he had mentally drawn.

Fortunately for the youngsters, this period of verbal instruction was brief, for we know that pictorial records and visual images have been

* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

** San Diego City Schools, San Diego, Calif.

used to record knowledge and communicate ideas from the time of the stone age to our present machine age. We can trace evidences of the uplifting power of visual education—in the crude animal pictographs upon cave walls, upon carved totem poles, in sculptured legends and myths upon temple walls, in starward pointing obelisks, in rose and amber colored paintings upon cathedral windows, in murals in modern art galleries, and in the life-like motion pictures screened in schools and theaters today. After centuries of visualization in education has come the art of photography in all its forms—the photograph, the stereograph, the glass slide, the still film, and the motion picture film. These visual aids now serve as a safeguard against verbalism, for although the book gives the interpretation of life as seen by the author and the painting represents the world as visualized by the artist, it is the photographic record that gives a true, unbiased reproduction of life itself. It alone allows the pupil to face it squarely, to study it, and to interpret its message and draw conclusions in terms of his own understanding. For this reason, the photographic record is a teaching tool directly fashioned to fulfill the needs of modern education, which aims to teach boys and girls how to study as well as what to study, and not only to memorize facts but how to weigh and handle facts.

When we realize that the film now discloses a whole new world for observation and study, bringing the miracles of nature realistically to the student and revealing many of the long-hidden secrets of Mother Earth, we understand why the alert teacher is eager to include the motion picture in her "kit of teaching tools." We understand also how Edison, who knew the possibilities of the new medium, had the vision to see that the film would take the place of the book in many lessons as the approach to learning.

Looking into the modern classroom, we see how, through pictorial experiences, geography becomes the "great, wide, beautiful, wonderful world, " with its varied peoples and their activities. History is relived, so that pupils cross the barren plains with the early pioneers in covered wagons or follow a good-will messenger in an aerial flight encircling the globe today. In the science laboratory, microscopic photography makes visible tiny objects that the human eye can not see. Slow-motion films show movements and growth that the eye does not ordinarily observe, and, within a few minutes, depict the tedious processes of days, weeks, months, and even years—such as the unfolding of a flower, or a river slowly digging a new channel in the earth. In the study of astronomy, the telescopic lens brings distant objects, such as the stars, down to a focused point of observation upon the classroom screen, while the film sound record, by means of amplification, reproduces audibly sounds that the human ear can not hear.

To fulfill the growing demand for motion picture films in education, school visual education departments are having to turn to many different sources. In the past, the chief sources for school film purchases have been educational divisions of commercial companies such as Eastman Teaching Films, Inc., and Bell & Howell Filmo Library; universities, including Harvard, Yale, and Chicago, which have produced educational films; and firms like the General Electric Co., which have made available industrial subjects at low cost or free to schools. A few travelogue films made by the major motion picture studios have proved satisfactory, although some of the subjects are out-of-date by the time they are released to the non-theatrical field. Today, we are looking with hope and enthusiasm to a new field—the great unexplored realm of the amateur and professional independent motion picture producer, from whom we expect to obtain a great wealth of artistic and accurately filmed photographic material. The shortening of the work-day and increase in leisure time are encouraging many creative and inventive workers to make photography a profitable hobby.

The great improvement in amateur equipment during the past few years is making it possible to use devices that produce pictures of truly professional quality. This fact is proved by the high standard that is set in the various competitive amateur cinema contests, which are yielding beautiful and highly instructional films that school film libraries may now include in their purchases—such films as *Japanese Lullaby*, *Water*, *Korean Rice Farmer*—all prize-winners in an amateur cinema contest.

In judging the attributes of a good teaching film such standards as the following act as guiding criteria:

(*1*) Does the subject-matter appeal to native human interests?

(*2*) Does it contain sufficient mental stimulus to be thought-provoking, problem-raising, or problem-solving?

(*3*) Does it have social values, and a positive emotional appeal which makes it elevating, healthful, and inspiring?

(*4*) Are the titles brief and simple?

(*5*) Is the continuity good, with the main points of the lesson clearly defined in a unified and balanced presentation of the subject so that some specific learning may be effected?

(*6*) Is it true, according to the nature of the theme being portrayed, whether realistic or fantastic?

(*7*) Is the photographic quality clear and artistic?

(*8*) Is it so edited as to conform to the span of attention and the comprehension of one of the four grade levels, namely, kindergarten-primary, elementary, secondary, and adult?

In addition to judging the quality of a film, another fact that must be taken into consideration is the type of motion picture to be selected. Should the film be silent, audible, or colored? We answer this question by saying that the purpose of the lesson should determine the type of film best adapted to its use.

For example, if we are striving for the emotional appeal and aesthetic appreciation of color elements, or if, as in nature study and science, color is in itself an important phase of identification of the object, then we select color. On the other hand, if we wish merely to visualize action, growth of moving life or development of a process, then we can use black and white. As for sound, if musical interpretation, sound, or voice effects contribute to the main point of emphasis of the lesson, the sound or talking film is chosen. As an example, it might be advisable to have a colored sound film on local birds, because the calls of the birds are as much a means of identification as their coloring. However, a colored silent film on the subject of the butterfly would serve our purpose.

Thus, it may be seen that, unlike the theatrical world, schools have refused to discard the silent film and substitute the talkie exclusively because we believe that each type of film has its specific contribution to make to education. We know there are great possibilities in bringing music of the highest caliber to all children, and in giving immortality to magnetic personalities of all ages. The talkie or lecture film may also bring master teachers to the most remote schools. Sound films are, therefore, of value in the study of music and folklore, drama, literature, and language, whereas the specific contributions of the silent film seem to be that it stimulates the imagination and intellectual faculties and is more favorable to creative contemplation on the part of the child. As it invites spontaneous comment and questioning by the pupil, the silent film is to the teacher what the x-ray is to the physician—an instrument that may be used, first, to diagnose the needs and interests of individuals in the class, and then to solve their problems. The motion picture film may be used to introduce and arouse interest in a subject, as development material, or for reviewing a lesson.

In order to insure the most desirable results from the use of classroom films, the motion picture equipment must be standardized and must be as carefully selected as are the films. Standards by which the apparatus is judged are safety, economy, durability, adaptibility, simplicity, portability, projection quality, and general efficiency. We have found that the 16-mm. projectors are the best suited for classroom use, judged by these items, and therefore recommend placing at least one portable motion picture machine as a part of the standard furnishings in each school building. One hundred per cent of the schools in San Diego are so equipped at this time.

While the motion picture projectors are placed permanently in the schools, the films are circulated, upon the requests of teachers, from a central library or visual education department. A glimpse at the shelves of such a film library would show topics covering practically every subject of the curriculum. The distribution records would reveal an ever-increasing demand with a turn-over of from 5000 to 10,000 film showings per month for every 500 subjects in the film library.

Motion picture appreciation is being developed in four ways in modern school systems:

(*1*) The schools are providing carefully selected film experiences for all children from the kindergarten through the senior high school by furnishing through the visual education library educational films to illustrate daily classroom lessons. Such films are selected according to certain attributes which go to make a good teaching film.

(*2*) Teachers are encouraging students to discuss good current pictures which they see in local theaters, such as *David Copperfield, Midsummer Night's Dream, Great Expectations, Little Women.* Not only are such discussions introduced as a regular part of English, drama, and public speaking courses, but such pictures as *Our Daily Bread, As the Earth Turns, Gabriel over the White House,* and *The President Vanishes,* which portray important social and economic problems of today, are used as the basis of lessons in social science and current history courses.

(*3*) Teachers who are organizing new materials for the course of study are now collaborating with the visual education department in collecting films, books, pamphlets, and outlines that may be used in motion picture appreciation courses to be introduced in the junior and senior high schools. Such a course would follow the lines of the appreciation of art and appreciation of music classes. Screen classics representing the various classes of photoplays, such as comedy, musical, melodrama, travelogue, cartoons, *etc.*, would be intimately studied, and definite standards for judging good films would be discussed with the pupils.

(*4*) The schools are endeavoring to provide for actual film production experience during school life by means of photography classes and photoplay clubs, especially in high schools. Opportunity is afforded these young people to gain experience in making motion picture films as well as still photographs, which are exhibited in their annual salons.

SYMPOSIUM ON NEW MOTION PICTURE APPARATUS

During the Spring Convention at Hollywood, Calif., May 20–24, 1935, a symposium on new motion picture apparatus was held, in which various manufacturers of equipment described and demonstrated their new products aud developments. Some of this equipment is described in the following pages; the remainder will be published in subsequent issues of the Journal.

A NEW HIGH-FIDELITY SOUND HEAD*

F. J. LOOMIS AND E. W. REYNOLDS**

The sound attachment, used in conjuction with a picture projector and its components, is a device employing the electrical and mechanical equipment necessary to scan a film sound record, translating it into electrical vibrations which are subsequently amplified and reproduced as a faithful counterpart of the original record sound. The struggle to develop a film record sound reproducer has extended over a number of years and this effort has produced a conventional type of machine which is in universal use. Along with other components, common to all, this conventional type makes use of a fixed sound gate, as shown in Fig. 1.

Experience has demonstrated that fixed sound gates have required constant attention because there has always been the possibility of accumulation of wax and emulsion upon the polished surfaces of the film guide and pressure shoes, and it is evident that frictional resistance to the passage of film results in wear upon the film, gate, and sprocket.

Another major problem, to which engineers have devoted much time and thought, is that of achieving a constant speed of the film at the sound scanning point. Attempts to attain constant speed have largely been concentrated upon causing the feed sprocket below the sound gate (Fig. 1) to revolve at a uniform velocity. Elaborate mechanical filters between the motor and the feed sprocket and various types of direct drive have been used, all of which were designed to produce uniform rotational velocity of the feed sprocket; but, with few exceptions, no effort has been made to eliminate the annoying ripple necessarily present in sound reproduction from film that is fed only by a sprocket past the sound scanning point.[1]

In spite of the study given to their many functions, sound reproducers have not kept pace with the advancement that has recently taken place in the recorder field,[2] and for that reason, we were called upon to develop and design a new sound attachment that could satisfactorily reproduce our high-fidelity recordings.

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*Presented at the Spring, 1935, Meeting at Hollywood, Calif.

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

This sound head consists of a housing containing a removable exciter lamp socket with its mounting; an optical system for focusing the light upon the sound-track of the film; a device for controlling the film laterally; a free-running film-driven sound take-off drum to which is attached a rotary stabilizer, which causes the sound-track to pass the scanning beam at a constant speed; a photo-cell and its transformer for translating the light variations, caused by the sound-track of the film, into electrical pulsations; and an electric driving motor with motor control, together with other necessary components.

Compact and unique in design, the main case, shown in Figs. 2 and 3, embodies

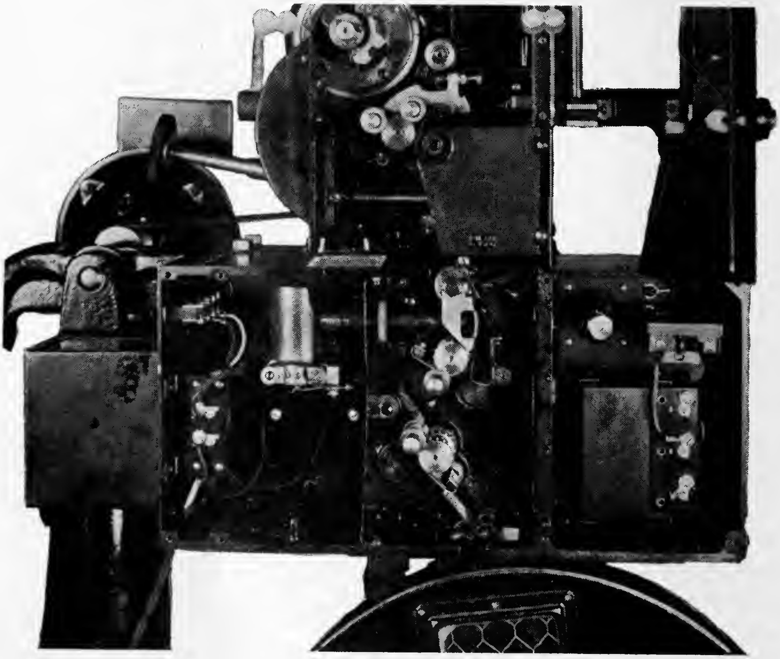

FIG. 1. Showing the film path and the fixed sound gate.

a great many features of construction that are bound to have a pronounced effect upon the extended life of the machine. Consisting of box sections, extending from either side of a center plate, the main case is cast of iron in one piece. The front section contains the exciter lamp and the film-handling compartments, and at the rear is a housing for the transformer assembly. All bearing mounting holes for the principal rotating shafts are machined in this single casting, assuring parallelism and permanent alignment. At one end of the case, provision is made for attachment of the sound head to a pedestal and on the other end is cast a circular projection which serves as the front end bell for the driving motor. Ample openings for ventilating the exciter lamp compartment have been cast in the main case in such a manner as to preclude stray light.

One of the leading features of this design is the use of precision ball bearings

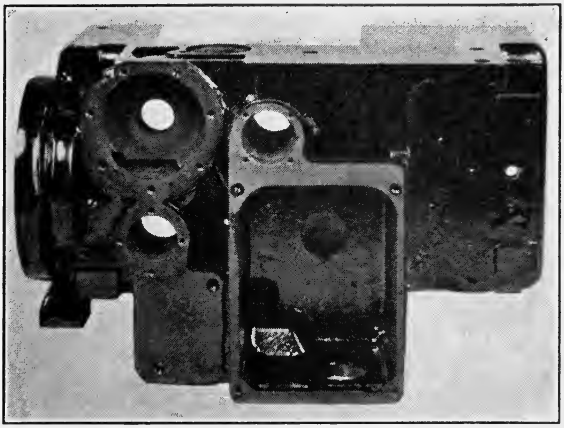

FIG. 2. Rear view of the main case, housing the transformer assembly and the drive gears.

upon all rotating shafts, including the motor shaft. The bearing retainers and deflectors protect the bearings from dirt and insure the retention of lubricant. By properly mounting, protecting, and lubricating the modern precision ball bearings,

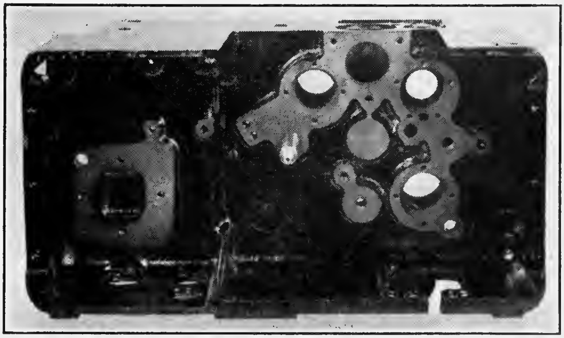

FIG. 3. Front view of the main case, housing the exciter lamp and film-handling compartments.

it is possible to gain a greater length of life and a much longer period of trouble-free operation than with any other type of bearing. Fig. 4 illustrates the compactness of the complete assembly.

Because of the wide range of power supplies, it seemed desirable that the sound head be designed for various combinations of voltage and frequency as well as for direct current. Of course, this interchangeability of drive required a special built-in arrangement allowing the use of certain standard parts upon all drives Each motor armature shaft has a worm, either cut integral with or fastened upon the shaft, and supported by two ball bearings; one slidable, mounted in the front bell

FIG. 4. The complete assembly.

of the motor and located upon the shaft as shown in Fig. 5; the other firmly mounted in the drive gear chamber of the sound head. The entire drive gear assembly, including the bearings, runs in a bath of oil, which is made possible by the use of an oil seal mounted behind the rear motor bearing. The rear motor bearing carries the thrust and the radial loads of the worm drive. The motor worm drives a worm-gear mounted upon the feed sprocket shaft which, through an external gear-train, drives the hold-back sprocket shaft, as shown in Fig. 6, with the projector located above the sound head.

The exciter lamp socket (Fig. 7) carries one standard 10-volt, 5-ampere lamp,

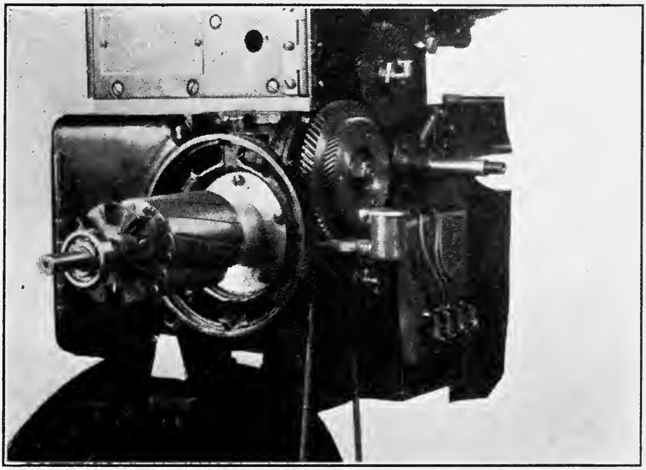

FIG. 5. Showing the method of mounting the motor.

the base of which is gripped uniformly around its circumference by a spring chuck cut into the end of a threaded sleeve which has a sliding fit in the socket body. The upper knurled nut is tapered inside and, when tightened, compresses the chuck

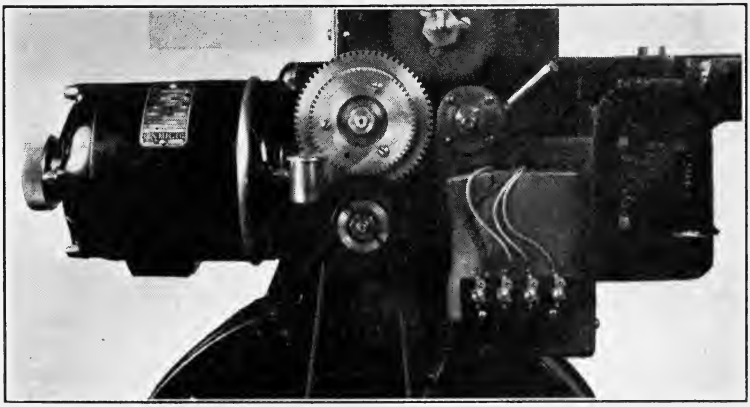

FIG. 6. External gear-train driving the projector, and the hold-back sprocket shaft.

jaws uniformly upon the lamp base, eliminating the possibility of deforming the base and ruining the lamp.

The filament is adjusted vertically by rotating the lower knurled nut, and the sleeve is prevented from turning by a locking screw which is tightened after the correct vertical adjustment has been made. Two long pilot-pins mounted in the head carry the socket body and permit instant and exact replacement of a burned-out lamp by a spare prefocused exciter lamp assembly provided with each sound head. A handle is cast upon the socket body to facilitate withdrawing and replacing the unit. This speed of replacement is especially important during a performance. The socket assembly, together with its mounting, is strongly made from die castings and machined brass parts, and is designed for long and satisfactory service.

The essential parts of the optical system are a condenser lens, a mechanical slit, and an objective lens, all mounted in a hermetically sealed barrel. In designing

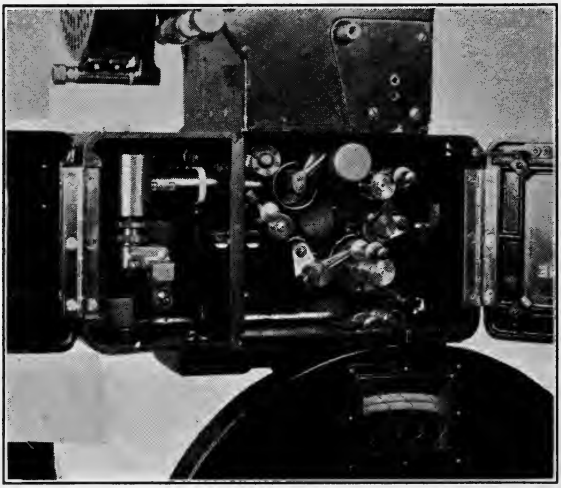

FIG. 7. Showing exciter lamp assembly, optical system, and film-handling mechanism.

the optical system, consideration has been given to keeping its interior free from oil and dirt. It is of the conventional type; the condenser lens collecting the light and illuminating the mechanical slit is placed as close as possible to the lamp; and the objective lens, in turn, throws a reduced image of the illuminated mechanical slit upon the film at the sound-track. The entire optical barrel is a sliding fit in the body casting which is accurately and firmly mounted in the sound head as shown in Fig. 7.

A knurled nut fixed axially and operating upon a threaded section of the optical barrel, provides focal adjustment of the system. At one end, the body is slotted transversely and is supplied with a lock-screw, thus forming a clamping means for definitely holding the optical barrel in the focal position. Focusing and locking are easily done directly from the front. Because of manufacturing precision, no angular adjustment of the mechanical slit is necessary.

After passing through the film, the modulated light-beam encounters a lens (Fig. 7) which is a combination of a condenser and a prism, and is condensed and deflected upward and outward to the target of a standard phototube. The phototube is mounted parallel to the drum and is shielded from extraneous light by a cover (Fig. 7) which serves also to hold the tube in correct position, both the cover and the phototube being instantly removable from the head.

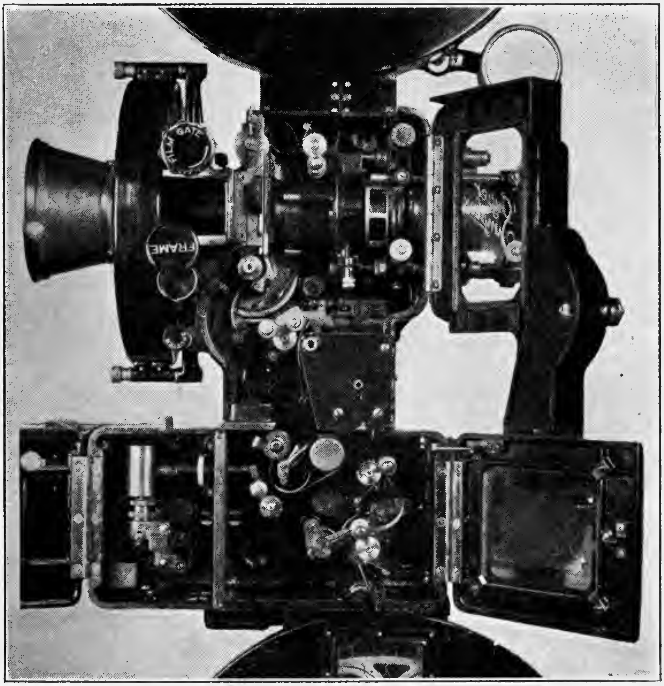

FIG. 8. Showing the film path through the sound head.

To assure proper shielding, leads from the phototube socket pass through the center of a large cored hole in the main casting to the phototube transformer, which is resiliently wrapped and placed inside a thick steel shield. This complete unit in turn is surrounded by resilient material placed between it and the walls of the transformer compartment, which is cast in the main case. By the double resilient mounting and double shielding provided by the cast-iron walls of the main case and the steel container, all audible disturbances, mechanical and electrical, are eliminated from the transformer.

A very accessible terminal board for connecting the amplifier cable is mounted upon the transformer support (Fig. 6), and a large cast-iron cover affords easy entrance into the compartment. Care has been taken to prevent oil from entering the transformer compartment, the top and side openings having oil-tight covers; and because of this, deterioration of insulating material within the transformer compartment is avoided.

Special care has been taken so to arrange the drum, contact roller and sprockets

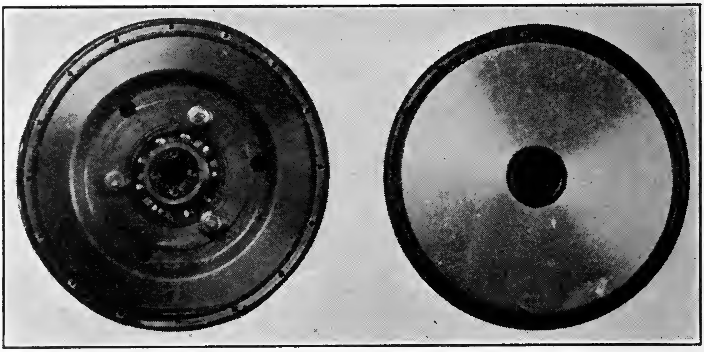

FIG. 9. The rotary stabilizer, disassembled.

that film, as it passes through, is bent into as wide curves as possible (see Fig. 8). The film strippers, although effective, do not interfere with threading, and can be solidly located in proper adjustment. A long bearing in the pad-roller support assures firmness of the pad-roller in all positions, and the new lock-plate permits

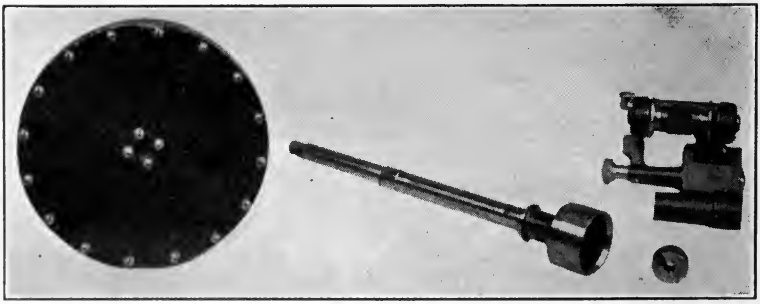

FIG. 10. The stabilizer drum-shaft and sound gate.

easy and positive adjustment and location of the pad-roller. These pad-rollers swing far enough away from the sprockets to make threading of the film through the head a very easy matter, and snap definitely into position.

In order to attain constant speed of the film at the sound scanning point, it has been customary in the conventional sound head to make use of large rotating masses in connection with other apparatus, and to achieve the desired results by what might be termed the "brute force" method.

However, all things are relative; and if the masses employed in the conventional sound heads were large, the disturbing forces were large also, so that the final result, in so far as constancy of speed was concerned, was seldom all that could be desired.

In this new sound head the rotating masses employed are comparatively small but the disturbing forces are relatively insignificant, so that the final result is much superior to that arrived at in the conventional manner. By mounting the sound

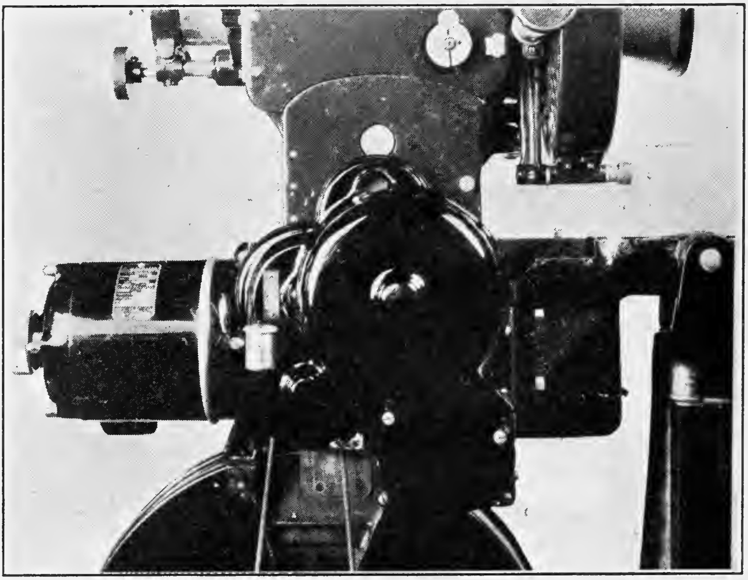

FIG. 11. The rear view of the machine, with the gear guard in place.

drum shaft in free-running precision ball bearings, friction is reduced to such a minimum that it is possible for the film to drive the drum without appreciable tension. The driving strain is so slight that the film is never pulled taut, except at the start. The curves assumed by the film when leaving the sound drum and approaching the feed sprocket, when in operation, are clearly shown in Fig. 8. Flatwise compliance inherent in the curves of the film, between the sound drum and the feed sprocket, positively isolates the sprocket tooth frequency from the scanning point. It also takes care of the small irregularities of speed introduced into the feed sprocket by the drive gears. Were it not for this compliance, it would be quite impossibele to use the direct drive, with all its advantages, that has been built into this new sound head. Because of the lack of tension upon the film as it is fed through the sound head, the feed sprocket can be dimensioned to accommodate maximum film shrinkage with no possibility of impairing the reproduced sound. Also, there is assurance of prolonged feed sprocket life.

It is apparent that the elastic film loop shown in Fig. 8 between the feed sprocket

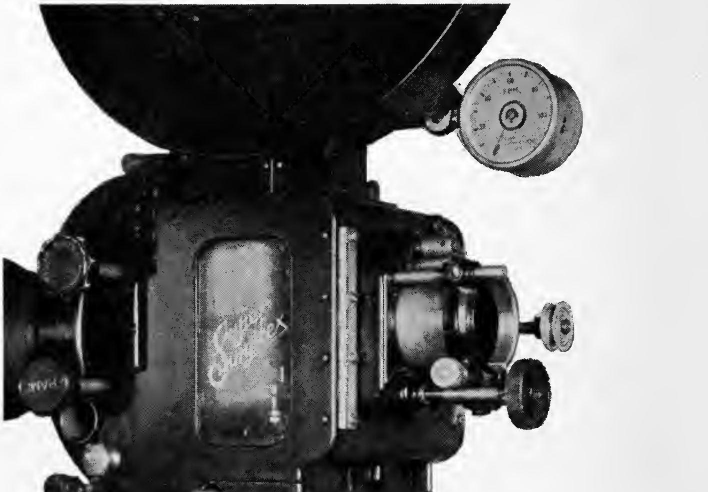

FIG. 12. The operating side of the machine, showing convenience of starting switch and framing knob.

and the drum will absorb film speed irregularities introduced by the sprocket, and in order to utilize this valuable film loop it is necessary only to insure uniform rotation of the drum. The time-honored expedient for uniform rotation is a fixed flywheel. However, fixed flywheel control of the drum speed is unsatisfactory, because the flywheel continually hunts or oscillates with the springy film loop in the same manner that a weight suspended from a coil spring will oscillate under the slightest disturbance. It might be suggested that sufficient friction drag be applied to the drum shaft to prevent or damp the oscillations, but when this is done the film is immediately stretched taut between the feed sprocket and the drum, and the valuable film loop is lost.

It was therefore necessary to develop a rotational speed control for the drum that would not oscillate with the springy film loop nor pull the loop taut so as to destroy it. The device that was developed to fulfill the requirements is called, for want of a more appropriate term, a "rotary stabilizer."

A number of years ago C. R. Hanna discovered that two rotating masses or flywheels coaxially mounted upon one spring-driven shaft would be critically damped or, in other words, would not oscillate with the driving spring if the assembly were constructed under certain conditions. These conditions were that the inertias of the two flywheels should be approximately in the ratio of 8 to 1, that the small flywheel be rigidly fastened to the shaft, that the large flywheel be free-floating upon the shaft and driven only through a perfectly viscous connection, and that the spring elasticity and the viscous connection have a certain relation to each other and to the flywheels. The mathematical theory disclosing these conditions, developed originally by Hanna, is further elaborated and expanded by E. D. Cook.[3]

It is sufficient to note that the theory leads to a device for controlling the drum speed which exactly meets the two conditions, first, that it does not oscillate with the elastic film loop, and, second, that it does not pull the loop taut.

The rotary stabilizer shown in Fig. 9 was designed, according to the theory, as follows: The light flywheel was constructed as a short cylindrical casing made of the lightest possible alloy and firmly fastened to the drum shaft, and the free-floating heavy flywheel was carried inside the casing upon a ball bearing mounted upon its hub. The viscous driving connection to the heavy flywheel is a light oil which completely fills the casing and surrounds the flywheel, and the spring drive to the assembly is the elastic film loop from the sprocket to the drum. The casing is, of course, hermetically sealed by a cover which retains the oil and excludes dirt from the assembly.

The results attained with the device constructed as outlined were in accordance with the theoretical predictions, and the passage of a film splice or a severe manual disturbance of the film loop does not result in a single complete oscillation of the drum and rotary stabilizer.

It is interesting to note that the theoretical proportions of the rotary stabilizer demand a construction that is at variance with earlier empirical designs of similar damping devices. In these devices the flywheel fastened to the shaft is very large in proportion to the free-floating damping flywheel, and the rotary stabilizer reverses this ratio with greatly improved results. The lack of oscillation between the stabilizer and the film loop is due to the fact that the energy of the disturbance passes from the film loop to the casing and is dissipated in the oil film between the casing and the flywheel. The proportional inertias of the casing and the flywheel are such that the small amount of energy stored in the light casing is insufficient to affect the rotation of the flywheel seriously. Over a period of years and in a large number of installations the rotary stabilizer has proved to be an extremely satisfactory, accurate, and trouble-free method of controlling film speed.

The drum and shaft (Fig. 10) are made from a one-piece chrome-nickel steel forging, heat-treated to assure sufficient rigidity.

The film is controlled laterally at the scanning point by the specially designed guide and contact roller shown.

In this assembly, the film passes between two flanged rollers mounted upon a common shaft. One roller is fixed in position, the other is slidable, being held against the rear edge of the film under slight spring pressure. Both flanged rollers are carried in a knee-jointed arm which swings upon a stud mounted in the main case, and lateral adjustment of the film is made by moving the entire assembly upon the stud. This assembly can be moved and locked in any desired position by rotating a split thumb-nut upon the front end of the stud, against which the assembly is firmly held by a spring located back of the lower arm. When the assembly is in the closed position, a resilient insert placed in the slidable half of the guide roller contacts the film firmly enough to assure proper traction upon the drum. This light contact is maintained at a fixed amount by a spring placed in the knee joint of the arm. Grooving the guiding flanges by the film is rendered impossible because of the rotation of the entire assembly upon the free-running ball bearings.

In a project of this character some attention must be given to the appearance and safety of the mechanism. Fig. 11, showing the rear view of the machine, clearly depicts the gear guard which not only protects the operator from injury, but completely covers all moving parts and adds to the general symmetry of the design. A view of the operating side of the machine, Fig. 12, affords an idea of the accessibility of the motor-starting switch and the framing knob placed upon the end of the motor shaft for the convenience of the operator.

Fully realizing the requirements of the motion picture theater and recognizing a sound-critical public, it has been our aim to create a mechanism which is substantially better mechanically and capable of excellent performance. The machine will do justice to high-fidelity recordings, and give long, uninterrupted service, with minimum film wear.

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[3]COOK, E. D.: "The Technical Aspects of the High-Fidelity Reproducer," *J. Soc. Mot. Pict. Eng.*, **XXV** (Oct., 1935), No. 4, p. 289.

SOCIETY ANNOUNCEMENTS

WASHINGTON CONVENTION

As this issue of the JOURNAL goes to press at the time of the Fall Convention at Washington, D. C., details concerning the Convention will be published in the December issue. The Tentative Program of the Convention, which was mailed to all the members of the Society recently, will, as usual, be followed by the Final Program, which will be distributed at the Convention. For the benefit of those who were unable to attend the Convention, the Final Program and a description of the highlights of the Meeting will be published in the next issue. The papers presented at the various sessions will be published in the JOURNAL during the next few months.

STANDARDS COMMITTEE

At a meeting held at the Hotel Pennsylvania, New York, N. Y., September 26th, the following items were considered by the Committee: (1) report on the European 16-mm. sound film situation by Mr. G. Friedl, who attended the recent Berlin and Paris Congresses as representative of the Sectional Committee on Motion Pictures under the A. S. A., and from Dr. W. Clark, who attended the Paris Congress as chairman of the American National Committee of the International Congress of Photography; (2) the relation of the S. M. P. E. Standards Committee to the various other standardizing groups, foreign and domestic; (3) proposed revision of various drawings in the Standards Booklet, in order to clarify them and increase their usefulness; (4) possibility of standardizing camera, sound, and printer sprockets; (5) possible standardization of screen brightness; (6) consideration of the photoelectric cell standards proposed by the British Standards Institution; (7) proposed layout for 8-mm. sound film; (8) 16-mm. sound test film, similar to the present S. M. P. E. Standard 35-Mm. Sound Test Film; (9) dimensions and footage of reels, proposed by the Academy of Motion Picture Arts and Sciences; (10) possibility of supplying standard densities to studios and laboratories for checking their densitometric work; (11) proposed change of lead of the sound over the picture from the present standard of 25 frames to 26 frames, proposed at the recent Congress at Paris; (12) definition of safety stock.

The various items listed above will be discussed in detail in the Report of the Standards Committee, to be presented at the Washington Convention and subsequently published in the JOURNAL.

BOARD OF GOVERNORS

A special meeting of the Board of Governors was held at the Hotel Pennsylvania, New York, N. Y., September 13th, for the principal purpose of completing work upon "Administrative Practices," which had been begun nearly a year ago, but the completion of which was constantly interfered with in the meantime by current matters. "Administrative Practices" is a compendium of all current operating policies and procedures of the Society, instituted by the Board of Governors aside from the provisions of the Constitution and By-Laws, and is for the guidance and reference of the members of the Board in their work. It is to be continually kept up to date, as new policies or actions are taken by the Board at the various meetings.

SOCIETY AWARDS

Announcement of the recipients of the Journal Award and the Progress Medal Award will be made at the Semi-Annual Banquet of the Society at the Washington Convention, October 23rd. The Journal Award is given for the most outstanding paper originally published in the JOURNAL during the preceding calendar year; and the Progress Medal is awarded in recognition of any invention, research, or development which, in the opinion of the Progress Award Committee and the Board of Governors, shall have resulted in a significant advance in the development of motion picture technology. The Progress Medal Award, it will be noted, does not necessarily apply to work done only during the current year.

PACIFIC COAST SECTION

Election of officers of the Pacific Coast Section has just been completed, with the following results:

G. F. RACKETT, *Chairman*
H. W. MOYSE, *Secretary-Treasurer*
C. W. HANDLEY, *Manager*

The fourth member of the Board of Managers is K. F. Morgan, *Manager*, whose term does not expire until December 31, 1936. Mr. E. Huse remains a member of the Board for another year, as *Past-Chairman.*

2000-FT. REEL

Proposals for the standardization of a 2000-ft. reel to take the place of the present 1000-ft. reel were recently made by the Academy of Motion Picture Arts and Sciences. The subject had previously been considered and reported on by the S. M. P. E. Committees on Projection Practice and Exchange Practice in the June, 1934, JOURNAL.

Meetings of representatives of the various exchange companies were recently held for the purpose of considering these proposals and for gathering economic and technical data involved in changing from the present standard to the proposed one, in the offices of the Motion Picture Producers and Distributors of America, under the chairmanship of Mr. A. S. Dickinson. As a result of these deliberations it appears that the industry is favorable toward making the change, if certain conditions are adhered to for the present, and a complete report on the subject will be presented by Mr. Dickinson at the Washington Convention, May 21st.

RESEARCH FELLOWSHIP

As an extension of the researches carried on at the U. S. Bureau of Standards in the Paper Section, relative to the preservation of records on paper, a study was recently initiated on the stability of cellulose acetate motion picture films with respect to their use for the reproduction of record material. Dr. J. R. Hill, formerly associate chemist in the Examining Division, Civil Service Commission, and assistant chemist in the Bureau of Chemistry and Soils, was appointed Research Associate by the sponsoring National Research Council to conduct the investigation.

SOCIETY SUPPLIES

Reprints of *Standards of the SMPE and Recommended Practice* may be obtained from the General Office of the Society at the price of twenty-five cents each.

Copies of *Aims and Accomplishments*, an index of the *Transactions* from October, 1916, to June, 1930, containing summaries of all the articles, and author and classified indexes, may be obtained from the General Office at the price of one dollar each. Only a limited number of copies remains.

Certificates of Membership may be obtained from the General Office by all members for the price of one dollar. Lapel buttons of the Society's insignia are also available at the same price.

Black fabrikoid binders, lettered in gold, designed to hold a year's supply of the JOURNAL, may be obtained from the General Office for two dollars each. The purchaser's name and the volume number may be lettered in gold upon the backbone of the binder at an additional charge of fifty cents each.

Requests for any of these supplies should be directed to the General Office of the Society at the Hotel Pennsylvania, New York, N. Y., accompanied by the appropriate remittance.

The Society regrets to announce the death of

WILLIAM KENNEDY LAURIE DICKSON

Honorary Member of the Society

September 30, 1935

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXV **DECEMBER, 1935** **Number 6**

CONTENTS

JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

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PROCEEDINGS OF THE SEMI-ANNUAL BANQUET OF THE SOCIETY OF MOTION PICTURE ENGINEERS

WARDMAN PARK HOTEL, WASHINGTON, D. C. OCTOBER 23, 1935

About two hundred members and guests of the Society assembled at the Fall, 1935, Semi-Annual Banquet at the Wardman Park Hotel, Washington, D. C., on October 23rd. Guests at the speakers' table included: Mr. Will H. Hays, President of Motion Picture Producers and Distributors of America, Inc., and speaker of the evening; The Honorable Kent Keller, Chairman of the Library Committee of Congress; The Honorable Justyn Miller, Special Assistant Attorney General of the United States; Dr. Lyman J. Briggs, Director of the U. S. Bureau of Standards, Washington, D. C.; Dr. R. D. W. Connor, First Archivist of the United States; Dr. John G. Frayne, Electrical Research Products, Inc., Hollywood, Calif.; and Mr. J. I. Crabtree, Editorial Vice-President of the Society of Motion Picture Engineers.

After an hour of dinner-dance music the guests at the speakers' table were introduced by President Tasker, who addressed the gathering as follows:

"The Society of Motion Picture Engineers, organized in 1916 for advancement in the theory and practice of motion picture engineering and the allied arts and sciences, has devoted itself to the cause of 'Progress' from that day to this. As time passed, the Board of Governors felt it expedient to establish certain awards which would tend to stimulate progress, and to that end there have been created the grade of Honorary Membership, the Honor Roll, the Journal Award, and the Progress Medal Award.

"Pioneers of the motion picture industry who have contributed substantially to the progress of the art have, from time to time, been awarded recognition by the Society in the form of Honorary Membership. Upon the demise of these notable pioneers, the Society has made provision for placing their names upon the 'Honor Roll,' which appears regularly in the JOURNAL of the Society every month. Honorary Members who now survive are:

FREDERIC E. IVES
LOUIS LUMIÉRE.

"The Presidencies of the Royal Photographic Society, The Society Française de Photographie, and the Deutsche Kinotechnische Gesellschaft have also been accorded Honorary Memberships. Those names which now appear upon the Honor Roll of the Society, all of whom were Honorary Members, with the exception of the first two, since the Honor Roll was not established until after their deaths, are:

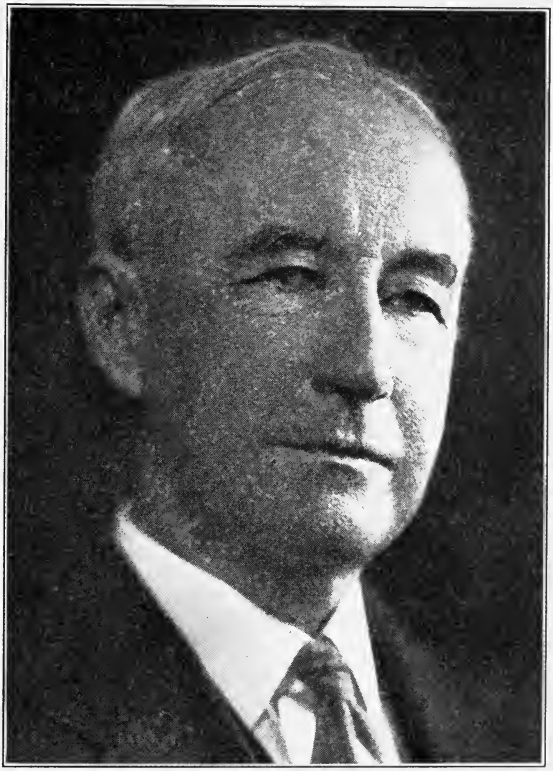
LOUIS AIMÉ AUGUSTIN LE PRINCE
WILLIAM FRIESE-GREENE
THOMAS ALVA EDISON
GEORGE EASTMAN
JEAN ACME LE ROY
C. FRANCIS JENKINS
EUGENE AUGUSTIN LAUSTE
WILLIAM KENNEDY LAURIE DICKSON

"At the Hollywood convention of the Society in May, 1935, Honorary Membership was conferred upon Mr. Thomas Armat of Washington, D. C., for his pioneer contributions to the motion picture art. Presentation of the scroll of Honorary Membership was deferred in order that it might be personally presented to Mr. Armat this evening, on the occasion of our semi-annual banquet. In connection with any proposal for Honorary Membership, it is the duty of the Historical Committee of the Society to study the historical records and documentary evidence, and to prepare a statement of the grounds upon which the candidate may be properly considered for Honorary Membership. It is therefore my pleasure to call upon Mr. Glenn E. Matthews, a member of the Historical Committee, for appropriate citation of Mr. Armat's contributions to the motion picture art."

CITATION OF THOMAS ARMAT

GLENN E. MATTHEWS

Forty-two years ago, while attending the World's Fair at Chicago, a young engineer named Thomas Armat visited the exhibit of the Anschutz tachyscope. This device consisted of a small disk around the rim of which was mounted a series of glass transparencies made from a group of photographs taken in rapid succession. Behind the wheel at the top was a Geissler tube, which furnished the light to illuminate one picture. The device was placed inside a box which had a peep-hole opening located opposite the illuminated transparency, where the scene was viewed by one person at a time. As the wheel rotated the light flashed, and an illusion of motion was produced. Describing this experience, Mr. Armat said, "The idea of



Thomas Armat.

bringing scenes from far distant and interesting countries and projecting them upon a screen before comfortably seated spectators, was an exciting thought."

A year later in Washington, D. C., Mr. Armat saw the Edison kinetoscope, and shortly afterward, during the summer, he began experimental research on projector design. To improve his knowledge of electric arc illumination, he enrolled in the Bliss School of

Electricity, in the Fall of 1894, where he made the acquaintance of C. Francis Jenkins, founder of our Society, who, he learned, was also interested in the subject of projection of pictures.

Armat and Jenkins joined forces in March, 1895, and constructed as their first model a projector, after the peep-hole kinetoscope continuous motion principle but employing a different method of illuminating the gate. The machine was unsuccessful, and under Mr. Armat's supervision a second device was produced which is said to have been "the first projecting machine ever made that embodied an intermittent movement with a long period of rest and illumination of the pictures on the film."

Joint patent protection was requested, and later granted (July, 1897) on this apparatus, which, however, turned out to be a mechanical failure. The heavy sprocket and mutilated gear that was used were soon battered out of shape. Although satisfactory in some respects, Armat regarded the machine as uncommercial, and addressed himself to the task of devising a practicable one.

The third machine was built in August, 1895, and utilized a modification of the Demeny beater type of intermittent movement. The temporary model, conceived by Armat, proved satisfactory, and a more substantial model was constructed immediately with which several successful exhibitions were given in his office in Washington. The projector was used also for several public showings at Atlanta, Georgia, at the Cotton State Exposition in September, 1895. Two duplicate machines were made and shipped to Atlanta. Early in October, 1895, Armat made further improvements in his machine, including the introduction of one of the most fundamental elements of a successful intermittent projector mechanism—the "loop" or slack-forming device.

Films for all models of the projector were those made by Thomas A. Edison and supplied through his agent, Raff & Gammon of New York. The success of the projector led Mr. Armat to contact Raff & Gammon, to find out whether they would be interested in the apparatus. A demonstration satisfied them, and a showing before Mr. Edison was arranged at the Edison plant at Orange, N. J., in February, 1896. As a result, a contract was signed between the parties concerned to manufacture eighty machines to be leased out on a royalty basis.

The first public demonstration with one of these machines took place before a large audience in Koster and Bial's Music Hall in

New York on the evening of April 23, 1896. Each scene was applauded enthusiastically, especially one showing the storm-tossed waves breaking over the pier at Dover, England, a scene that was made by another pioneer of the motion picture, Robert Paul.

Thus was launched one of the precursors of the modern motion picture projector. It was named by Mr. Armat the "Vitascope," and marketed by agreement as the Edison Vitascope. In September, 1896, a patent was filed on the use of the Geneva cross movement, which greatly improved the intermittent action of the projector. This patent was issued to Mr. Armat in March, 1897.

These are the principal details in the story of the development of the Vitascope by one of the noteworthy pioneers of this great industry. Mr. President, I have the honor to present the name of Thomas Armat for formal recognition by this Society.

Amid enthusiastic applause from the audience, Mr. Armat approached the speakers' table, where President Tasker presented to him the scroll of Honorary Membership, addressing him as follows:

"Mr. Armat, no mere words of mine could increase the pleasure or importance of this great occasion, nor add to our high esteem of the contributions that you have made to the early development of this art which is so near to the heart of all of us. I deem it an honor and a privilege to award to you this certificate of Honorary Membership."

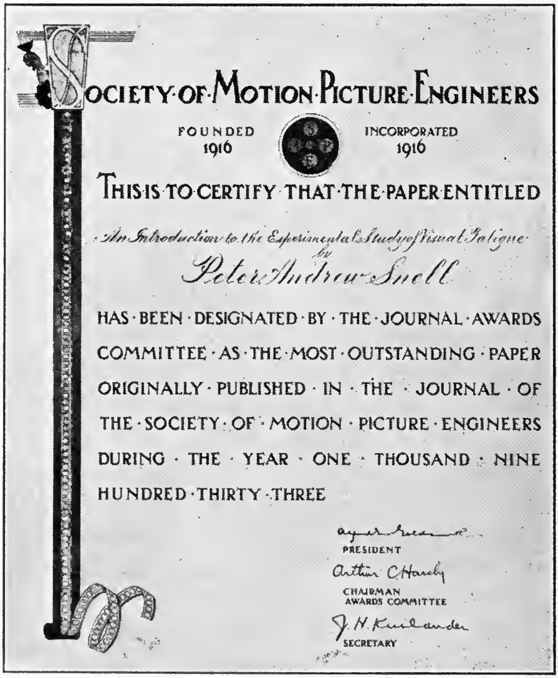
Mr. Armat responded, "I wish to thank the Society of Motion Picture Engineers for bestowing upon me this honor. I shall always cherish this scroll of Honorary Membership and will endeavor in every way possible to support the ideals and further the purposes of the Society of Motion Picture Engineers."

When Mr. Armat had resumed his seat, amid further applause, President Tasker continued as follows:

"Realizing that Honorary Membership is necessarily limited to the recognition of the pioneers of the industry, the Society gave thought to means that might stimulate and reward present-day workers in this field. In consequence, there was recently established the "Journal Award," consisting of a prize of fifty dollars accompanied by an illuminated certificate of award, to be presented annually to the author or authors of the most outstanding paper originally published in the JOURNAL of the Society during the preceding calendar year. The first such award (1933) was granted to Dr. Peter Andrew Snell of

Rochester, New York, for his paper entitled "An Introduction to the Experimental Study of Visual Fatigue," which was published in the May, 1933, issue of the JOURNAL.

"The research upon which Dr. Snell based his paper was done at the University of Rochester under the S. M. P. E. Fellowship established by Mr. George Eastman, then Honorary Member of the Society.



SOCIETY OF MOTION PICTURE ENGINEERS

FOUNDED 1916 — INCORPORATED 1916

THIS IS TO CERTIFY THAT THE PAPER ENTITLED

An Introduction to the Experimental Study of Visual Fatigue
by
Peter Andrew Snell

HAS BEEN DESIGNATED BY THE JOURNAL AWARDS COMMITTEE AS THE MOST OUTSTANDING PAPER ORIGINALLY PUBLISHED IN THE JOURNAL OF THE SOCIETY OF MOTION PICTURE ENGINEERS DURING THE YEAR ONE THOUSAND NINE HUNDRED THIRTY THREE

PRESIDENT

Arthur C. Hardy
CHAIRMAN AWARDS COMMITTEE

J. H. Kurlander
SECRETARY

Journal Award Certificate.

Unfortunately, Dr. Snell passed away soon after the publication of his paper, and so it happened that a year ago the fifty dollar prize was presented posthumously to his widow. At that time the Journal Award was so recently established that the design of the illuminated certificate was not yet finished. It was to have been our pleasure to present this certificate this evening to the parents of Dr. Peter Snell, but this afternoon I received from them the following telegram: 'Kindly express to members of the S. M. P. E. our sincere appreciation of the honor bestowed upon Dr. Peter A. Snell. We regret our inability to attend the banquet and will greatly appreciate it if Mr. Crabtree will receive the certificate for us. Sincerely, Dr. & Mrs. Albert C. Snell.'

"Mr. Crabtree, I feel that it is most appropriate that you who are responsible for the publication of the JOURNAL of the Society of Motion Picture Engineers, and for the establishment of the S. M. P. E. Fellowship under which Dr. Snell worked, and further, through whose diligent efforts this beautiful and symbolic Journal Award certificate was created, should now be the one to receive this first certificate of its kind on behalf of Dr. and Mrs. Albert C. Snell."

Mr. Crabtree replied as follows: "I am sure that Dr. and Mrs. Snell will greatly appreciate this beautiful certificate which has been awarded to their son, Dr. Peter Snell, and I shall be very happy to convey it to them."

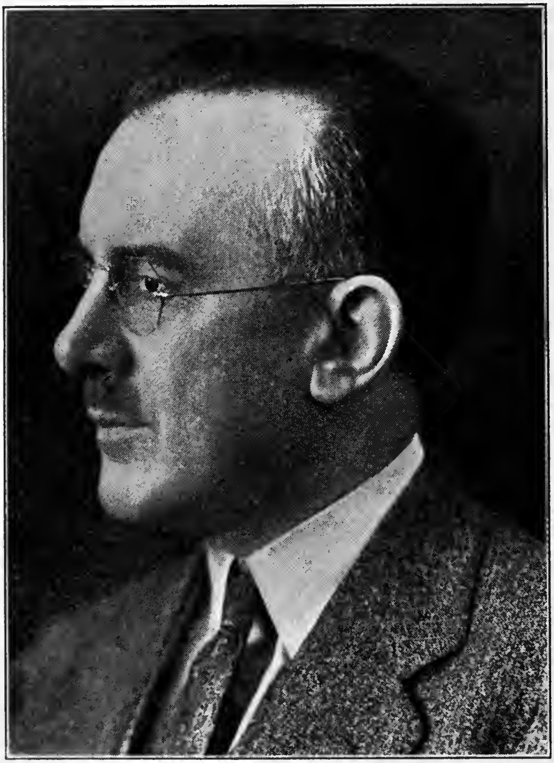
President Tasker: "A year has passed since the original award to Dr. Snell and it is now my very great pleasure to announce that the Journal Award Committee, after careful study, has recommended that the 1934 Journal Award be granted to Dr. Loyd Ancile Jones and Dr. Julian Hale Webb, for their paper entitled "Reciprocity Law Failure in Photographic Exposure." It is my pleasure to call upon Mr. E. A. Williford, a member of the Journal Award Committee, for appropriate citation."

THE WORK OF DRS. L. A. JONES AND J. H. WEBB

E. A. WILLIFORD

The award for the most outstanding paper published in the JOURNAL of the Society for the year 1934 has been made to Drs. Loyd Ancile Jones and Julian Hale Webb for their paper entitled "Reciprocity Law Failure in Photographic Exposure," published in the September, 1934, issue.

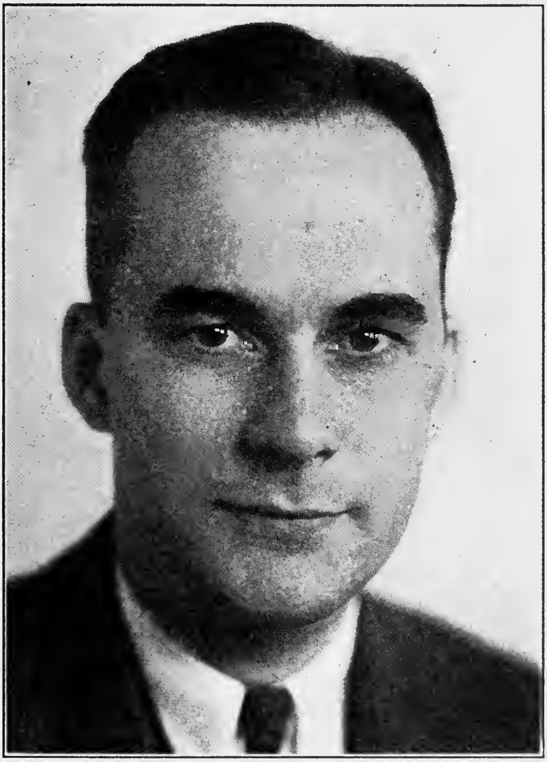
Dr. Jones and his co-workers have investigated the subject of reciprocity failure for over a decade and have published no less than eleven papers of which the award paper was one. It is well known that photographic exposures vary over a wide range, depending upon the nature of the subject being photographed and the intensity of the light. For example, a picture of a star through a telescope may require several hours' exposure, whereas the average snapshot in daylight requires only one-fiftieth of a second. According to the reciprocity law, an exposure for which the product of the intensity of the light and the time of exposure is the same should produce the same photographic results, other factors being constant. The papers by Dr. Jones and his co-workers have shown, in general, that photographic materials do not obey such a law. In the paper for which



Loyd Ancile Jones.

the award was made, a useful method of interpreting reciprocity data was described, which makes it possible to apply such data effectively for use with motion picture film. It was also shown that motion picture films are generally being used to utilize their characteristics to the maximum advantage.

Dr. Jones has been chief physicist of the Kodak Research Laboratories since 1916. He received an Electrical Engineering degree from the University of Nebraska in 1908 and a Master of Arts degree in 1910. The University of Rochester honored him with a Doctorate in Science in 1933. Prior to entering the Kodak Laboratories in 1912 he was engaged as a physicist at the U. S. Bureau of Standards from 1910 to 1912. During the World War in 1917–18, he was



Julian Hale Webb.

commissioned a Lieutenant in the U. S. Naval Reserve Force in charge of camouflage investigation.

Dr. Jones has been active for many years in the Society of Motion Picture Engineers, having served as its President from 1923–26 and its Engineering Vice-President since 1933. The Optical Society of America honored him by naming him as their President in 1930–31, and he is an active member of a number of other scientific societies.

He has conducted and published extensive investigations in the fields of photometry, physical optics, illumination, colorimetry, physics of photography, visual sensitometry, and motion picture engineering.

Dr. Julian Hale Webb received his Bachelor of Science degree in Electrical Engineering from Clemson College, South Carolina, in 1923, and his degrees of Master of Science in 1925, and Doctor of Philosophy in 1929, from the University of Wisconsin. From 1925 to 1929 Dr. Webb was assistant in the Physics Department at Wisconsin University, and instructor of physics at Williams College from 1920 to 1931. He joined the Kodak Research Laboratories in 1931 and has specialized in theoretical electrostatics and photographic theory. He is a member of the American Physical Society and the Optical Society of America. Mr. President, I have the honor to present Dr. Loyd Ancile Jones, who will receive the joint award in the absence of Dr. Julian Hale Webb."

Amid prolonged applause Dr. Jones approached the speakers' table and received the Journal Award certificates for himself and for Dr. Webb, and responded as follows:

"Members of the Society and friends, it is said that the genius of a great executive lies in the selection of his associates. Perhaps it could also be said that the genius of a research worker consists in the fortunate selection of very able co-workers. If this be the case, then, with Dr. Julian Hale Webb as the example, I am sure that I am a genius!"

Mr. Tasker: "It is a requirement of the Journal Award that honorable mention be made of five other outstanding papers originally published in the JOURNAL during the corresponding year. The following are the papers thus given honorable mention:

"On the Realistic Reproduction of Sound with Particular Reference to Sound Motion Pictures," H. F. Olson and F. Massa.

"Sound-Film Printing," J. Crabtree, Bell Telephone Laboratories, New York, N. Y.

"Stroboscopic-Light High-Speed Motion Pictures," H. E. Edgerton and K. J. Germeshausen, Massachusetts Institute of Technology, Cambridge, Mass.

"Further Investigations of Ground-Noise in Photographic Sound Records," O. Sandvik, V. C. Hall, and W. K. Grimwood, Eastman Kodak Co., Rochester, N. Y.

"Direct-Current High-Intensity Arcs with Non-Rotating Positive Carbons," D. B. Joy and A. C. Downes, National Carbon Co., Cleveland, Ohio.

"Now, it is a simple matter to decide that a Progress Medal shall be awarded, but to create a beautiful and appropriate medal is far from being simple. This task the Board of Governors imposed upon Mr. J. I. Crabtree, through whose efforts a number of very beautiful preliminary designs were submitted. One design, the work of Mr. Alexander Murray of the Eastman Kodak Company, Rochester, was particularly outstanding in its beauty and symbolic significance. Mr. Murray was asked to complete the design, which he has since generously donated to the Society; whereupon dies were made, the medal struck, and I hold in my hand the beautiful result. Since I

The Progress Medal awarded to Dr. Edward Christopher Wente.

can not pass it around for each of you to see, a photograph of the medal will be thrown upon the screen.

"Referring first to the reverse face of the medal, the central horizontal panels afford opportunity to designate the name of the medalist and the purpose of the award. They also carry a number of little triangular elevations, which many of you will recognize at once as bromide crystals. Above the inscription appears an H&D curve, symbolic of the classical researches of Hurter and Driffield, to whom the industry is indebted for clarifying the photographic basis of successful motion picture photography, both of sound and of scene. In curved panels to the left and right appear sine waves, symbolic both of sound and light, which it is our modern purpose to imprison and again release for the enjoyment of a world-wide audience. An outermost circular panel bears the name of the Society.

"Turning now to the obverse, we find that the center is a replica of the official emblem of the Society, itself inspired by the motion picture reel. Above and around this emblem are embossed the words 'For Progress,' and below are laurel branches, symbolic of achievement.

"Surrounding the central portion of the design, a circle of film perforations form a decorative motif, which coöperates symbolically with what, to my mind, is the most unique and significant feature that I have observed in a medal of this sort. It is, in fact, a reproduction of the earliest known bit of motion picture photography, the work of the early French scientist, Eugene Marey.

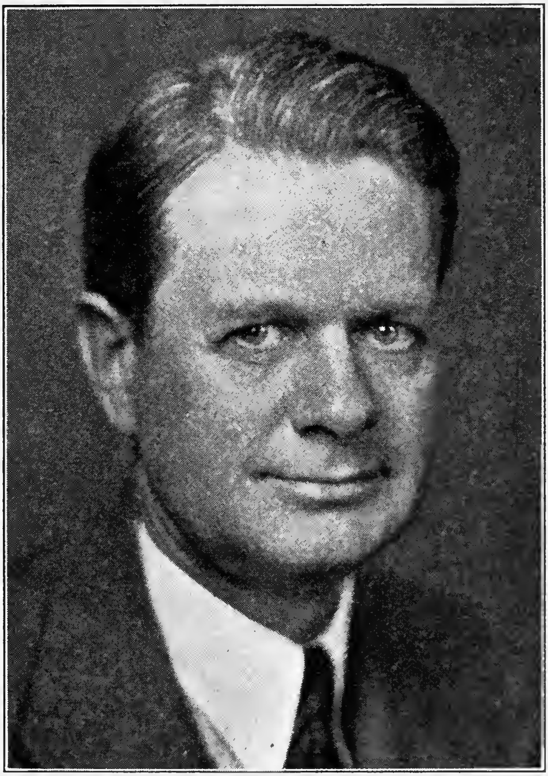
"Much care was given by the Progress Award Committee, under the Chairmanship of Dr. Alfred N. Goldsmith, to the task of selecting the recipient of this, the first such award of the Society. At first it appeared that the task would be one of exceedingly great difficulty because of the enormous progress and the many contributions that had been made in recent years. Yet, before long, it became very clear indeed that one man stood out above the others in the importance and volume of his contributions to the motion picture art. This prolific worker was Dr. Edward Christopher Wente of the Bell Telephone Laboratories. His selection by the Progress Award Committee has been confirmed by the Board of Governors and it is to him, therefore, that the first Award of the Progress Medal will be made.

"It is particularly fitting that the citation of Dr. Wente's contributions to the motion picture art should be made by the man whose untiring efforts brought about the creation of this beautiful and impressive Progress Medal. It therefore gives me a great deal of pleasure to call upon our Editorial Vice-President, Mr. J. I. Crabtree, for appropriate citation of Dr. Wente's researches and inventions in the motion picture field."

THE WORK OF EDWARD CHRISTOPHER WENTE

J. I. CRABTREE

For the past twenty years Dr. Edward Christopher Wente has been engaged at the Bell Telephone Laboratories and its predecessor organization in acoustical problems and in the development of special types of acoustical devices. One of the early problems upon which he worked was the development of a high-quality microphone that would translate sound into corresponding electrical currents with a degree of fidelity not previously approached. Microphones available at the time, while successful in telephony, were unsatisfactory for the transmission of music or the more subtle characteristics of the voice,



Edward Christopher Wente.

upon which the success of actors and public speakers so largely depended. This problem was successfully met in the condenser microphone, which depends for its action upon the change of electrical capacity between a metal diaphragm and a metal plate as the diaphragm vibrates. Microphones of this type are used extensively at the present time not only for recording sound for motion pictures but also for broadcasting and recording phonograph records.

They have been invaluable in fundamental studies of the characteristics of speech and music, and are part of the international reference system for telephony. The John Price Wetherill Medal was awarded to Dr. Wente by the Franklin Institute in recognition of this work.

In 1931 he completed the development of another high-quality microphone of entirely different type, known as the moving-coil microphone. In this device the voice currents are generated in a delicate coil of wire which is attached to the diaphragm and vibrates in a magnetic field. This microphone has also found extensive application recently in recording sound for motion pictures and in broadcasting.

The production of high-quality microphones required the development of a number of auxiliary devices, in particular, means for measuring their performance quantitatively. For this purpose Dr. Wente devised an alternating-current potentiometer and a thermophone to apply a known sound pressure to a microphone diaphragm. No satisfactory means for carrying out this necessary procedure in measuring the operating characteristics of microphones was previously available.

The study of recording sound upon photographic film by the variable-density method, which is the type of record now used by many of the major motion picture producing companies in this country, has occupied a large part of Dr. Wente's time since 1920. This led to the development of the light-valve, which provides means for varying the light falling upon the film in accordance with the current generated by the microphone. The device is now exclusively used by all Western Electric Company licensees in the production of sound pictures.

Another essential element in the reproduction of sound is the loud speaker. In this field Dr. Wente introduced new principles of design which resulted in a loud speaker more than fifty times as efficient and with at least one hundred times the sound output capacity of those previously available. Still more important, it gives a much more faithful sound reproduction. This loud speaker was used in the first showing of sound pictures by the Western Electric System, through the Vitaphone Corporation of the Warner Brothers in 1926, and still constitutes the sound reproducer in a large proportion of the theaters of the country.

Control of acoustics both in the studio and the theater is of great importance in determining the quality of the sound that reaches the audience. Dr. Wente has made valuable contributions in studying these problems also. One of the factors that affect the acoustical characteristics of a room is the reverberation time, or the rate at which sound builds up and decays. To measure this he devised an electrical method which has completely supplanted the older and less accurate methods both here and abroad. More recently he has developed another device known as the high-speed sound level recorder, which operates with such extreme rapidity that it has made available entirely new information upon the acoustical characteristics of rooms.

The transmission of music by the Philadelphia Orchestra in auditory perspective from Philadelphia to Washington in 1933 was carried out with microphones and special loud speakers developed by Dr. Wente. This demonstration showed not only that the music of a large orchestra could be carried over telephone circuits many miles and reproduced so faithfully as to be indistinguishable from the original, but that the range of loudness under the control of the director at the receiving end could be increased to many times that of the orchestra itself, thereby permitting previously unattainable emotional effects.

The results of his investigation in sound recording, communication engineering, and acoustics have been published in various scientific and technical journals, including those of the Society of Motion Picture Engineers, the American Institute of Electrical Engineers, the Acoustical Society of America, and also in the *Physical Review, American Architect,* and the *Bell System Technical Journal.*

Dr. Wente was graduated from the University of Michigan in 1911, after which he received a degree in Electrical Engineering at the Massachusetts Institute of Technology in 1914 and that of Ph.D. from Yale University in 1918. He was elected a member of the honorary society of Sigma Xi during his senior year at college, and held the John Sloane Fellowship in physics at Yale University. He taught physics at the University of Michigan while a student and was instructor in physics and mathematics at Lake Forest College from 1911 to 1912. In 1914 he began his association with the Research Division of the Engineering Department of the Western Electric Company, the predecessor of the Bell Telephone Laboratories. Dr. Wente is a Fellow of the American Physical Society, the American Association for the Advancement of Science, the Society of Motion Picture Engineers, and the Acoustical Society of America.

He has been a member of the Editorial Board of the Acoustical Society since its organization, and is at present a member of its Executive Council.

With the exception of two years spent in graduate study at Yale University, Dr. Wente has been continuously engaged since 1914 in technical research work in the Bell System. He has displayed rare inventive ability and has had exceptional success in encouraging the efforts of others by fruitful suggestions in a difficult field of work. This work has been related for the most part to acoustics and acoustical instruments, with special reference to their application to the recording, transmission, and reproduction of speech and music.

As Mr. Crabtree concluded, the audience with one accord arose to its feet, and amid loud applause Dr. Wente approached the speakers' table, where the Progress Medal was presented by President Tasker with the words: "Dr. Wente, I account it a very great honor, which I have not earned, to bestow upon you this honor which you so gloriously have earned." In response Dr. Wente said:

"Thank you, Mr. President. I want to express to the Society my great appreciation of this honor, coming from an organization that can justly be proud of the many outstanding technical achievements of its members. I assure you that this beautifully embellished medal will be a most cherished possession."

President Tasker: "As you are all aware, the feature of this evening's program is to be an address by Mr. Will H. Hays, President of the Motion Picture Producers and Distributors of America, Inc., which will be broadcast over the facilities of the National Broadcasting Company. The hour of the broadcast is at hand, and there remains just time for us to express our deep appreciation to the many firms and individuals who have made possible the tremendous success of this thirty-eighth convention of the Society of Motion Picture Engineers.

"March 11, 1922, is a date with a permanent identity and a lasting significance in the motion picture industry. On that date was organized the Motion Picture Producers and Distributors of America, Inc., with Mr. Will H. Hays as President of the Association. So strongly has his personality become imprinted upon its activities that its original name is rarely heard. It is known throughout the world as 'The Hays Organization.'

"In his fourteen years of stewardship of this industry, innumerable issues and questions have arisen. It has required sound leadership, tireless activity, tact, and skill to deal with the diverse interests of many men and many minds, both inside and outside the motion picture industry. I know of no man who could have brought to this position a greater aptitude in solving our complex and divergent problems. His ability to lay down those sound principles by which the motion picture industry governs itself, his success in meeting any new difficulty, the wideness of his vision, and the courage that has ever kept him upon the straight road to his ideals have placed him at the forefront of all motion picture improvements.

"No art has ever depended so much upon science as the art of motion pictures. Steady progress in scientific and technical fields has made the motion picture undergo many readjustments. The advent of sound, the use of color, the betterment of camera and projection technic have come swiftly upon us, and leadership and genius in meeting these advances were essential. In all the technical developments of the industry, Mr. Hays has given of his time and ability, and has recognized that the engineering progress of the industry must go apace with its artistic and cultural advancement.

"The achievements of Will Hays have been many and far-reaching. He has gained national recognition for his genius in organization and leadership, and he has won the confidence and esteem of all who have come in contact with him.

"Ours is more than a business, far more than an industry; above everything else, it is a servant of happiness, of enlightenment, of culture, of human understanding. With the greatest of pleasure, I present to you tonight, a man who has served his country well and who for fourteen years has been the distinguished leader of our industry: the President of the Motion Picture Producers and Distributors of America, Will H. Hays."

THE NEW ERA IN MOTION PICTURES

WILL H. HAYS

I am a movie fan. Fourteen years of most intense application to the problems and realities of this complex art-industry have increased this enthusiasm. I like them—as the most ardent youngster likes them. I like them for the happiness they bring; for the relief they afford; for the information and knowledge and inspiration they carry; for the sheer service they accomplish as they lift a tired human being out of his fatigue and rebuild him with the magic of entertainment.

With many mistakes and some successes, at grips with their difficulties and intimate with their miraculous achievements, I have learned that no story ever written for the screen is as dramatic or as romantic as the story of the screen itself. It is rather a privilege, you know, as well as a responsibility at times overwhelming, to have such a part in providing the principal and essential amusement of all the people. I am grateful for that privilege. And I am grateful, as all must be grateful, for the immeasurable contributions which you and your craft have made. To say immeasurable does not overstate this service.

The pace of progress is slow. It seldom moves at a thunderous gallop, but sure-footed, it circles the earth with short, unending steps. Thus you have worked in field and laboratory. Patience and ingenuity have developed the intricate and complex processes which have given us action, sound, color, the effect of light and shadow—the instruments which have made it possible for the motion picture to perform its service to art and industry, and become the greatest universal entertainment the world has ever known. Your efforts will result in developments of tomorrow, challenging the writers, directors, and the artists to employ their talents to the utmost to make full use of the infinite resources you put at their disposal.

I like to think of our present inventive and engineering factors as disciples of the master of your craft, and I commend you now in that spirit. A thousand years from now men will revere the name of the man who also gave us this really priceless gift. I would salute him now as the master miracle worker of all time, the man who made the dreams of the world come true—Thomas A. Edison.

It is the very nature of the art that pictures reflected from the screen should be ever moving toward wider fields of human service. Dynamic in its appeal, the screen can not long be standardized into a single art form. It is the one art-industry, the very essence of which is motion, sound, and color, vivified into the nearest possible representation of life. Only a few years have elapsed since the moving shadows have received a voice, and the utterly silent picture of yesterday seems like a poor crippled thing, stumbling along in speechlessness, desperately trying to make itself understood by placards and pantomime. The silent film depended for its impression upon external conduct and behavior—upon *action*. What the screen players did could easily be portrayed; what they thought, the audience learned only through indirection, or through printed captions. Today it is possible for the camera to photograph mind, as well as movement, and to reveal the intellectual and emotional interpretations of life and literature. The subtleties of psychology and the drama of human motivation can now be shown upon the screen.

We must remember that motion pictures are at once an art, a science, and a business. From the very beginning our technical and artistic progress came hand in hand. It was essential at every step that art wait upon science. For, after all, the elements of drama have not changed materially in three thousand years. We are still building upon the original dramatic situations. In essence, Elizabethan drama, barring costume, stage effects, and scenery, is not vastly different from the Broadway efforts of today. When this new medium of expression flickered into the public's consciousness thirty years ago, film entertainment had to deal with *A*, *B*, *C*'s of the art—with action that had to speak louder than words. Thus the early stars dived into raging rapids. They fled from comic policemen. They chased villains across the plains. In those early days, it was no wonder that those who saw the then technical limitations of the "movies" envisioned a perpetual babyhood for motion picture art.

The problem of the screen has been viewed from many angles. Some saw this problem in a single dimension. Make better pictures, they argued, and better audiences will support them. They did not recognize the dual process of development which required both constantly improving standards of production and higher standards of appreciation. They did not know that improved supply and improved demand were twin necessities, equal one with the other.

We of the industry, who must face the problem from all standpoints, know that to advance steadily, motion pictures must proceed in three parallel lanes. There must be technical development by which the screen may enlarge its artistic field; there must be better pictures from the dramatic as well as from the social standpoint; and there must be standards of public appreciation by which the right pictures will find the right audiences. These movements must be simultaneous. We can not lag upon one road without stopping progress upon all three. Without the technical development that went side by side with artistic progress, talking motion pictures could not have reached their present artistic merit.

We are now reproducing, in the form of high entertainment, the great spectacles of history and the vivid chronicles of our own country. Too, pictures are moving into higher spheres of dramatic and educational appeal. The severest critics of the movies, from the social if not from the artistic standpoint, have been loud in their praise of recent films based upon fine, wholesome drama, upon entertainment that enriches human understanding. We have now reached the stage where the great music of the opera, the symphony, and the concert hall, dramatized in the universal entertainment that delights both the eye and the ear, is being brought to millions.

In the past year, in addition to its treatment of original and current themes, the industry has vivified great works of classical and current literature into outstanding film entertainment. All this trend is on an upward curve, as evidenced by *A Midsummer Night's Dream* and such forthcoming productions as *A Tale of Two Cities, Peter Ibbetson, The Three Musketeers, Dodsworth, The Good Earth, Green Pastures, Ivanhoe, Kim, Marie Antoinette, Mary of Scotland, Pickwick Papers, Romeo and Juliet, Hamlet, Silas Marner, The Life of Beethoven, Under Two Flags, Pasteur, Captain Courageous, Dr. Samuel Johnson, Ramona, General Grant, Twelfth Night, As You Like It, Last of the Mohicans, Valley Forge, Sutter's Gold, Sam Houston, Courtship of Miles Standish, Samson and Delilah, Way Down East*, and many others.

This list sounds a little like Dr. Elliott's Book Shelf—yet it is part of the projected program for mass entertainment; and it is, indeed, mass entertainment, for not less than ten million persons per day see motion pictures in this country alone, and not less than 27,000 miles of film are handled each day in our exchanges. That list, and the pictures that are coming—it will be hard to deny them.

Toscanini had once concluded a great performance. The hall rang with thunderous applause. The concert was so successful there were expressions of mutual appreciation in the orchestra. The first violinist alone was sour, standing with wry face. So obvious was his distress that Toscanini, inquiring as to the trouble, said: "Pedro, didn't you like the selection of the program?" "Oh, yes," said the violinist, "I thought it was perfect." "Well, Pedro, didn't you like the way I read the score?" "Yes, Maestro, it, too, was perfect. No one could have read it better." "Well, Pedro, didn't you like the way I conducted?" "Oh, Maestro, it would be sacrilege to suggest otherwise. No one is as great as Toscanini." "Well, then, in Heaven's name, Pedro, what was the matter?" Pedro, with another wry face, exclaimed, "Ah, Maestro, I *just don't like music.*"

Such combined entertainment and cultural service to millions would not be possible if, in addition to the will, there were not the means to accomplish them. To develop the mine of literary, dramatic, and musical material, the screen not only had to have a voice, but had to learn how to use it. The marked achievements in technical development argue conclusively that research, resourcefulness, and invention will continue to underline further progress. The talking picture is only at the beginning of its career, artistically and socially. Our studios are the workshops of authors, scenario writers, directors, musicians, artists, and producers, as well as the laboratories for scientists.

And what workers they are! I sometimes think that to do the job as they do it they must have all been fed the spinach of Pop-Eye, the Sailor. From centuries of study of light and sound, from the profundity of pure science, they have builded a peak of sheer art as a platform upon which to present the monkey-shines of Mickey Mouse, and for him they have won wild applause from the learned; even as they have brought from the masses acclaim loud and long for the art of George Arliss, as Richelieu. Paradoxical. It simply can't be done. But there it is. The miracle of the movies. The most significant social phenomenon of the generation.

Like the printing press, the invention of the camera marked a fundamental stage in the march of human knowledge. The motion picture camera which brought to life the characters photographed was another development. Improved technic has given full rein to the skill of our camera experts. Our technicians have performed miracles of illusion. But such advance will never stop short of its true goal—which is the closest possible imitation of nature and life. Natural objects have three dimensions. So I am confident that the audience of tomorrow will witness pictures with the qualities of natural perspective, height, width, and depth.

Thrilling as a baby's first cry was the event which announced that shadows could talk as well as walk. But no less important are the later achievements of sound recording and reproduction. Artistry, at last, has learned to use speech and music effectively in the creation of talking motion picture entertainment. Too, the screen's début into the field of great music, not merely as a background for action, but as a part of the main entertainment theme, is as significant perhaps as was the fact that at last it had received a voice.

It is only by the creation of the better, the truer, the finer, that we can measure the progress still possible. Men were thrilled by the fact that their first motor cars reached a speed limit of twenty miles an hour. They sat riveted to radio sets that hissed and crackled and faded. They were content with the crudest stage devices until greater artistic progress was achieved. Sufficient for the day was the good thereof. The victories of greater screen illusion, both in sound as well as sight, are before, and not behind, the art.

As with sound, so with color. Color plays an important and continuous part in our lives. It is another element of vivid dramatic presentation. It is a stroke of realism which eventually must mean much to motion picture appreciation. We shall learn not only to achieve the highest form of naturalness in color and color combinations, but also the most effective manner of their use.

Artistically as well as technically the film is growing in the importance of its appeal. Every form of dramatic expression finds its outlet today in modern talking pictures, and they are coming to receive their measure of artistic recognition—growing to a high artistic and esthetic stature from an infancy whose promise few could distinguish. In a single generation a world public has witnessed the development from silent flickers of motion to a great new art of the theater, where all that is fine in drama, literature, music, painting, and sculpture may be reproduced in motion, sound, and color.

But the industry can not and does not rest upon its artistic and technical success. Underlying the advance of the screen is a continuous process of education, translated in the form of self-regulation within the industry and public coöperation without. It would matter little what science and technical progress could create, what artistic genius could achieve, if the right kind of pictures did not find the right kind of audience. Motion pictures are an industry as well as an art. Universal entertainment demands that the screen be within the reach of the vast majority of our people. The industry can not outrun with impunity the requirements of the public which it serves. But it can, should, and must strive for ever-higher forms of entertainment appeal. It is, indeed, a continuous educational task, in which public coöperation and constructive criticism must play their vital parts. This is not the occasion to discuss the many procedures of self-regulation which we have developed during the last fourteen years. The sum and substance of such procedures must be reflected upon the screen. Pictures, not words, must tell that story. The technical, artistic, and social progress has a very definite bearing upon the educational and cultural aspects of the screen.

I have on a previous occasion discussed before your body the importance of collecting and preserving the picture records of historical occasions. I have called attention to the value of sound, action, and color that would preserve significant contemporary events for the coming generations with the vividness, realism, and certitude of life. Through no other means can the pageant of history be recorded in the living tempo of the time in which the events occur.

The American motion picture industry has produced, and has, countless miles of newsreels and historical subjects reporting the outstanding events and picturing the great figures in the international arena during this, the most stirring period, perhaps, of world development. Moreover, the entertainment screen is constantly adding highly artistic and faithful reproductions of the American scene as described in the records of history. Some progress has been made since I emphasized this need at your meeting on May 7, 1930, but it would be a gross injustice to posterity if we failed to organize this moving, living, talking record so that historical and educational material might be available to the students of the future.

Films are printed upon celluloid. These are records infinitely more perishable than the records carefully tended in libraries and educational institutions. Many priceless chronicles of current and contemporary events are literally fading away for want of careful, scientific preservation, which must follow a system of collation and selection of films from a vast footage of material produced every year.

Therefore, I commend the purpose of a Film Library in the National Archives Building in Washington, as an important step in the right direction. The full task will require the coördinated efforts of many agencies, public and private, and I reiterate the desire of the industry to give full coöperation. To this end, it is willing to contribute its facilities and its expert knowledge.

We have now reached the stage that clearly warrants the extension of the motion picture art into the field of teaching. Through its technical, artistic, and cultural development, the film has opened a new vista of educational possibilities. Sound and color have added vastly to its range.

A great field of service calls for the joint coöperation of science and education, on one hand, and technical development by the industry, on the other. There is no substitute, in the field of visual demonstration, for modern motion picture photography synchronized with sound. There is no substitute for the graphic appeal to imagination and memory which the talking picture makes. "Visual education" may have expressed the limitations of the old art, but a wider term is necessary where we can combine sound, color, and motion in the service of teaching and learning. Every step of progress which the motion picture industry makes brings us nearer to the day when text-books will be written upon celluloid as well as upon paper and the value of this supplemental tool for the teacher is demonstrated. The educational community will owe much to the pioneers who have been and are seeking to make this new medium effective both in adult and child teaching, in the lecture halls of the Universities and the classrooms of our schools.

With progress such as this, we may well envision a screen in which even closer realism, molded by the basic principles of art, will mark the great motion pictures of tomorrow. Finer harmony will characterize every phase, and the widest possible service of entertainment, information, and education will obtain.

We may imagine the visual surface of a screen animated with a stereoscopic background, with every natural color undiminished. We may face, in a great rendition of opera, a scene more impressive in its vividness and naturalness than an opening night at La Scala or the Metropolitan, taking the finest artistry of the world to every town and city in the nation.

We may foresee entertainment which will continue to draw upon new story values of high dramatic intensity, both from life and from literature. But progress will not be limited purely to dramatic features. The newsreel will achieve an even greater place in the country's informational services, ranging the world in trail of significant events. Short subjects will continue to show one half of the world how the other half lives, works, and sings. The teaching film will become a standard medium of education, and not a novelty in the classroom. So far, indeed, has the science of the motion picture advanced, technically and mechanically, so surely has its art quality been demonstrated, so wide is its scope, that its present possibilities constitute a tremendous challenge to those who would create something of beauty or of lasting value.

This progress is a challenge to the teacher to discover the films maximum usefulness, and to adapt it to his field of education. It is a challenge to those groups which seek to advance good taste and social welfare. It is a challenge to science to apply the film's capabilities to the full. It is a challenge to the artistic mind and hand to advance their purpose with the infinite means now placed at their disposal. It is perhaps the greatest challenge of all to the writer, and the producer, and the director, because the screen's major purpose is entertainment.

If imagination can project a humanity deprived of its entertainment release, all screens silent and lifeless, then it will conjure the true measure of the vast and vital benefit of the motion picture. It satisfies a deep and fundamental craving as basic and human as the desire of a hungry man for bread. Great civilizations of the past perished amid the fanfare of distorted entertainment standards. The motion picture is working in historical contrast to those decadencies, profound and far-reaching. The continued evolution of the screen to higher forms of entertainment may be one of the strongest fortifications of our own civilization.

ANALYSIS OF THE DISTORTION RESULTING FROM SPROCKET-HOLE MODULATION*

E. W. KELLOGG AND H. BELAR**

Summary.—*That constancy of record speed should be sought in sound recording and reproduction has been recognized throughout the history of the art, but standards of performance have usually fallen far short. Especially have the speed variations due to sprocket-tooth action failed to receive from many engineers in the sound-picture industry the consideration which their harmful effects warrant. This is due to imperfect understanding of inherent limitations and to the fact that the impairment of sound quality is of a kind which may easily be ascribed to other causes. An analysis is made of the loss of true tones and production of spurious tones, as a result of speed modulation at sprocket-hole frequency. A recorder in which not only are disturbances of this kind eliminated, but all speed variations reduced to a minimum, has been available to the film recording industry for several years. Film phonographs, rerecording machines, and projector sound heads of which this is true are now also available, thus making possible an over-all performance which sets a new standard in the sound reproducing art.*

Ever since the beginnings of the art of recording and reproducing sound, constant speed has been recognized as a desideratum. Edison's first phonograph employed a large flywheel and, in the discussion in his U. S. Patent, No. 227,679 (May, 1880), he showed a very clear understanding of the importance of speed constancy. Many other pioneers in the sound recording art have either shown expedients for improving the speed constancy of their devices or else, without showing any expedients, have postulated "constant speed." Although it was realized that perfect functioning of a recording and reproducing system called for constant speed, an approximation to constancy has had to suffice even to the present day, both in phonographs and in sound-picture equipment. In the phonograph field, commercial considerations permitted the acceptance of standards which have not represented the best results attainable. Considerably more effort, however, has been devoted to speed constancy in the case of recording machines than in reproducing machines, since only

* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

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

small numbers of machines are involved, and the defects of these machines are impressed upon all the records made.

In the sound-picture field the fact that so much equipment of inferior performance has been developed has been due to several causes. There has been much misunderstanding of the problems; and, in particular, the harmful effects of sprocket-tooth action have not been fully appreciated. This has been the more true because the effect upon sound quality is of such a character that it is readily attributable to other causes. The presence of many other faults and sources of distortion has diverted attention from the speed modulation problem, and standards of performance have been accepted which did not represent the best attainable. The faults in reproduction due to speed irregularities are more obvious with music than with speech, and the fact that the sound equipment became largely a vehicle for speech rather than for music has not stimulated the adoption of the best possible designs.

In the pioneer development of Photophone apparatus at the General Electric and Westinghouse Companies, speed constancy received more attention than it might otherwise have received for the reason that the function of sound equipment was at first conceived to be for musical effects quite as much as for speech. The imperfect reproduction of piano music as a result of speed fluctuations was subject to immediate criticism and a number of different types of film-moving systems were evolved in an effort to find the best solution. In nearly all these arrangements, provision was made for the elimination of sprocket-tooth disturbances by carrying the film past the optical system upon a smooth rotating drum, and all the studio type recorders employed by RCA Photophone have had this feature. Experiments directed toward finding the best means of insuring correct and uniform speed of the drum culminated in the adoption of the magnetic drive recorder, described by one of the present authors[1] in 1930. In this recorder a rotating magnet imparts to the drum flywheel a smooth torque of sufficient magnitude to overcome bearing friction, with the result that the film loops upon either side of the drum are so slack that appreciable impulses are not transmitted to the drum from the adjacent sprockets. The magnetic drive not only serves to keep the film loops slack, but also effectively damps out any oscillations that may occur in starting, or which might in the absence of adequate damping be built up by periodic repetitions of even a very feeble pull through one of the film loops.

Experimenters in general have recognized that a badly designed or poorly fitting sprocket introduces disturbances, but it has probably been far less widely recognized that truly constant speed can practically not be attained with a sprocket. So far as the writers are aware, this fact was first published and emphasized with explanations in the paper just cited. How wide spread has been the misunderstanding of the inherent limitations of sprocket-tooth propulsion is illustrated by the numerous attempts of inventors to prevent slippage upon the sprocket by employing pressure rollers or tension devices. If teeth are provided, the film *must* slip upon the supporting cylindrical surface, unless the perforation pitch happens to be exactly equal to the tooth pitch; a condition which, owing to varying film shrinkage, can occur only rarely. Application of pressure tending to make slipping difficult only makes the slippage more irregular by causing a greater accumulation of misadjustment before the correcting slippage takes place. Another fallacy is that the speed irregularities are reduced by having a large number of teeth in engagement at once. No matter how many teeth are in engagement, only one tooth works at a time; and when it disengages, the film slips an amount necessary to bear against the next tooth.

Further discussion of the inevitable irregularities of motion due to sprocket-tooth action appears in a recent paper by J. Crabtree.[2]

The impairment of the quality of reproduced sound resulting from speed fluctuations varies greatly with the rapidity of the fluctuations. Very slow "wows" cause musical tones to sound out of tune. More rapid fluctuations seem to cause a change in the quality of the tone, giving the impression of a cheap, poor instrument; while still more rapid variations may cause effects which might be described as flutters, gurgles, or tremolo, or may simply rob some of the tones of their clearness, making them sound "wheezy" and adding to the apparent ground-noise. Often the effects of a speed variation will be brought out more by one note than by another. For this reason continuous-tone listening tests for "wows" are not altogether conclusive unless a series of tones is used. Our general observation has been that high-pitched tones are most sensitive to the rapid speed changes. When the cycle of speed variation, however, comes itself into the range of audio frequencies, we are likely not to recognize the impairment of quality as a speed variation phenomenon, unless we have had opportunity to give our ears special education on the subject.

The purpose of this paper is to present a brief analysis of the effects upon tones of various pitches, of a speed variation which may be taken as fairly representing or approximating the variations which a well designed sprocket would, under average conditions, introduce. A more general treatment of the subject has recently been published by Lautenschlager.[3] It has seemed to us that the analysis, which shows the breaking up of the original tones and production of numerous spurious tones, illustrates very effectively the nature of the distortion which the sprocket-tooth action causes.

For the purpose of the analysis we have assumed that the film is advanced and retarded 96 times per second through an amplitude of one mil. In other words, superimposed upon the continuous travel of the film is an alternating displacement of $0.001 \sin (2\pi\ 96t)$ inch. This, of course, purports to be only a first-order approximation of the sprocket-tooth disturbance. In estimating the displacements to be expected from the action of a sprocket, it should be remembered that for smooth action a sprocket must operate definitely as either a pulling or a hold-back sprocket, and be designed accordingly. For a pulling sprocket the tooth pitch must be equal to or greater than the film perforation pitch. The sprocket can, therefore, not be designed for average film shrinkage but must be designed to work well with film which has shrunk the minimum amount. The departure from a perfect fit will, therefore, be at least equal to the difference between the minimum shrinkage for which the sprocket is designed, and the shrinkage of the film in question. Since minimum shrinkage is of the order of 0.2 per cent and maximum may be as high as 1.5 per cent, the amount of misfit must vary all the way from zero to 1.3 per cent. The perforation pitch for unshrunk film is 187 mils, and 1.3 per cent of this is 2.42 mils. A film of 1.5 per cent shrinkage, when pulled by such a sprocket would travel at a speed 1.3 per cent above its average so long as a given tooth is doing the pulling, and then slip back 2.42 mils to make contact with the next tooth, thus oscillating between positions 1.21 mils ahead and 1.21 mils behind its average or normal position. For simplicity in the calculations, the modulation frequency was taken as 100, and the displacement amplitude as 1 mil. The amplitude chosen, therefore, corresponds to a degree of shrinkage which would often be exceeded in practice, but would perhaps be a little more than the average. On the other hand, the wave-shape of the actual displacement would be irregular, and contain components of frequencies higher than 96 cycles per second, and these would cause some further splitting up of the reproduced tones beyond what is shown in our diagram. Furthermore, the reproducing machine is not the sole source of sprocket-tooth flutter. Many recording machines record directly upon a sprocket, printer sprockets introduce a similar disturbance, and tolerances in the perforations themselves produce further irregularities. While it is conceivable that some cancellations may occur in the summation of these effects, more additions than subtractions are to be expected. In view of these numerous sources of disturbance, our analysis is probably not pessimistic for average conditions.

EQUATION FOR OUTPUT FROM SINE WAVE RECORDING WITH MODULATED SPEED

If a film upon which a sine wave has been recorded is moved past a reproducing optical system, the transmitted light at any instant will depend upon the distance which the film has travelled from a designated starting point; or, in other words, upon what portion of the recorded wave the scanning light falls. The instantaneous value of the alternating-current output from the photo-tube may be written as

$$i = I \sin \frac{2\pi x}{\lambda_s} \tag{1}$$

in which I is the maximum value of the alternating current, λ_s is the wavelength of the recorded wave in inches, and x is the distance from the reference point in inches. If the film (which is assumed to have been *recorded* at uniform speed) travels during reproduction at a uniform speed, s, the distance, x, travelled in t seconds will be simply st, in which case the output is a pure sine wave

$$i = I \sin \frac{2\pi}{\lambda_s} st \tag{2}$$

We wish to consider, on the other hand, the case in which the speed is not constant but varies sinusoidally, causing x to be alternately greater and less than it would be with constant speed. This condition may be represented by writing

$$x = st + A \cos \omega_m t \tag{3}$$

in which s is the average speed in inches per second.
t is the time in seconds since the zero point passed the optical system.
A is the maximum displacement of the film in inches, from the position it would occupy with constant speed.
$\omega_m = 2\pi f_m$ in which f_m is the frequency at which the speed is modulated.

Now since the instantaneous output from the film at a point x inches from the start, for a sine wave recording, is known, the equation for the speed-modulated wave can be written by substituting equation (3) in (1):

$$i = I \sin\left(\frac{2\pi st}{\lambda_s} + \frac{2\pi A}{\lambda_s}\cos\omega_m t\right) \tag{4}$$

Since $\frac{s}{\lambda_s} = f_s$ = frequency of recorded sound, let $\omega_s = 2\pi f_s$:

$$i = I \sin\left(\omega_s t + \frac{2\pi A}{\lambda_s}\cos\omega_m t\right)$$

Using the relation: $\sin(\alpha + \beta) = \sin\alpha\cos\beta + \cos\alpha\sin\beta$

$$i = I \sin\omega_s t\cos\left(\frac{2\pi A}{\lambda_s}\cos\omega_m t\right) + I\cos\omega_s t\sin\left(\frac{2\pi A}{\lambda_s}\cos\omega_m t\right)$$

Expanding this into a series of Bessel functions[4]

$$\cos(X\cos\phi) = J_0(X) - 2J_2(X)\cos 2\phi + 2J_4(X)\cos 4\phi - \ldots$$
$$\sin(X\cos\phi) = 2J_1(X)\cos\phi - 2J_3(X)\cos 3\phi + 2J_5(X)\cos 5\phi - \ldots$$

$$\frac{i}{I} = \sin\omega_s t\left[J_0\left(\frac{2\pi A}{\lambda_s}\right) - 2J_2\left(\frac{2\pi A}{\lambda_s}\right)\cos 2\omega_m t + 2J_4\left(\frac{2\pi A}{\lambda_s}\right)\cos 4\omega_m t - \ldots\right]$$
$$+ \cos\omega_s t\left[2J_1\left(\frac{2\pi A}{\lambda_s}\right)\cos\omega_m t - 2J_3\left(\frac{2\pi A}{\lambda_s}\right)\cos 3\omega_m t + \ldots\right]$$

Performing the multiplications indicated, and making substitutions according to the formulas

$$\sin\alpha\cos\beta = {}^1/_2\sin(\alpha+\beta) + {}^1/_2\sin(\alpha-\beta)$$
$$\cos\alpha\cos\beta = {}^1/_2\cos(\alpha+\beta) + {}^1/_2\sin(\alpha-\beta)$$

gives:

$$\frac{i}{I} = J_0\left(\frac{2\pi A}{\lambda_s}\right)\sin\omega_s t$$
$$- 2J_2\left(\frac{2\pi A}{\lambda_s}\right)\left[\frac{1}{2}\sin(\omega_s + 2\omega_m)t + \frac{1}{2}\sin(\omega_s - 2\omega_m)t\right]$$
$$+ 2J_4\left(\frac{2\pi A}{\lambda_s}\right)\left[\frac{1}{2}\sin(\omega_s + 4\omega_m)t + \frac{1}{2}\sin(\omega_s - 4\omega_m)t\right]$$
$$- \ldots$$
$$+ 2J_1\left(\frac{2\pi A}{\lambda_s}\right)\left[\frac{1}{2}\cos(\omega_s + \omega_m)t + \frac{1}{2}\cos(\omega_s - \omega_m)t\right]$$
$$- 2J_3\left(\frac{2\pi A}{\lambda_s}\right)\left[\frac{1}{2}\cos(\omega_s + 3\omega_m)t + \frac{1}{2}\cos(\omega_s - 3\omega_m)t\right]$$
$$+ \ldots$$

Substituting $2\pi f_s$ for ω_s and $2\pi f_m$ for ω_m results in:

$$\begin{aligned}\frac{i}{I} = & J_0\left(\frac{2\pi A}{\lambda_s}\right)\sin 2\pi f_s t \\ & + J_1\left(\frac{2\pi A}{\lambda_s}\right)\left[\cos 2\pi(f_s + f_m)t + \cos 2\pi(f_s - f_m)t\right] \\ & - J_2\left(\frac{2\pi A}{\lambda_s}\right)\left[\sin 2\pi(f_s + 2f_m)t + \sin 2\pi(f_s - 2f_m)t\right] \\ & - J_3\left(\frac{2\pi A}{\lambda_s}\right)\left[\cos 2\pi(f_s + 3f_m)t + \cos 2\pi(f_s - 3f_m)t\right] \\ & + J_4\left(\frac{2\pi A}{\lambda_s}\right)\left[\sin 2\pi(f_s + 4f_m)t + \sin 2\pi(f_s - 4f_m)t\right] \\ & + \dots\end{aligned}$$

This equation shows the speed-modulated wave to be broken up into the original frequency and an infinite number of side-frequencies. These side-frequencies are

$$\begin{array}{ll}(f_s + f_m), & (f_s - f_m) \\ (f_s + 2f_m), & (f_s - 2f_m) \\ (f_s + 3f_m), & (f_s - 3f_m) \\ \textit{etc.} & \textit{etc.}\end{array}$$

The amplitude of the fundamental is a Bessel function of the order zero, whose argument is the amplitude of phase-shift of the film expressed in radians of the recorded wave. The amplitude of the first pair of side frequencies is a Bessel function of the first order of the same argument, *etc.* The composition of a wave modulated by variations in film speed is similar to that obtained in a frequency- or phase-modulated transmitter.[5,6,7]

An illustration of a frequency-modulated wave is given in Fig. 1. The top curve shows a sine wave from which the frequency-modulated wave at the center has been drawn by a graphical method.

At the bottom of Fig. 1 the same wave is shown broken into its sine-wave components, which, added together, result in the frequency-modulated wave shown at the center. The amplitude of modulation and its frequency relative to the signal frequency have been chosen with a view to showing the entire cycle of change within a few waves. They would correspond, in the case of 35-mm. film running at a speed of 90 feet per minute, to the effect of a film displacement of 1 mil at 1000 cycles upon a recording of 3000 cycles.

Fig. 2 shows the loss in fundamental output with frequency, for the assumed speed-modulation (resulting in a displacement of one mil) calculated from the equation with the aid of a table of Bessel functions. The position of the side-tones in the frequency spectrum with

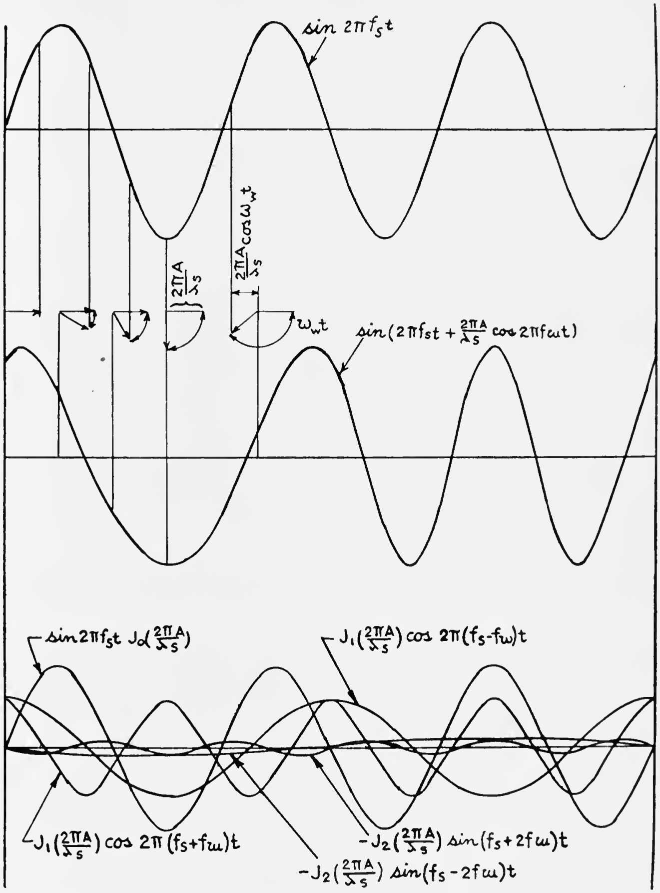


FIG. 1. Graphical illustration of film-speed modulation.

respect to the fundamental is dependent only upon the frequency of modulation of the film speed.

In Fig. 3 the amplitude and distribution of the side-tones and the fundamental are shown for tones of various pitches. Fig. 3 is based upon the same assumptions of amplitude and frequency of modulation. It shows what the ear perceives in the case of sprocket-hole modulation which is itself of audio frequency. Such rapid fluctuations of speed can not conceivably be followed by the ear and recognized as changes of pitch. It will be noted that with the assumed values of modulation a 6000-cycle note is badly distorted. The fundamental has been reduced to 15 per cent of the value it would have had with constant speed, and there is one pair of side-tones almost four times as high. The next pair of side-tones is more than twice as high, and a third set almost as high as the fundamental. In addition to

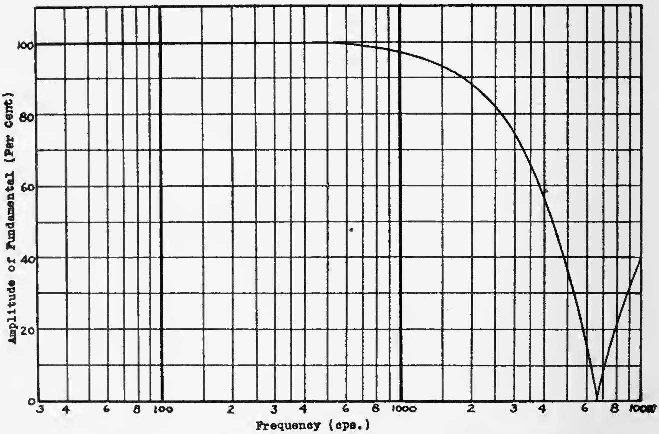


FIG. 2. Effect of a 1-mil amplitude film-speed modulation upon the amplitude of the fundamental frequency: sine wave recording and sinusoidal modulation assumed.

these, there is an infinite number of side-tones of lesser amplitude rapidly diminishing in importance.

It will be noticed that the higher the frequency of the recorded sound, the more seriously is the reproduction affected, until at 6900 cycles the original tone is completely obliterated, and a series of side-tones substituted. At another amplitude of modulation this would occur at a different frequency, but all the higher pitched tones are seriously affected. It is evident that if clear reproduction is to be attained, disturbances of this sort must be eliminated, and this is particularly true if the system is one capable of reproducing high frequencies. So many other factors have contributed to the loss or distortion of the high-frequency components of sound reproduced from film, that sprocket-tooth disturbances have often escaped the blame which they deserved, and the limited frequency range in many systems has tended to cover up their faults. The fact that the highest possible standards of speed constancy are imperative for successful extension of the range to higher frequencies was emphasized by Dimmick and Belar,[8] in 1932. The breaking up of the tones into side-bands is pointed out in the paper, and the seriousness of the rapid modulation by sprocket teeth is discussed. The demonstration given at that time employed a film phonograph designed on the same principles as the magnetic drive recorders, and as free as possible from all speed fluctuations.

Progress toward higher standards will be possible only when the seriousness of various kinds of distortion is recognized and a con-

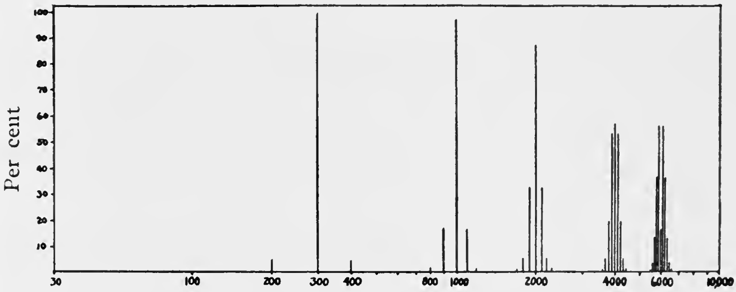


FIG. 3. Effect of film-speed modulation upon sine wave recordings of 300, 1000, 2000, 4000, and 6000 cycles. Assumed: speed modulation of 1-mil amplitude at 100 cps.

certed effort made to eliminate them. No matter how nearly perfect a recorder may be, the patron in the theater enjoys little of the benefit if the reproducing machine puts in a bad flutter. All sources of flutter in the release print, whether due to recorders, re-recorders, or printers, must be minimized, or the theater operator will have little incentive to install the best available reproducing equipment. The principles which give the best results in the case of recorders should be applied to re-recorders,[9] printers, and reproducing machines as rapidly as possible. These principles may be summarized as follows:

(1) The film should be moved past the optical system by means of a smooth (toothless) rotating drum. The recording or the reproducing point should, if possible, be directly upon the drum rather than in an adjacent sound-gate; and the film must be maintained sufficiently firm in contact with the drum to prevent any possibility of slipping or jumping out of focus.

(2) The film loops upon either side of the drum must be sufficiently flexible to avoid imparting any appreciable impulses to the drum.

The drum must rotate at constant speed,* which means not only that an adequate flywheel should be used, but bearings must be smooth in action, there must be a high order of balance and concentricity, and adequate damping must be provided to prevent oscillations in speed. Whatever damping means are employed must, of course, not introduce disturbances.

(3) Vibration must be minimized, especially any vibration which might cause relative movements between the optical system and the film.

The magnetic drive, already referred to, is in our experience the most nearly complete answer to the problem of providing constant drum speed, but an interesting alternative is described and discussed in two papers by Loomis[10] and by Cook.[11]

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* The drum must be allowed to fix its own speed; otherwise one or the other of the loops will become tight, and the film begin to slip upon the drum.

THE CALIBRATED MULTI-FREQUENCY TEST-FILM*

F. C. GILBERT**

Summary.—*After discussing some of the requirements of a multi-frequency test-film, some of the early efforts to produce test-films and the difficulties involved in so doing are described. The present technic of producing test-films is very involved because of the need of exactness of calibration. Microdensitometric measurements of each frequency are made in order to assure as great constancy of the sound level as possible. The films when finished are reproduced on a special reproducing system which furnishes correction values for each film.*

SOUND SYSTEM TESTING

Picture, if you can, a circuit consisting of hundreds of elements, some connected in series and others shunted at various places across the circuit. Most of these elements exert a critical influence upon the level delivered at the system termination: some tend to discriminate against certain frequencies and permit others to pass freely; others are prone to manipulate the incident signals and pass them on in distorted form; still others introduce flutter or noise. Such a circuit is the over-all recording-processing-reproducing system which connects the ears of a movie audience with the recording stage. Only by designing each component or group of components of this extremely complicated structure as a highly perfected unit is a satisfactory result attained when the full system is assembled. Yet, the problems of design are in many respects less difficult than those attendant upon the maintenance of satisfactory performance from so intricate a structure, because parts do not all remain as they were when manufactured—vacuum-tubes lose activity with service, mechanical parts wear, pressure contact surfaces corrode, foreign matter such as oil and dirt interferes, adjustments are subject to human error.

The second half of this composite system begins with the film record and terminates at the ears of the theater patrons. It is this

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

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portion of the system that the service engineer is required to maintain in the degree of perfection and reliability dictated by commercial requirements.

In so far as the state of the science permits, the engineer replaces individual opinion and qualitative, ambiguous terminology with reproducible quantitative measurements based upon a known system input and reliable measuring instruments at the output. By these means he arrives at a precise determination of the influence of the reproducing system upon the record introduced at the input. If this performance is normal he will discover that it is so; or conversely, if it is subnormal he will learn by just how much and in what particular respects it fails to measure up to standard. Furthermore, if a score of engineers separately examine the same system, each will arrive at the same conclusions.

Refinement of the process of measurement yields ample dividends. The exhibitor has the assurance that all is well with his reproducing system. The engineers' supervisors know of each theater where an undesirable condition with respect to the sound system exists, and what measures are taken to correct the condition. Incipient troubles are very often revealed by careful system measurement before they become serious, so that such test plays an important role in preventive service. These are some of the products of test, obtainable only from adequate refinement of technic and tools.

Meters of the required accuracy have been made available to every one by the meter manufacturers. A known input—the calibrated test film—was not available, and it was necessary to develop a technic of preparing one which would permit testing to the required degree of accuracy.

TEST-FILM REQUIREMENTS

The science has not yet made available means, applicable to rapid use in theaters, of measuring accurately all the characteristics of sound that affect the discriminating ear. It is still necessary to depend to some extent upon subjective reactions for certain portions of the testing job, and for this purpose a test-film containing selected samples of well recorded speech and music is used.

However, exact methods can be applied to measurement of the performance of the film pick-up equipment and the amplifying system. The accuracy of such measurement is limited only by the limitations of system stability and the error in meters and test-film. It is this portion of the system that contains the majority of the elements and those most subject to change, leading to inferior results or interruption of the show. Of this equipment, therefore, rigid tests are made at frequent intervals, and the characteristics are compared closely to insure that the components are performing in the optimal manner. Test-film for this purpose is divided into two classes: material to be spliced into loops, and multi-frequency test-reels.

The loops are used when continuous signals of a single frequency or when two alternately recurring frequencies are required, primarily for making adjustments. One of the most important adjustments, that made on the optical system, requires from a few minutes to perhaps half an hour in cases where unusual difficulty is experienced. A non-repeating strip of single-frequency film is subject to some level variation, and experience indicates that such variation causes uncertainty as to whether the optical system is in optimal adjustment at the completion of the process. Great care in obtaining the best adjustment possible is warranted here, because small errors of azimuth or focus in the lens adjustment are magnified in effect by azimuth variations on the sound-tracks of release prints, or improper film position resulting from warping of the print.

The multi-frequency test-film should contain frequency sections of sufficient length to permit careful reading of the level indicator; separation adequate to allow time enough in which to record the readings; a frequency range covering the significant audible spectrum; and frequencies properly distributed and sufficient in number to provide a full-spectrum test, yet not so numerous as unnecessarily to extend the time required for the run. The need for accurate calibrations has already been discussed and the greatest attainable accuracy is fully justified. The steadiness of level throughout the sections has an important bearing upon the accuracy of the results obtained with the film. For obvious reasons, no discoverable amount of azimuth may be present and the recording should be flutter-free.

DEVELOPMENT OF A TEST-FILM

Early efforts to obtain a multi-frequency test-film and constant-frequency material for use in loops followed the obvious method of preparing a negative with all normal care and printing from it the necessary number of copies. For a time these films appeared to be satisfactory, since present-day requirements of accuracy were not then contemplated.

With the passage of time, level-indicating instruments were improved and testing technic advanced, with the result that test-film accuracy came under more critical examination. Negatives were made under laboratory conditions with all steps controlled as closely

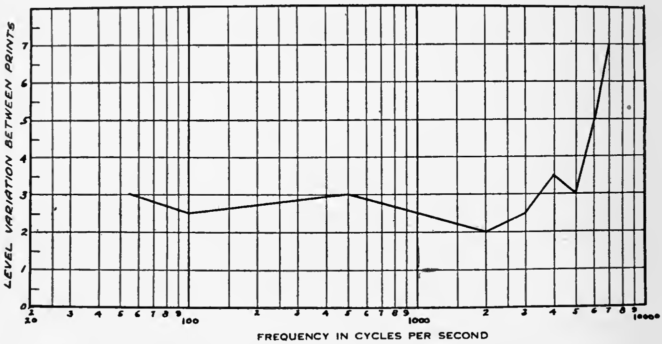

FIG. 1. Film level variations, in db., in a single printing.

as the state of the art permitted. Prints from the same negative were made by a number of commercial laboratories and the laboratory able to do the best job was selected. Examination of a number of

TABLE I

Level Variation throughout 5000 Feet of 7000-Cps. Recording Printed upon Nitrate Base

(Decibels)

Reel No.	Max. Level*	Min. Level*	Variation
1	14.0	12.5	1.5
2	15.5	12.5	3.0
3	13.0	10.0	3.0
4	14.0	9.75	4.25
5	15.0	12.0	3.0
Over-all	15.5	9.75	5.75

prints all made at one time by this laboratory revealed variations shown in Fig. 1. Included in the readings at the high frequencies is the effect of noise level which, due to the low signal levels at these frequencies, was sometimes almost equal to the signal level. This

* Neither maximum nor minimum level points occurred at the same parts of different reels, indicating that level variations could not be attributed to the negative.

unsteadiness and the low signal level eliminated the possibility of attaining results of sufficient accuracy with these films even when the films were individually calibrated.

Difficulties were likewise experienced in the preparation of high-frequency prints for use in loops in connection with the adjustment of optical systems. A quantity of 5000 feet of 7000-cycle recording printed by a single laboratory revealed generally low level and slow

TABLE II

Azimuth Losses in 5000 Feet of 7000-Cps. Recording Printed upon Nitrate Base*

Reel No.	Distance from Start (Feet)	Azimuth Loss* (Db.)	Double Azimuth Loss** (Db.)
1	1000	0.8	2.5
1	0	0.6	2.0
2	1000	0.6	2.0
2	0	0.25	1.0
3	1000	0.25	1.0
3	0	1.3	4.0
4	1000	0.8	2.5
4	165	0.6	2.0
5	860	0.8	2.5
5	560	0.4	1.5
5	440	1.0	3.0
5	0	1.0	3.0

variation of level; and, more serious, a rapid fluctuation of level and variable azimuth of the striations. The level variation and azimuth were measured at various points through the lot, with results as shown in Tables I and II. The latter table includes a column, "Double Azimuth Loss." Assuming that commercial release prints are subject to the same azimuth loss as that found on this film, an optical system adjusted to this film would reproduce a 7000-cycle release print recording having equal azimuth in the opposite direction, with the losses shown in this column.

The years of trial-and-error development have led to the test-film now in use. Most of the deficiencies of the early film were attribu-

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* Azimuth Loss is the difference in reproduced level with the optical system adjusted to the film azimuth and with the optical system in perfect adjustment.

** Double Azimuth Loss is the loss obtained from an azimuth angle double that of the film.

table to the printing process. The solution lay in the use of negative for the final film and thus avoidance of the printing process. To attain a sufficiently pure wave-form, the recording is made at the "toe" of the H&D curve. The toe-recorded negative test-film can be prepared commercially in quantity with satisfactory steadiness, good level throughout the spectrum, and free from flutter and azimuth. However, the general level and frequency response can not be sufficiently controlled to eliminate the necessity of individual calibration, and it appears at present that this step will never be eliminated.

PRESENT TECHNIC OF MULTI-FREQUENCY TEST-FILM PRODUCTION

Test-films are produced in quantities of 200 to 300. To minimize the level variation from film to film, the acetate stock used is all of the same emulsion number. The light-valve is tuned to 9500 cps. and carefully checked for azimuth after it is secured in the recording machine. The usual studio checks are made with more than usual care prior to starting the recording. A lamp test is made and processed to evaluate the exposure necessary for operation at the optimal point on the "toe." When the recording constants for the stock to be used are known and all adjustments completed, the long ordeal begins. From 1800 to 2700 adjustments of frequency and level are made at the proper footage points in the following order:

Frequency	Length of Section
8000	15
7000	15
5000	15
3000	15
1000	15
300	15
130	15
55	15
1000	35

A ten-foot space is left unmodulated between the frequency sections. Four of these 245-foot frequency groups are recorded upon each roll of stock. Since the negative is not printed, the sequence of frequencies given above reproduces in reverse order.

The developed negative, fifty to seventy-five thousand feet of it, has next to be calibrated. The most exact means of calibrating film levels known to us is afforded by the microdensitometer. This equipment, already described in the JOURNAL,[1] consists of a slow-motion propelling mechanism which carries the film past a light-beam 0.0003 inch wide, the transmitted light setting up a photo-electric cell current which, amplified by a d-c. amplifier, actuates a galvanometer mirror and so deflects a light-beam across a moving strip of sensitized paper. This paper, developed, provides a permanent record of the point-to-point transmission of the sound-track. Fig. 2 shows such a record. The distance above the base line is pro-

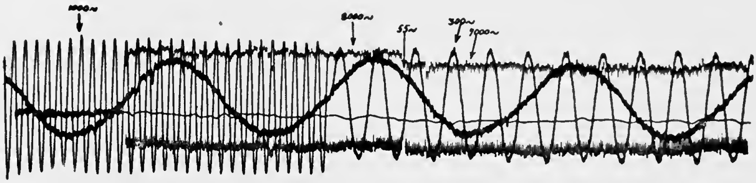

FIG. 2. Typical microdensitometer trace.

portional to transmission, and the horizontal axis represents length along the sound-track. The average vertical dimension of the envelope of the trace at any frequency, expressed in units of per cent of transmission, is the average transmission swing, S. "Densitometric film level" is then

$$L = 20 \log S$$

Since the microdensitometer is capable of scanning only 2.1 inches of sound-track at a single setting, three or four records similar to Fig. 1 are made at each frequency in order to average the possible level variation due to inconsistent emulsion characteristics throughout the frequency sections. To reduce the records to numerical data with the maximum accuracy, a planimeter is used in determining the average value of transmission swing. Since the microdensitometer permits careful evaluation of sound-track characteristics through fundamental standards, the instrument will at any time permit work to an invariable probable error.

This method possesses the required degree of precision, but to calibrate an entire production in so slow a manner would involve expense beyond all possibility of justification. However, a single film so calibrated provides a standard through which to calibrate a special reproducing system. Readings may then be taken and calibrations derived for all the film of the production by reproducing it over this system.

Accordingly, when the time comes to calibrate test-film, one film is selected for the standard and calibrated by the microdensitometer. The reproducing system is set up and its calibration is determined with the standard. A sub-standard is then calibrated, and this film is reproduced at frequent intervals throughout the period of the production calibration in order to discover and evaluate any changes in the gain or frequency response of the system. Should the sub-standard be affected by its excessive use, this will be revealed by occasional comparison with the standard.

The calibrating reproducing system is designed with stability of characteristics as the principal consideration. Pressure contacts and such variable elements as vacuum-tubes are minimized in number. Meters and rheostats are introduced in all branches of the current supply, and one engineer's time is devoted largely to maintaining these controls at the proper values.

The entire quantity of film is reproduced on the calibrating reproducing system; the output readings are carefully observed, recorded to the nearest 0.1 of a decibel, and later converted to calibration values. Finally, the frequency groups are cut apart, provided with leader, title, and tail-piece, wound upon a small reel and placed into a can. Each group is given a test-film serial number, and this number is printed upon the can along with the correction values (negative calibration values) applying to each frequency of the film in that can. The film is then ready for use.

To complete the calibration of 200 test-films requires the full-time services of two engineers for a little longer than one month.

Some of the steps mentioned above may appear to be unnecessary to the casual reader, but the author, through experience derived in the calibration of more than 1300 test-films and a not inconsiderable amount of experimentation, has found each safeguard to be necessary. The entire procedure constitutes perhaps the most costly method of preparing test-films, but it is fully vindicated by the practical value of the precise instrument it provides the service engineer.

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DISCUSSION

MR. SCHULTZ: It was stated, I believe, that before the method of negative release was adopted, variations of commercial laboratories were only in variable azimuths of the prints, and ranged from 0.25 to 1.3 decibels. At what frequency was this variation in azimuth found in the prints? Also, how was it measured; that is, what was the width of the scanning beam with which it was measured?

MR. BARNICOAT: The differences between prints from commercial laboratories were not limited entirely to azimuth errors. Such azimuth as was found resulted in the losses stated at 7000 cps. The determination was made upon a projector by reversing the film and obtaining the frequency loss for the double azimuth angle, from which the true azimuth could be calibrated. It was, of course, necessary to re-focus the lens tube assembly in a jig which permitted the independent adjustment of azimuth and focus. The scanning beam used was the standard reproducing slit one mil wide.

UNIFORMITY IN PHOTOGRAPHIC DEVELOPMENT*

J. CRABTREE**

Summary.—*The difficulties encountered in achieving a uniform degree of development from point to point upon a photographic surface and the reasons therefor are discussed. Various methods tried in an effort to realize uniformity in the development of plates and cut film are described. Continuous wiping of the surface of the film being developed is necessary to remove emerging reaction products sufficiently rapidly, and recommendation is made of the use of a series of jets of developer to achieve this without damage to the emulsion surface.*

Photographic materials and processes find their widest application where pictorial representations of objects are required. They play, however, an increasingly important role in technical applications to the problems of astronomy, chemistry, and physics. The astronomer, for instance, has for many years been interested in the physical characteristics of photographic materials, and the chemist and the physicist have utilized light-sensitive materials for recording a wide variety of phenomena. Spectroscopy, photomicrography, and radiography are illustrative of such applications. The recording of sound upon film in the motion picture industry represents a commercial application of photographic materials in a way which requires a knowledge of the possibilities as well as of the limitations of the materials and processes.

In general, some departure from true proportionality between the initial light values and the light transmission of the developed image has been quite permissible. In certain cases, however, it is highly important that every precaution be taken to insure linearity between initial values of illumination and their corresponding values of light transmission of the final print. In order to realize this proportionality it is necessary to adhere closely to the well known laws of exposure and development. These laws, however, presuppose homogeneity of the photographic medium and an efficiency of the various manipu-

* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

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lative procedures that is not achieved in ordinary practice. It is with the errors introduced by imperfections in the developing operation that this paper is concerned.

It is obvious that if the photographic film or plate is to be used as a tool of precision, it must, when subjected to a uniform light exposure, exhibit a uniform photographic deposit following the developing operation. Simple as this latter procedure may at first appear, a few trials quickly convince one that uniformity is very difficult to achieve. Many workers have proposed a solution of the problem with varying degrees of success. Indeed, in 1925 W. Clark[1] stated that ". . . the general experience has been such that it is now the opinion of many that uniform development is unattainable."

During development, the developing reagents diffuse into the gelatin matrix and there react with the silver halide crystals. The products of the resulting chemical reaction diffuse outwardly by virtue of their different osmotic pressures and are replaced by more developer. The accumulation of these products of reaction not only decreases the concentration of the developing reagents at the site of the reaction but also has a definite depressing effect upon that reaction. In developing a uniformly exposed surface, therefore, anything that will affect locally the rate of diffusion through the gelatin (internal effects), or the rate of interchange of liquid at the gelatin surface (external effects), will result in a localized difference in composition of the developer. This will result in a change in the speed of the chemical reaction, and hence in the density of the resulting photographic deposit, so long as development is arrested before gamma infinity is reached. Some of the local irregularities that may cause such effects are, for example, (internal) variations in coating thickness, differential hardening of the gelatin, and (external) current eddies in the developer originating from local differences in temperature, topography of emulsion surface, or methods of agitation of the body of liquid. The user of the photographic material has little control over the internal effects resulting from the structure of the emulsion, but has a certain control over the external. Assuming a uniform material and light exposure, uniform developing conditions will exist when (*a*) removal of the reaction products from the surface and their dissemination throughout the body of the liquid proceed at the same rate at all points, or (*b*) when the rate of removal is increased to such a degree that the time element involved is negligible compared with that occupied by the diffusion process.

In practice photographic records seldom deal with a single uniform light exposure as postulated above, but rather with a series of exposures of different magnitudes. In this case, because of the time lag of diffusion, no matter how effectively and rapidly the reaction products are removed from the emulsion surface, there will always be within the gelatin layer—where the actual development proceeds—a greater concentration of reaction products in the regions of greater exposure than in the lesser, and so, of course, a difference in the rate of development. Theoretically, therefore, it is impossible to achieve uniform development of the average photographic record if development is arrested before gamma infinity is reached. Just how far the best performance that can be attained in practice departs from theoretical perfection is difficult to determine, and is, in fact, probably unimportant so long as the departure under a given set of conditions is consistent and reproducible. Ordinary practice, of course, usually departs so far from the optimal as actually to cause irregularities in any given area due to streaming of reaction products from contiguous areas. This phenomenon has been dealt with in the literature on numerous occasions. (*Cf.* J. I. Crabtree and Ives.,[2] Bullock,[3] and J. Crabtree.[15])

It will be noticed that the optimal conditions of development are, however, the same both for uniformly distributed exposures and the average photographic record, that is, immediate removal of reaction products from the emulsion surface. It is, therefore, reasonable to assume that development conditions that result in a uniform deposit in the first case will also be optimal for the second. The ability, therefore, to produce a uniform density from a uniformly distributed light exposure may be taken as a measure of developing performance.

As above stated, many workers have essayed a solution of the problem, chiefly in connection with glass plates and cut film, as used in investigational work and in routine emulsion testing. The favorite method of development is, or was, that of submerging the material in the solution contained in a tray, shallow or deep according to the preference of the individual,[4] and carrying the body of liquid across the material by repeatedly tilting the container according to a regular or irregular pattern, the worker usually evolving a technic of his own. Bloch[5] attempted to improve upon the system by rolling the plate with a velvet-covered roller. Of recent years the use of a brush has become increasingly popular, the emulsion surface of the plate being repeatedly stroked with a soft bristled brush during development;

this action serving not only to agitate and mix the body of liquid, but also forcibly to wipe away the emerging reaction products from the emulsion surface, as described by Clark.[1] Nietz[6] in his experiments immersed his materials in a tube filled with developer, which he shook by hand. Mees and Piper[7] employed the same method but used a Dewar flask. Sheppard and Mees,[8] Davis and Walters,[9] and Otashiro[10] rotated plates about a vertical axis in pairs, back to back. Callier[11] secured his plates in shallow cells and moved them up and down in ebonite frames. Sheppard and Elliott[12] secured film to the outside of a drum, inside of which was a screw agitator. Rotation of the drum streamed the liquid past the film with a uniform flow without eddy currents.

Harrison and Dobson[13] used a vertical tank, to one side of which the plate or film was secured. A plunger clearing the plate by a small margin was reciprocated by hand past the plate, the strong swirl of developer created by its passage effectively sweeping away reaction products. Sheppard and Crouch[14] constructed an automatic, power-operated machine working on the same principle.

The present author and J. H. Waddell have discussed development irregularities in a continuous developing machine for motion picture film previously in this JOURNAL,[15,16] and have advocated the use of multiple squeegeeing, preferably by means of successive sprays of developer.

During certain investigations at the Sound Picture Laboratory of Bell Telephone Laboratories, it was necessary to be able to produce from films or plates uniform photographic deposits 3 or 4 inches in diameter, at various gammas and densities and with an allowable variation of density of less than 0.01, which is less than is permissible for the usual sensitometric measurements. In endeavoring to realize this requirement most of the above-mentioned methods were tried. Since the permissible range of density was less than the experimental error of the usual methods of density measurement, visual inspection alone was relied upon as the criterion of uniformity. Given a uniformly illuminated background of sufficient light intensity against which the plate or film under test is viewed, it is possible to detect very small variations of density in this way, particularly if a slight degree of motion in its own plane is imparted to the surface being viewed. Numerical relationships between the respective performances can not, of course, be arrived at.

Experimental.—The photographic plate or film supported upon a black background was given a uniform exposure from a suitable distant light-source, subjected to the mode of development under test, immersed at once in an acid stop bath, fixed in a chrome alum fixing bath, washed for a few minutes in running tap water followed by distilled water, the surface gently squeegeed free from drops of water and dried not too rapidly in a tunnel in a gentle current of air at room temperature, conditions which proved to give uniform drying and did not cause any perceptible density variations. The temperature of the various baths as well as of the wash water was kept between 65° and 70° F. The resulting plate or film was then viewed in a special viewer against a uniformly lighted white background, the light intensity being adjusted to the optimal for the particular sample. The materials were classified qualitatively according to the results of this inspection.

Development under static conditions gave very poor results, *i. e.*, a streaky and patchy image. No method of tray development in which rocking was relied upon for agitation was found which gave results other than what were regarded as "poor." In the case of plate development, it was thought that a source of irregularity in the developing pattern might lie in the wave generated by the raised plate edges. Fitting the plate into a recess so that a perfectly smooth surface was presented to the developer proved to be of no particular advantage.

In this general category might be included two methods of violent motion of the plate in a large, deep tray. The plate was secured on the glass side at its center to a rod bearing a rubber suction cup; it was then immersed in the bath and either (*a*) spun rapidly on the rod as axis or (*b*) thrust up and down as a plunger much as in certain types of domestic washing machines. The results were disappointing, being characterized as "fair." In this group also can be placed attempts to achieve violent circulation by placing the plate into a shallow recess in a sheet of hard rubber at the bottom of a tray and passing a narrow straight edge (windshield wiper) to and fro across the plate, the depth of the recess providing a clearance between the straight edge and the plate. The results, while distinctly superior to any rocking method, showed some patchiness; the less the clearance, down to about $^1/_{16}$ inch, the better was the result.

Brush development showed improved, but still imperfect results—streakiness and mottling, even when the brushing was speeded as much as possible without splashing the developer out of the tray.

A leisurely brushing, such as is often administered, conferred no particular benefit over the rocking.

Vigorous brushing was apt to result in scratching, particularly with emulsions of a soft nature. Harrison and Dobson's method was tried, the material being secured to one side of a narrow vertical tank provided with a solid plunger just clearing the plate. Various clearances, from $^1/_{32}$ inch and up, were used. The plunger was operated as rapidly as possible (20 strokes per minute), resulting in a violent surge of liquid past the plate. The results were, however, disappointing. Violent bubbling of air through the mass of developer, with the plate surface either in the vertical or horizontal plane, was also unsatisfactory.

It was concluded from the various trials that the wiping methods—by brush or liquid surge directed along the surface—were superior to mere agitation, but that the period occupied by the actual wiping was too small a fraction of the total cycle and that some method of multiple wiping at very short intervals was called for. A trial of this principle at once showed its soundness. Use of a single squeegee (windshield wiper), as in brush development, had given results comparable to the latter. A multiple squeegee was then built up of additional parallel wipers set $^3/_4$ inch apart. With this arrangement the greater the number of squeegees used, the better were the results attained up to the point at which the assembly was large enough to cover the plate at all times. Under such conditions no density variations would be detected in the developed image, at any rate, up to a density of about 1.5. Any kind of assembly fulfilling these conditions of continuous wiping proved to be equally efficient; *e. g.*, a square brush considerably larger than the area of the plate, a large velvet-covered surface worked to and fro over the plate, a large pad of sponge rubber with parallel slots, and so on. Unfortunately, all these methods resulted in a fine scratching of the gelatin surface which was not permissible for our purpose.

It was concluded that a jet of liquid under pressure could most effectually wipe the emulsion surface without mechanical injury. A device was therefore assembled which delivered a number of jets of developer under pressure over an area larger than the area to be developed. It proved to be highly efficient from the standpoint of uniformity. It comprised (Fig. 1) a deep tray, pump, motor, and spraying device. The plates and films being used were 5 by 4 inches, so the spray was made 6 inches square and delivered 144 jets from orifices $^1/_{32}$ inch in diameter. The hydraulic pressure used was 60 to 100 pounds per square inch. In use, the plate (or film, secured to a flat support by thumb-tacks or water-proof adhesive tape), held by its edges in the hand, is introduced beneath the spray, is tilted slightly to allow a free sweep of liquid, and is moved continually and at random over a distance of about 1 inch, to even out the action of the jets. Unless this is done during the whole period of development, the pattern of the spray becomes apparent in the developed image. The direction of the tilt is also changed from time to time. The jets may be submerged or may emerge into the air; their efficacy seems to be the same one way or the other, although, of course, oxidation of the developer may proceed more rapidly under the latter circumstance.

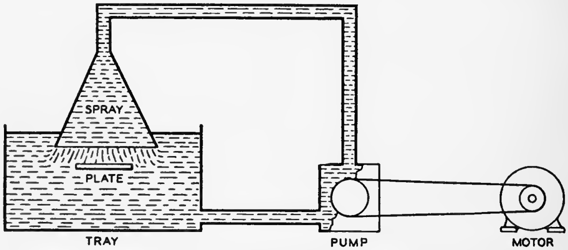

FIG. 1. Device for underwater "wiping" of emulsion surface by liquid spray.

Development under these conditions produces, within a wide range of gamma, a deposit in which practically no detectable variation of density occurs, provided the development time is not less than 30 seconds.

In this connection it should be noted that the conditions under which the directional irregularities of development were eliminated in continuous motion picture developing machines were precisely similar; *i. e.*, multiple wiping by squeegee or jet of developer (at $^1/_2$-second intervals).

Larger sections of film can be very satisfactorily handled by wrapping them around a cylinder of appropriate material about 4 inches in diameter and of convenient width. This is rotated by any suitable means beneath the spray at a speed of about 2 revolutions per second. During development either the spray or the cylinder must be continually worked to and fro in the direction of the axis of the cylinder to smooth out the spray pattern which would otherwise result.

From the present series of experiments and from the previous work upon developing machines noted above, it was concluded, therefore, that to achieve good conditions of development it is necessary to wipe away the products of reaction from the surface of the developing emulsion at close intervals and with the use of some degree of force. What is the maximum permissible interval or the force necessary, we have not so far attempted to determine. These factors doubtless vary with the type of emulsion, the image density, and the developer composition. It was at first believed that the production of a uniform photographic image upon plates or cut films would be impossible by reason of the well known variations in thickness of coating upon these products and of the differential swelling of the gelatin. The latter defect is very obvious in many batches of plates, as soaking

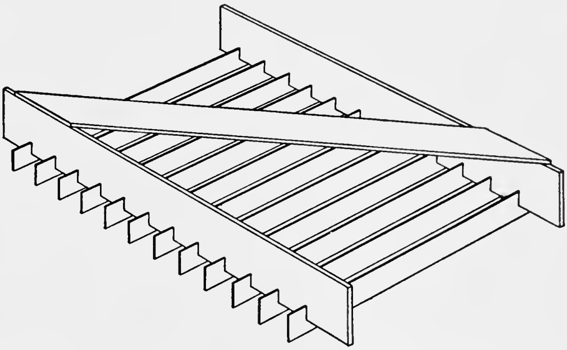

FIG. 2. Multiple squeegee device of hard rubber, used as illustrated in Fig. 3.

the undeveloped plate in water produces a decided relief pattern in the emulsion layer. However, experience has shown that when the method of development is efficient, as above, variations in the image density from these causes can not be detected.

That is not to say, however, that the spray method of development will give uniform densities from any batch of plates or films. Many batches as purchased in the open market, and particularly during the summer months, will show mottle whatever the conditions of development may be. The unevenness in these cases is very probably due to local variations in sensitivity which may arise from many causes.

While the above-described device has proved convenient where large numbers of specimens are to be handled and where the development must be as efficient as possible, a simpler method was sought which would not involve the permanent assembly of specialized apparatus and which could be used in the usual type of developing tray. This was finally realized in a multiple squeegee device consisting of a series of hard rubber blades, each about 1 inch wide, 8 inches long, and $^1/_{16}$ inch thick, mounted $^3/_4$ inch apart and secured by their rear edges to two narrow bars to which a handle was attached for manipulative purposes (see Fig. 2). Accessory to this appliance is a large developing tray with a flat bottom and a plate of hard rubber or other material fitting the tray fairly snugly, in the middle of which is cut an aperture equal to the size of the plate to be developed. The rubber plate rests in the bottom of the tray. A photographic plate is placed (emulsion side up) in the recess thus formed, the thickness of the plate being such as to allow a clearance between the emulsion surface and that of the rubber plate of $^1/_{16}$ to $^1/_8$ inch (Fig. 3). The squeegee device is placed in the tray, the developer poured in, and the squeegee pushed vigorously backward and forward across the photographic material at right angles or diagonally to the direction of the squeegees, until the desired degree of development is attained. During the motion of the appliance, a surge of liquid is generated in the clearances between the edges of the squeegees and the photographic material which washes away the reaction products, forcing them up through the open framework into the body of liquid above. This arrangement has proved very effective for production of uniform development, although not so efficient as the spray system. It is, essentially, a hydraulic brush, and fulfills the requirements set up above, of continuous wiping. Unfortunately, it is not applicable to film unless the film is secured uniformly to some flat surface, because the clearance between the squeegee and the emulsion surface must be the same at all points.

If a spray system is not available, very good results can be attained in the case of film by using the rotating cylinder previously described. While rotating the drum fully submerged, a gang of 3 or more camel's-hair brushes suitably arranged parallel to one another and of a width at least equal to that of the film, is held against the emulsion surface while the cylinder is rotated. The brushes must be moved to and fro in the direction of the axis of the cylinder. A tray sufficiently deep to submerge the cylinder is, of course, necessary.

Another method used in conjunction with the rotating cylinder is to submerge in the deep tray a large handful of "lamb's wool." This swells out and presses up against the surface of the cylinder, acting as a brush of large surface area. It tends, however, to become entangled in the rotating parts and to produce streaks unless the wool is uniformly disposed.

It will be remarked that the methods here described as essential to achieving uniform development are based upon the thesis that it is necessary continually to wipe the surface of the emulsion to remove what is apparently a relatively stagnant film of emerging reaction products. In this connection it is interesting to note that, according to Koenig,[17] "there is generally at the surface of a solid in contact with a solution, an unstirrable liquid film."[1] Also, Davis and Crandall[18] state that "there is good evidence that . . . a liquid stationary film exists at a liquid-solid interface," and that ". . . the similarity of the phenomena caused by the liquid stationary film at various

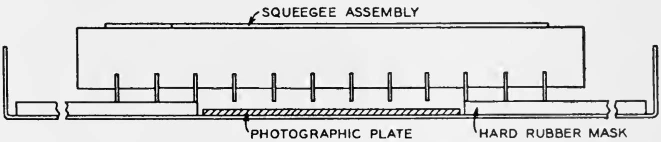

FIG. 3. The squeegee assembly (see Fig. 2) moving above the plate acts essentially as a hydraulic brush, an effective arrangement for obtaining uniform development.

types of interfaces (liquid-gas, liquid-liquid, and liquid-solid) should be emphasized."

It is doubtless the existence of some such liquid zone at the surface of the emulsion layer being developed that leads to most of the difficulties encountered in securing uniform and efficient development.

Uniformity and efficiency in the developing operation are of considerable importance in the production of sound records upon film. These factors may be somewhat obscured in present practice, but they will assume greater importance as the distortions from other causes are reduced. There is little doubt that the average motion picture continuous developing machine is inefficient from the standpoint of the present inquiry, as is evidenced not only by the separation of the H&D curves from "direction pairs" of sensitometric strips, but by the fact that the speed of a given emulsion varies from laboratory to laboratory, as does also the ratio between different types of sensitometry, the shape of the H&D curve, and the degree of gamma change resulting from exposure through the base, all which anomalies can be explained by the degree of density depression of the higher densities resulting from imperfect removal of reaction products from these regions.

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A CONSIDERATION OF SOME SPECIAL METHODS FOR RE-RECORDING*

E. D. COOK**

Summary.—*Re-recording seems to be a necessary part of present-day production technic, because of which many of the limitations that otherwise face the original recording process may be altered. The increasing demands for higher quality make it desirable to examine the available methods for the original recording so that the eventual re-recording process may yield the best results.*

This paper reports the results of an examination of the various methods of employing wax and film recording for this purpose. Such problems as the required frequency characteristics, harmonic distortion, available volume range, ground-noise suppression, speed constancy, and other similar considerations have been reviewed theoretically and experimentally. While the data itself will not be presented in detail, the results of the investigation and the conclusions that have led the RCA Manufacturing Company to regard the so-called push-pull film recording method superior for re-recording work, will be outlined.

The problem that confronted the early talking motion picture was to make some form of record of a sound desired in connection with a picture. Recording of sound, in spite of the existing phonograph art, was poorly understood, and the limitations of the recording operation were not fully appreciated. Artifices, designed to circumvent these limitations to at least some extent, were unthought of, largely because of the pressure of production work.

It was soon found that the recording system possessed powers of discrimination quite different from those of the human being. For example, the microphone stubbornly refused to differentiate between the desired and the background noises on any basis other than that of the relative pressure produced at the microphone position. It was not interested in the fact that a large portion of its response might be due to reflected waves and not to the direct wave; and, furthermore, the frequency characteristic varied quite differently from that of the human ear as far as directive sensitivity was concerned. Likewise, the experts had provided some treatment for the

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walls of the studio; but in some manner, the walls still insisted upon intruding in one way or another, in the final result.

The years following the introduction of sound recording have been full ones for those charged with the responsibility of its development. There were many problems to be investigated and the rudimentary principles underlying them had to be determined, at least to some extent. Frequently production problems could not await development.

The difference between the present-day technic of any one company and that of any other is not so much a result of the unavailability of any given method to the one or the other, because, in the main, all systems were available to the larger companies at least. It is rather the result of different objectives and points of view. The following discussion considers briefly the problem of re-recording in the light of the present knowledge of the problems involved.

One of the especially unpleasant problems was found to exist in connection with the desired background sounds mentioned above. An early attempt to record a discussion on fishing by Grantland Rice may be recalled by some of those who assisted in making this film. The shots were taken out of doors, and the swish of the line, the noise of the oars in the locks as well as in the water, were mute testimony to the sensitivity as well as to the stubbornness of the microphone. The scene would not rank very high as an example of recording art today. The incidental noises served largely to distract the attention. A very similar result was obtained in a recording of Dr. Langmuir giving a scientific lecture on the surface tension effects of films (not photographic) on water. The background noises due to laying glass stirring rods upon the slate-topped lecture tables and the splashing of the water were highly unpleasant. Another incident that may be recalled by some involved the "thunder" effects added to a film by a certain microphone man whose taste for unshelled peanuts was his undoing.

Those whose responsibility it was to deliver the product in final form soon developed methods of recording in which the desired background noises were under better control. Often the primarily desired sounds were added at a later time. This was the beginning of the development of a new technic. Its need was due to the desire to effect a more perfect illusion and lessen distractions from the main theme. Today, almost no feature picture is released without more or less re-recording, and the extent to which re-recording is used in the final product is said to be steadily increasing. It is interesting to note that when the development engineer first considered the idea of re-recording, he was mainly concerned with other problems; but the operating engineer has employed it for entirely different reasons.

With the use of process photography,[1,2] another real need for re-recording is encountered. The background of the picture may or may not have been taken upon an ocean liner in a storm, but the actor was almost certainly in a studio. The "library" supplied the sound effects to enhance the illusion. And even in scenes of this type, the constantly varying theater of action can create the need for variations of sound level and quality of recording to fit the scene so that even the studio recording may require re-recording.

It is, therefore, quite necessary to provide adequate tools for this important phase of the general production problem, which is not without its special limitations. There are the various problems of ground-noise, lessening the available volume range of the final product; the loss of fundamental response; the creation of spurious, new, and undesired sounds, such as those due to harmonic distortion if proper care has not been exercised; and those due to lack of sufficient constancy of speed of both reproducers and re-recorders. In fact, in many of the work-shops this latter problem is still so poorly handled as to be a very real bar to satisfactory high-fidelity work. In this connection, it is not unlikely that the relatively near future will see a real advance if recent events of far-reaching significance are indicative of the future.

Re-recording makes it possible to choose the recording process and the medium upon the basis of what is necessary for the best final product. Certain media are known to be unavailable today if the highest quality of sound is sought. The reasons for this in many cases require a detailed discussion too lengthy for the present purpose. In general, it can be said that, utilizing the present known technic, one is limited to two general methods for the original recording of superlative quality:

(1) Photographic recording, as on film.
(2) Mechanical recording, as on wax.

It is unnecessary to mention the several methods available in each classification to engineers engaged in this work. There are, however, certain sub-divisions which it is essential to mention and discuss.

In film work, there is available the possibility of using a higher linear velocity of the carrier for the original recording process; film stock of greater resolving power, having other improved characteristics; special treatments for reducing ground-noise; the push-pull sound-track;[3] wider sound-tracks, for the purpose of increasing the signal to ground-noise ratio; increased high-frequency recording level for the same reason, which level would be corrected in re-recording. It is even possible to use special devices to increase the amplitude of low-level sounds in comparison to higher level ones, finally decreasing the level in the re-recording process so that all the sounds bear a correct volume relation to one another.

In disk work, there is likewise the possibility of higher record velocities, to reduce the higher-frequency losses; newer recording stock, with a lower level for ground-noise; sputtering rather than carbonizing, to form a conducting master; increased high-frequency recording level in comparison to the low-frequency level; and devices to increase low-level sounds compared to higher-level sounds, with the eventual correction to the proper volume balance in re-recording. Certain of the other advantages available to film are not available in mechanically recorded disk work; for example, a push-pull sound-track might be devised in an obvious manner, but it would not perform in exactly the same way nor would it yield the equivalent advantages found in film.

Original Recording upon Wax.—Considerable work has been, and is still being done at Camden on the problem of disk recording. In this development program, both the lateral and vertical methods have been considered from the standpoint of distortions and other characteristics, until it is hard to see where either system possesses any advantage for which an offsetting advantage can not be claimed for the other system. Public demonstrations[4,5] have shown that equivalent results have been attained.

In general, wax systems for recording have an advantage in that the record can be played back at once by providing a second record for that purpose; and whether or not the recording was properly done can frequently be determined by microscopic inspection. It is not regarded as practicable to increase the record speed in order to decrease the high-frequency losses. One reason for this is that such an increase, of necessity, would be accompanied by an increase in record size, which is not considered practicable at present.

Wax recording is further unlike film recording in regard to increasing the amplitude of the recorded wave in an endeavor to increase the signal to ground-noise ratio. Materially larger amplitudes may not be used in disk records designed to operate at the present speeds because the recording and reproducing distortions are increased considerably thereby. The "pinch" effect, in records of one type, and the shift of the contact point of the stylus in records of the other type, would be made more serious. Moreover, if the "cut" on records of either type is regarded as a hill, it is easily seen that the size of the hill can not exceed a certain amount for a given dimension along the length of the record groove before it will be easier to shear the crest than to follow the groove.

In order to provide as satisfactory a signal to ground-noise ratio as is commercially realized in film work, it is essential to establish and maintain the utmost in clean, dust-proof surroundings. The best known method of rendering the surface of the record conducting, capable of providing a result of sufficient quality for high-fidelity re-recording work, is the sputtering process. Our attention was invited by Heinrich Schomburgh to the use of gold in this process, which it seems had been used by Edison[6] as early as 1900 for metallizing the original record wax. Schomburgh had apparently already equipped several British recording laboratories for this work by 1931. Other methods, such as chemical deposition or brushing finely divided carbon particles upon the surface of the master, does not yield as quiet records.

This means a special processing division with specially trained operators and equipment, or the dependence upon plant equipment of other companies involved in such work. There would be considerable duplication of personnel, since it is improbable that the theater owner would ever care to return to the disk record for his sound. He is too well satisfied with the single carrier for both picture and sound. It is also desirable that the producer have the single medium to deal with, and if he is to depart from it, he must be shown wherein any proposed system excels the former standard in a way that can not be approached.

The problem of providing constant-speed drives for the reproducer for use in re-recording is not a simple one; and with the use of a pick-up device, vibration must be minimized if extraneous effects are not to be introduced into the final record. This is a problem that is inherently more difficult than in the film reproducer. While it is not impossible to build a disk reproducer having a high degree of speed constancy, no such reproducers are available at present that approach the present high-fidelity projector sound attachment in this regard. Practically, one can hardly be satisfied to lower his standards in this respect. No high-fidelity performance is possible without very severe restrictions in regard to speed constancy.

In editing wax records there is less flexibility than in editing film. One can not cut out sections, piece them together in any desired order, and run the result continuously upon a single machine without an additional step of re-recording. This lack of flexibility is a serious handicap. Editing a film sound-track, aided by sight to increase the accuracy of cutting out the undesired parts, is by contrast a much simpler process. For these reasons, it was felt that upon reëxamining the art to provide adequate tools for re-recording, we should be justified in discarding the wax record for the original recording.

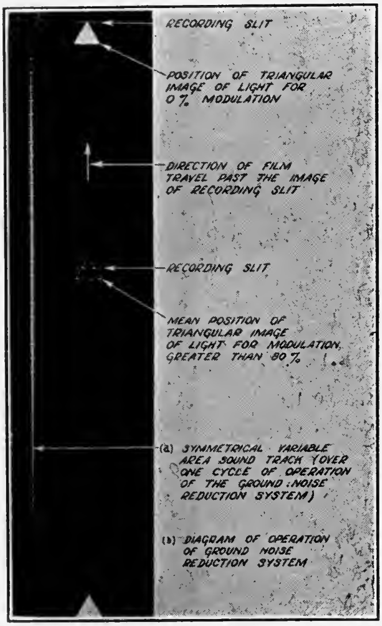

Fig. 1. The bilateral sound-track, showing operation of recording triangular light-spot for one cycle of ground-noise reduction system.

Original Recording upon Film.—In re-recording work, the record material that is used might logically be expected to assume a more important role. Actually, present materials may be used satisfactorily. However, it is understood that there are several new emulsions that seem to give considerable promise at this time. The producer will use them, no doubt, if they are material improvements, and if they become commercially and economically available.

In both the variable-density and variable-width methods of recording, there are high-frequency limitations. The ultimate resolving power of the film may not be fully realized due to the necessity of attaining a maximum signal to ground-noise ratio. The attainment of satisfactory high-frequency response with minimum distortions depends, in part, upon film processing,[7,8,9,10] width of aperture,[11,12] and constancy of film motion.

It is a tribute to the work of the many investigators in this field that the effects of these limitations have been so materially reduced. For example, it is possible, using reasonable compensation, to make a film record whose output-frequency response is flat up to approximately 10,000 cps., and whose signal to ground-noise ratio at the high frequencies is commercially satisfactory. This represents a marked improvement over the earlier recordings, which, incidentally, were further favored by the limited reproducer frequency-response characteristics, whereas the modern reproducer has to operate with the disadvantage in this regard of being compensated to give nearly full response over this extended frequency range.

The recording aperture limitations have been reduced by improve-

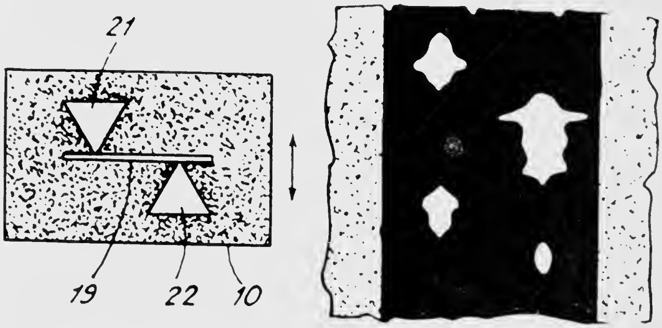

FIG. 2. Push-pull sound-track and recording apertures.

ments in the optical systems which permit the use of smaller apertures because more light can be collected and used in the later designs. One such improvement may be found in the mirror system of the recording galvanometer,[13] while the method of moving a triangular light-beam over an aperture[14,15] has also contributed to the advance made in this connection.

The deflection-frequency characteristic of the newer galvanometers has been considerably extended, and, while this ordinarily would result in a material loss of sensitivity because of the mechanical multiplication of armature movement attained together with the "scissors" action of the light-beam at the aperture, this has not resulted in a serious change in power requirements. The "scissors" action of the light-beam may be seen in Fig. 1, in which the present standard bilateral sound-track is shown for a complete cycle of operation of the ground-noise reducing equipment. One of the advantages of this type of sound-track is to be found in the fact that a small lateral motion or weaving of the film during its progress past the reproducer aperture need not affect the sound.

The introduction of harmonic distortion in the variable-width negative due to filling in of the clear spaces or valleys between the exposed parts of the recorded wave, is partially compensated in making the print by carefully choosing the print density, which, in effect, fills in the valleys or clear parts of the print. The resulting wave in the print is thus more nearly symmetrical. Since the second-harmonic distortion is therefore reduced while the amplitudes of the

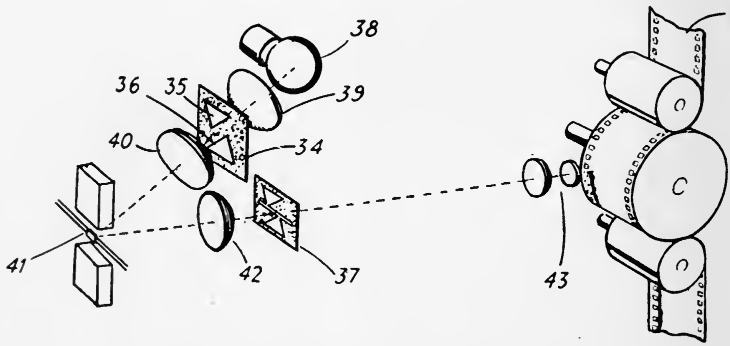

Fig. 3. Push-pull recording optical system.

higher harmonics are still quite trivial, the resulting wave closely approximates a true sine wave. It is general practice to use negative sound-track densities of from 1.4 to 1.5, a negative gamma of about 2.0, and positive densities of from 1.3 to 1.4. For such conditions, Sandvik and his colleagues[10] have shown that the total harmonic distortion of the print is not more than 5 per cent at 4000 cycles, using a recording aperture of 0.0005 inch and sound positive stock.*

* It is interesting to note that the aperture used by these investigators was about 11 per cent of the wavelength at 4000 cycles. On the basis of infinite film sensitivity, a superior limit for the second harmonic produced in the negative due to aperture effect[11] alone, would be about 14 per cent. The measured value reported by these authors for total distortion in the negative under standard conditions was 15 per cent. This, however, includes the effect of image spreading as well as that of the finite aperture. Knife-edge tests upon the same emulsion under similar conditions indicate that the image spread was probably of the general order of 0.0003 inch, with the exposure gradually decreasing away from the core of the image.

This agrees rather well with the results obtained from Foster's work,[12] particularly when the nature of the problem is considered. The conditions for such low second-harmonic distortion when the negative was known to have greater distortion for this harmonic, also assisted in reducing to a low value that part of the variation of average transmission that is due to film characteristics. The latter effect is of considerable importance in those parts of the record where the level is varying rapidly. It would be particularly noticeable in expulsive and sibilant sounds.

In recording upon film for eventual re-recording, many of these limitations may be reduced still further, if desired, by increasing the film speed in the original recording. This would result in a reduction

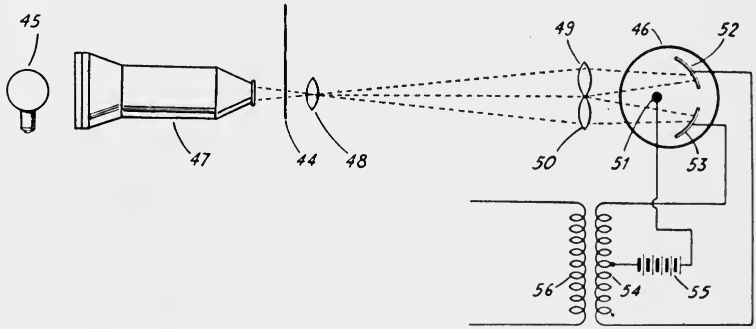

FIG. 4. Push-pull reproducer optical system.

of image spreading and consequent fundamental loss in recording, and hence in later reproduction for the production of the final negative. Furthermore, the effects of finite aperture width in both processes would also be reduced. Errors in focusing the optical systems, alignment of apertures,[16,17,18] *etc.*, could be rendered trivial in their effects. Compensation for film loss at the higher frequencies could then be materially decreased, or utilized to aid the signal to ground-noise ratio, as will be mentioned later. The producer is not likely to view the additional film cost with much pleasure, but it may be that a narrower film, if used in quantity, could be produced at a satisfactory price. Whether or not this possibility would be attractive for original negatives would depend largely upon the fidelity demanded by the producer.

Furthermore, it is inherently possible to use wider sound-tracks, because, since the ground-noise increases less rapidly with an increase in the width of the sound-track than does the volume of the desired signal (the noise due to random effects, such as hiss, increases as the square root of sound-track width), the signal-to-noise ratio is improved by this device. In addition, although it may be unimportant, system noise is reduced because less amplification is required.

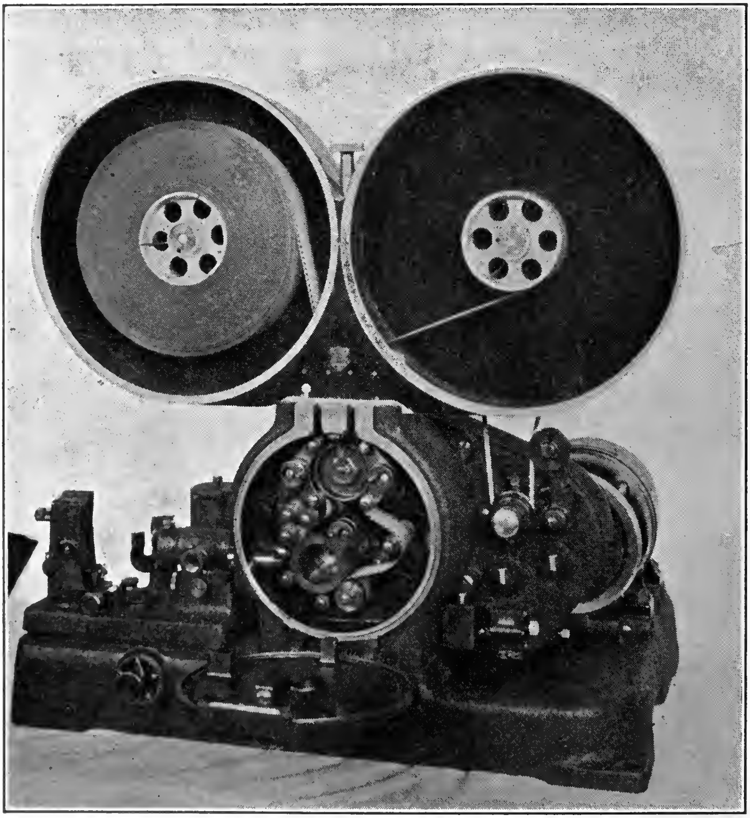

FIG. 5. The *R-4* recorder (front view).

Since high-frequency sounds ordinarily have less energy than those of lower frequency, it is possible to effect some gain in the signal-to-noise ratio by increasing the recorded level of all high-frequency sounds as much as possible beyond the amount required to offset the film loss, and correcting for this by reducing the high-frequency level to the proper amount during re-recording. Obviously, the method is limited by the extent of high-frequency correction required for normal film losses, because where such correction is required, it should be made in the original recording. In any case, high-frequency losses of the original record should not be compensated in the re-recording channel, because in such a case the signal and the noise are amplified equally in the frequency range wherein the amplification has been increased, and no change in ratio is encountered while

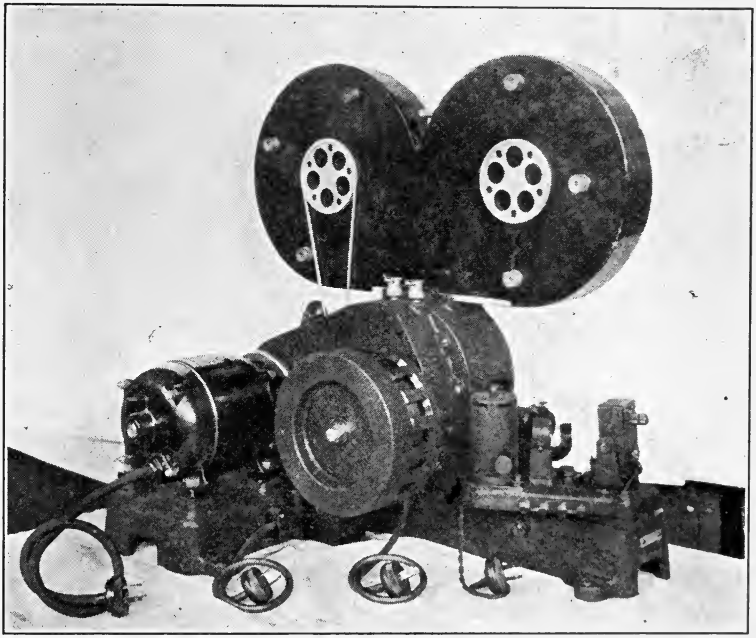

FIG. 6. The *R-4* recorder (back view).

the net result, when the added noise from the re-recorded negative is considered, is a loss. This method is, therefore, mainly useful when the film losses are not too great, so that the majority of the high-frequency "boost" in the original recording can be used to apply a high signal level to the record.

There are several devices for minimizing the disturbing effects of ground-noise during the low-volume portions of the record. One of these involves the use of a "control tone" sound-track located upon the otherwise unused portions of the original sound negative and recorded at the same time. It is supposed that during the original recording the volume level is held more or less constant by means of the gain control, and at a fairly high value at all times. The "control tone" track is used to record the required variations in the volume control of the original recording amplifier. It is, therefore, an accurate picture of the volume variations in the original sound to be recorded, and can be used during the reproducing operation of the re-recording cycle to correct the volume level fed to the re-recording amplifier. Thus, the volume variations of the original sound are reëstablished in their correct relations in the re-recorded negative.

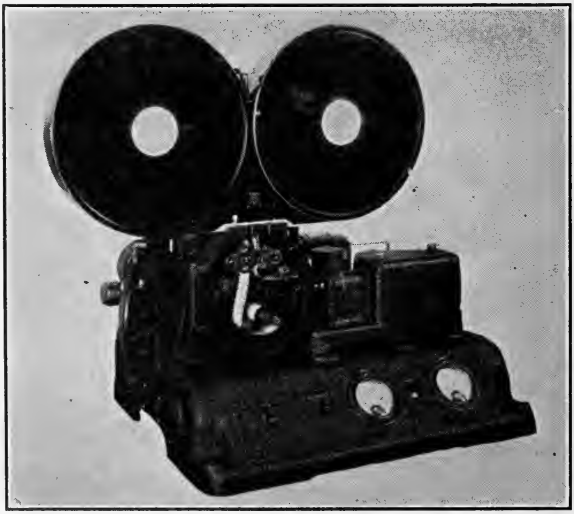

FIG. 7. The *PR-18* recorder (front view).

Something quite similar to this idea may be used if the original sound is permitted automatically to exercise its own control action upon the volume-level contracting and expanding circuits without a "control tone" track. However, it is evident that this method has at least one point of major inferiority compared to the auxiliary or "control tone" method; some volume-level variations must be permitted in the original record in order to cause the expanding device on the reproducer to function at all. Since the operation of the "expander" with the "control tone" method is not dependent upon the volume level as recorded upon the original negative, a wider range of faithful control can be attained.

Nothing further will be said about the use of expanding and contracting devices for re-recording at this time because other and simpler expedients are available for increasing the useful volume range, which can accomplish as much as is required at present in the further reduction of ground-noise. Such devices can be added to the apparatus at any time the need for them is felt.

At least one improvement has been perfected which will more than meet the present requirements for original recordings to be used in a

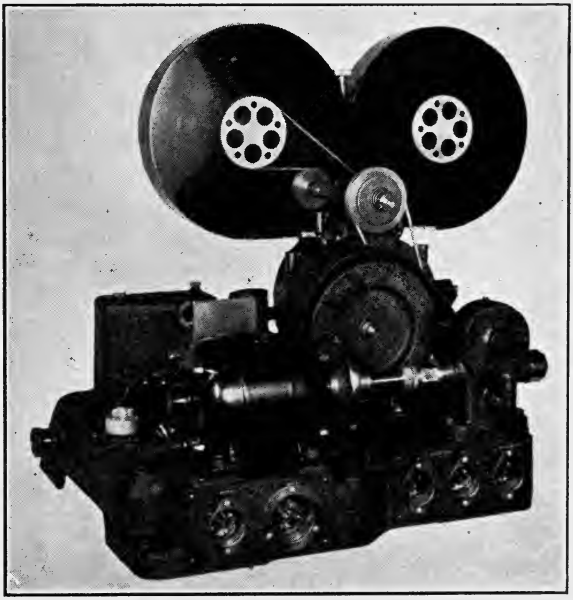

FIG. 8. The *PR-18* recorder (back view).

high-fidelity re-recording system. It consists of a special record using the so-called push-pull sound-track,[3] shown in Fig. 2.

Since for zero signal, the two individual half sound-tracks have no light transmission other than that due to the fact that the density can not be really infinite in any of the black portion, the illumination of the photoelectric cells is reduced to an extraordinarily low level, and the resultant ground-noise is greatly diminished. The transmitting areas of the individual half tracks accurately measure the wave-shape and instantaneous pressure level of the sound. Hence, only the minimum of clear track necessary to provide correct modulation is employed at any instant. The available volume range is, therefore, considerably improved at low sound levels. In addition, the problem of the ordinary ground-noise reducing system in choosing the rate of operation is not present in this case, with the result that transient sounds may be properly recorded.

Public demonstrations have shown that in addition to being an almost perfect ground-noise reducing system without the necessity for adding special equipment, it has other desirable properties. In the first place, even the small amounts of generated even harmonics, which might accompany both the unilateral and the bilateral variable-amplitude sound-tracks under certain improperly chosen processing or operating conditions, are largely cancelled out by the push-pull action of the associated circuits. Variations in average transmission are almost completely eliminated by this sound-track. Hence, there is a marked reduction in sibilant distortion due to improper film processing and resulting from sudden variations in average transmission. The increased volume range, which accompanies the correct use of this sound-track, adds materially to the realism.

It is possible to use this new sound-track for original recordings, making a considerable improvement in re-recording, and yet not be forced to use only sound-tracks of this sort in the reproducer employed for the work. If one of the halves of the push-pull track occupies the position now assigned to the normal sound-track and an equal space is allowed elsewhere upon the original sound negative for the remaining half waves, both the push-pull and the normal sound-tracks may be spliced together and run through the re-recording reproducer without fear of the outcome.* The auxiliary photocell circuit receives no illumination when the normal sound-track is used, and hence is merely idle during such times. The producer is therefore not faced with an obsolescence of his sound effects "library," and neither must the re-recording staff be continually taxed to make alterations, however simple, in the equipment to accommodate sound-tracks of both types. While the present push-pull system requires more careful adjustment and some additional attention to provide a good balance, this is really not a serious problem, as experience with the system has shown. The method may be readily understood from

* This ingenious suggestion is due to Mr. Douglas Shearer, M-G-M Studios, Hollywood, Calif.

Figs. 3 and 4, which show the operation of the recording and the reproducing optical systems.

The recording problem is not much more complicated, since an optical system is now available that will record either a normal bilateral or a push-pull sound-track of the variable-amplitude type. After the change-over,[19] which may be accomplished in a few seconds, no further complications are encountered, and recording may proceed as in the past with sound-tracks of the conventional types.

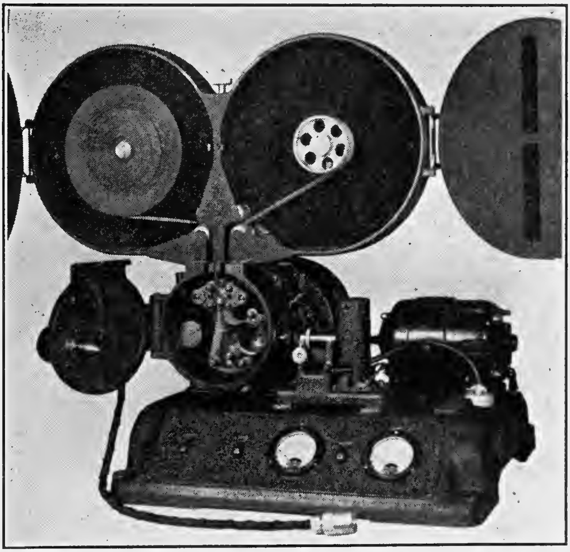

FIG. 9. The *PB-36* re-recording film phonograph (front view).

It has been the experience of operators that monitoring for level to prevent "overshooting" is most easily and accurately accomplished by a visual method. This method should have the same dynamic characteristics as the recording modulator for most accurate results. Variable-amplitude film is particularly fortunate in having available an optical method whereby the operator can observe the motion of the recording beam upon a calibrated card. This is accomplished by splitting off a part of the vibrating light-beam coming from the recording galvanometer and throwing it upon the calibrated monitoring card. This system offers obvious advantages over the older form of monitoring meter. Furthermore, it may be used in remote locations if desired. It is available for any of the older types of variable-amplitude recording optical systems. The operator can assure himself that the record is being kept within the proper modulation range as the record is being made; hence it is unnecessary to process and reproduce the film before it is known whether the record is "overshot." This is probably more important in the original recording (where, in the case of a re-take, the actors would have to be reassembled at some

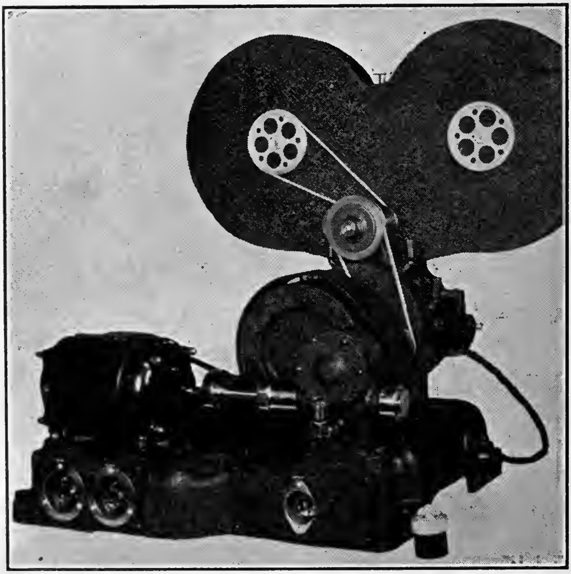

FIG. 10. The *PB-36* re-recording film phonograph (back view).

future time) than in re-recording, but the advantages even here are sufficient to make it a preferred tool for the operator.

Finally, the necessity for constant speed can hardly be overstated. The seriousness of this limitation becomes even more apparent as the reproducer frequency range is extended and more faithful records are made. Fortunately, the knowledge of the causes and the methods of correction for this problem have been known for some time. Probably one of the most satisfactory recorders in this regard now has a service record of many years to its credit. It was described by Kellogg[20] in 1930, and is available for both the purposes of a recording machine and a reproducer for a re-recording channel. The original commercial recorder of this type is shown in Figs. 5 and 6, while Figs. 7 and 8 show a later model,[21] built upon the same principle and using the latest type of recording optical system with the high-fidelity galvanometer and optical monitoring screen. The optical system shown on the recorder produces the bilateral track shown in Fig. 1, with ground-reduction features. It is noticeable that the system is completely enclosed so as practically to eliminate the effect of stray light. The modification required for push-pull operation is slight.

Speed constancy in reproduction is likewise of extreme importance, and for re-recording work a special reproducer built somewhat like the present high-fidelity recorder is available. This device is shown in Figs. 9 and 10. The special reproducer optical system with adjustments for focusing and aperture alignment is shown rigidly fastened to the heavy base while the photoelectric cell is mounted upon the main case door.

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REPORT OF THE COMMITTEE ON NON-THEATRICAL EQUIPMENT*

Considerable interest has been expressed in the possible recommendation of a series of screen sizes for normal use with the view to adopting them as recommended practices. Some interesting comments and suggestions on the subject have been submitted by the various Committee members, but before presenting them in the form of a report it has been deemed advisable first to study additional data and information that have come to the attention of the Committee.

A wide variation in construction exists among the various 16-mm. projectors upon the market, so the question is naturally raised as to whether it is at all possible to make satisfactory recommendations as to screen sizes, except that such recommendations might be made by each manufacturer for his respective individual machines.

The following is extracted from an article in *Film für Alle* covering a series of recommended standards promulgated by the Reichskommission for Educational Film. Parallel comments by the Committee follow the German recommendations (which are in small type), and it is hoped that this analysis will be of interest and value to the members.

A difference is to be noted between "small equipment" to be used in classrooms up to about 30 feet long, with a customary size of screen of area about 2 square meters; and "large equipment," which may be used for classrooms longer than 30 feet and which must be sufficient for the customary size of screen. The apparatus must come up to the following requirements:

(*1*) The large equipment should offer the possibility of easy installation of auxiliary sound equipment.

There seems to be some trend toward making a projector so that the sound reproducing attachment can be added. However, to say the least, this is a factory job.

(*2*) Back reeling (if possible, projective back reeling) and stand-still devices must be provided in both sizes of apparatus.

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* Presented at the Spring, 1935, Meeting at Hollywood, Calif.

Reverse and still picture projection are features of most 16-mm. projectors in America.

(3) The large apparatus must be equipped with an electric measuring instrument and resistance for the lamp. In small apparatus these features are desired. *All equipment with these features should also have a protecting device, which permits operation of the apparatus with the load of the lamp reduced to the absolute minimum.*

The variable resistance and the voltmeter are definitely recommended and are standard equipment in most of the higher grade projectors in this country. It must be noted, however, that many schools have definitely decided against the use of these items, preferring a line voltage lamp without gadgets as being simpler. They feel that there is too much danger of starting the projector with the resistance turned off instead of on.

(4) Either type of apparatus must offer the possibility of easily centering the lamp and reflector; the device holding the lamp must hold it securely, so that it will remain in the position to which it has been adjusted, even if the equipment is subjected to such shocks as may occur when the projector is used in a normal manner. The lamp itself must be easily exchangeable.

The use of factory precentered lamps in American projectors takes care of the centering of the lamp quite effectively, although some projectors have additional means for critically adjusting the reflector, *etc.*

(5) Small apparatus must be provided with a standard lamp of 200 watts, 50 volts; large apparatus must be equipped with a lamp of 375 watts, 75 volts.

In this country the preference is for projectors of 500, 750, and even 1000 watts for school work, in order to project adequately brilliant pictures, considering the deterioration of the screens under the handling received in schools. This also allows the classrooms a higher ambient illumination, which is very desirable.

(6) The lamps for either type of apparatus must have an average operating life of at least 50, if possible 70, hours of operation.

Most American lamps now have a life of 25 hours, which is quite adequate for all normal purposes.

(7) The illumination actually attained must amount to at least 130 lumens for the large apparatus; and at least 50, if possible 60, lumens for the small equipment, with the shutter running.

A rating of 130 lumens is rather high for a 375-watt lamp, especially if it must be under-voltaged to get 50 to 70 hours of operation. Inasmuch as the small equipment specifies a screen of about 2 sq. m. (21.5 sq. ft.), with 60 lumens specified for the small equipment, this provides a screen illumination of only 2.8 foot-candles. It seems probable that the comparatively high lumen rating for these low-wattage lamps is attained by using a two-bladed shutter, which conflicts with Specification No. 8.

(*8*) Absence of flickering of the screen picture at 16 picture changes per second is the condition for both types of equipment, with a screen 120 cm. wide (47$^1/_4$ inches) and viewed from a distance of 20 feet.

In this country, it is usually felt that at least 48 interruptions of the light should take place every second in order to achieve satisfactory projection.

(*9*) The total consumption of current of all apparatus should be such that a 6-ampere fuse will not be damaged.

The current is naturally a function of the wattage of the lamp. In this country it is usually specified as 10 amperes; although with sound, a 15-ampere fuse is usually necessary. Most school circuits will stand this quite easily.

(*10*) The focal distance of the objectives of both types of apparatus must be 50 mm. The focal device of the objective must not have a dead thread.

A 2-inch lens is the standard projection lens in this country also, though here greater stress is placed upon the interchangeability of lenses of different focal lengths.

(*11*) The uniformity of lighting of the picture area should not be worse than 1: 1.5.

We recommend that the illumination at the center of the screen should not exceed that at the extreme sides by more than about 15 per cent. The recommendation of 50 per cent seems excessive.

(*12*) The screen picture with either apparatus must be as steady as possible; when using an exactly perforated film and a screen size of 120 × 160 cm. (47$^1/_4$ × 63 inches) its oscillation must not be in excess of 4 mm. horizontally and vertically.

The specification for image jump is satisfactory. A recent War Department, Air Corps, specification called for a maximum jump of $^1/_4$ inch on a 6-ft. screen.

(*13*) The driving motor of all apparatus must operate satisfactorily under the load of a full film reel (especially when starting).

Specification *13* is satisfactory.

(*14*) Both types of apparatus must operate as noiselessly as possible. The operating noise at a distance of 2 meters in all directions should not exceed 45 phon, if possible.

This specification is not understood, as the *phon* is the European equivalent of the decibel.

(*15*) Stray light of the lamp during projection must be avoided with either type of apparatus.

Specification *15* is satisfactory.

(*16*) Both types of apparatus should be supplied with the following accessories: one reserve lamp, two 120-meter reels, one cleaning rag, one dust brush, a pair of pliers, one screw driver, one scraper, one oil can and 30 grams of oil in a bottle, one bottle of film cement, 10 meters of extension cable, a flashlight with bulb (but without battery), one testing lamp, 20 tin foil 6-ampere fuses, one rewinder, one press cementing work.

The accessories usually indicated in this country are splicer, spare lamp, and two or three additional lenses.

(*17*) Accessories and projector must be supplied in a carrying case. The case must also provide space for a pair of film scissors, a resistance, possibly also a reserve resistance, and a second objective.

(*18*) The carrying weight without the case and without accessories and without sound-film equipment of either type of apparatus must not exceed 15 kilograms (33 lbs.).

Specification *18* is satisfactory.

R. F. MITCHELL, *Chairman*

V. C. ARNSPIGER	H. A. DEVRY	R. G. HOLSLAG
D. P. BEAN	R. E. FARNHAM	E. ROSS
E. W. BEGGS	E. C. FRITTS	A. SHAPIRO
W. B. COOK	H. GRIFFIN	A. F. VICTOR

HIGHLIGHTS OF THE FALL CONVENTION

WASHINGTON, D. C.
WARDMAN PARK HOTEL
OCTOBER 21–24, 1935

Since the last Convention of the Society at Washington, held in May, 1932, much activity has arisen in governmental circles in connection with motion pictures and their various applications; and particularly, with the establishment of the motion picture division of the National Archives, it was specially fitting that the Convention this year was held at the nation's capitol. The Convention was well attended by representatives of the governmental departments as well as by those from out of town, the total registration being in excess of two hundred persons.

The program of papers and presentations, as actually followed at the sessions, was as published on succeeding pages of this issue of the JOURNAL.

On the evening of Wednesday, October 23rd, the Semi-Annual Banquet and Dance of the Society was held in the *Continental Room* of the Wardman Park Hotel. Distinguished guests at the speakers' table were the Hon. Will H. Hays, President of the Motion Picture Producers and Distributors of America; Hon. Kent Keller, Chairman of the House Committee on Libraries; Hon. Justyn Miller, Assistant to the Attorney General of the United States and in charge of the President's Committee on Crime Investigation; Dr. R. D. W. Connor, Chief Archivist of the United States; and Dr. Lyman J. Briggs, Director of the United States Bureau of Standards.

After a brief address by President Tasker, leading up to the subject of Society presentations and awards, a citation reviewing the contributions of Mr. Thomas Armat to the design of the motion picture projector was read by Mr. Glenn E. Matthews on behalf of the Historical Committee The scroll of Honorary Membership in the Society was then presented to Mr. Armat by President Tasker.

The President then announced that illuminated parchment certificates would be presented to the 1933 and 1934 winners of the Journal Award. The recipient of the 1933 award was the late Dr. Peter Andrew Snell who died March 14, 1933. At the request of Dr. Snell's father, Dr. A. C. Snell of Rochester, N. Y., Mr. J. I. Crabtree accepted the certificate.

The recipients of the 1934 Journal Award were Dr. Loyd Ancile Jones and Dr. Julian Hale Webb of the Kodak Research Laboratories, Rochester, N. Y. A short citation on their work was read by Mr. E. A. Williford.

The Progress Medal of the Society, described in the July, 1935, issue of the JOURNAL, p. 98, was presented this year for the first time. The recipient was Dr. Edward Christopher Wente, who was introduced by Mr. J. I. Crabtree with a citation of the many accomplishments of Dr. Wente in his long period of service in motion picture technology.

At 10:30 P.M., the Honorable Will H. Hays, President of the Motion Picture

Producers and Distributors of America, Inc., addressed the Society after a brief introduction by President Tasker. The proceedings were broadcast from coast to coast through the courtesy of the National Broadcasting Company.

Entertainment provided by Messrs. H. D. Lohmeyer, Nat Glasser, and Carter Barron of the Warner Bros. and Loews' Fox Theaters in Washington concluded the evening. Complete details of the banquet are given in "Proceedings of the Semi-Annual Banquet at Washington" on p. 467 of this issue of the JOURNAL.

PAPERS PROGRAM

As mentioned previously, one of the features of the Convention was the large number of presentations by representatives of the various governmental bureaus and departments. These presentations included papers on the use of films in the Army and Air Corps; for microphotographic duplication; motion pictures as government archives; the interest of the Federal Government in educational films; in addition to a number of presentations at the Bureau of Standards on Wednesday afternoon on the subject of color. One of the outstanding presentations of the Monday sessions was on "The Development and Use of Stereo Photography for Educational Purposes," by Prof. Clarence Kennedy of Smith College. The "Demonstration of Photography by Polarized Light," by J. W. McFarlane was postponed until Thursday afternoon because of the absence of the author. The process consists in using individual polarizing filters in sheet form, consisting of crystals of certain organic chemicals oriented in a flexible film base. By rotating such filters placed before the source of illumination and before the camera, various effects can be obtained in respect to eliminating glare, darkening skies, *etc.* Professor Kennedy's demonstration consisted of projecting polarized anaglyphs onto an aluminum screen and viewing these through spectacles fitted with polarizing filters. Over one hundred such spectacles were distributed among the audience and a large number of objects of sculpture and outdoor scenes were seen in stereoscopic relief.

The symposium on screen brightness, held on the morning of Tuesday, October 22nd, included papers dealing with the relation between screen brightness and the visual functions; the screen brightness requirements of the public; characteristics of screens; printing densities; and methods of measuring screen brightness. This symposium was a good example of what can be accomplished by collaboration of the various members of a technical Committee, the purpose in this instance being principally to collect such data and information as are available, in order to pave the way for future studies of the subject by the Committee, and possibly and ultimately, recommendations as to good or standard practice in the matter of screen brightness.

Two papers were presented by Dr. E. C. Wente, recipient of this year's Progress Medal, one of which was a requirement incident to the granting of the medal. His "Contributions of Telephone Research to Sound Pictures" described some of the work done which formed the basis of the Committee's selection of Dr. Wente as the Progress Medalist. In addition, his "Principles of Measurement of Room Acoustics," presented originally at the Hollywood Convention of the Society last May, was repeated.

The Apparatus Symposium, conducted on Thursday afternoon, was followed by a photographic session, which included the Report of the Committee on Laboratory Practice. This report constitutes a very notable contribution to the work of the S. M. P. E. Technical Committees, and it is hoped will pave the way to a future standardization of laboratory procedure and technic.

APPARATUS EXHIBIT

Although the Exhibit was not as large as at some previous Conventions of the Society, it nevertheless included a number of interesting exhibits, and aroused considerable interest among those attending the Convention. Some of the equipment included will be described from time to time in succeeding issues of the JOURNAL, in addition to the equipment that was described in short papers during the Apparatus Symposium on the afternoon of Thursday, October 24th. The following firms exhibited their new equipment:

- Ampro Corp.
- André Debrie, Inc.
- Bigelow-Sanford Carpet Co.
- Brenkert Light and Projection Co.
- Electro-Acoustic Products Co.
- Forest Manufacturing Co.
- General Electric Co.
- Griswold Machine Works
- Hertner Electric Co.
- H. A. DeVry Corp.
- International Projector Corp.
- Neumade Products Corp.
- RCA Manufacturing Co.
- Strong Electric Co.
- Victor Animatograph Co.

In addition, there were other companies whose equipment was not formally exhibited upon the exhibition floor, but was used from time to time during the Convention, and provided the various facilities for conducting the sessions, *etc.* These companies are listed in the following paragraphs.

ACKNOWLEDGMENT

Credit for the success of the Convention, which may be measured in terms of a great increase of interest in the activities of the Society, its Conventions and Local Section meetings, its JOURNAL, and technical activities, was largely due to the efforts of Mr. W. C. Kunzmann, *Convention Vice-President;* Mr. J. I. Crabtree, *Editorial Vice-President*; Mr. C. N. Batsel, *Acting Chairman* of the Papers Committee; Mr. H. Griffin, in charge of projection; Mr. R. T. Friebus, in charge of installing the sound equipment; Mr. W. Whitmore, *Chairman* of the Publicity Committee; Captain H. T. Cowling and Mr. Nat Glasser of the Local Arrangements Committee; Mr. O. F. Neu, *Chairman* of the Apparatus Committee; Mrs. H. T. Cowling, in charge of the Ladies activities; and the Projectionists Local No. 224, I. A. T. S. E.

Various Washington members of the Society should be especially thanked for their untiring efforts and coöperation toward making the Convention a success, among whom should be included Capt. John G. Bradley of the Division of Motion Pictures, National Archives; Mr. N. D. Golden of the Bureau of Foreign and Domestic Commerce, Washington, D. C. Dr. R. D. W. Connor, Archivist of the United States, should be thanked for so courteously receiving the Society at the new National Archives Building on Wednesday afternoon; Dr. Lyman J. Briggs, Director of the Bureau of Standards, for so courteously receiving the Convention at the Bureau and for conducting its Tuesday afternoon session; the Smithsonian Institution and the Library of Congress for receiving the members on their Wednesday afternoon bus tour; the National Broadcasting Company for broadcasting the proceedings of the banquet; and Messrs. H. D. Lohmeyer and Nat Glasser for providing entertainment for the banquet.

The sound and projection equipment used at the meetings was supplied and installed by the International Projector Corporation, National Theatre Supply Company, Bausch & Lomb Optical Company, National Carbon Company, Raven Screen Company, Electrical Research Products, Inc., Electro-Acoustic Products, Inc., General Electric Company, and J. E. McAuley Co.

Thanks are due to the management of the following theaters for the passes courteously supplied to the members during the week of the Convention: Loews' Fox and Palace theaters, Warner Bros' Earl, Ambassador, Metropolitan, and Tivoli theaters, and R. K. O. Keith theater.

Thanks are due also to the following exchanges for supplying the films projected during the Monday and Tuesday evening entertainment programs: Paramount Pictures, Warner Bros.-First National, United Artists, RKO Radio Pictures, Metro-Goldwyn-Mayer, Vitaphone Corp., Walt Disney, Twentieth Century-Fox, and Paramount News.

PAPERS PROGRAM

MONDAY, OCTOBER 21st

9:30 a.m. Registration.

10:00 a.m. *Little Theater;* **Business and Technical Session. President H. G. Tasker, Presiding.**

Report of the Convention Committee; W. C. Kunzmann, *Convention Vice-President.*

Presidential Address; H. G. Tasker.

Report of the Membership Committee; E. R. Geib, *Chairman.*

Election of Officers for 1936.

"Use of Films in the U. S. Army"; Major M. E. Gillette, U. S. Army.

"Microphotographic Duplication in the Service of Science"; W. Davis, *Director,* Science Service, Washington, D. C.

"Some Technical Aspects of Microphotography"; R. H. Draeger, U. S. Department of Agriculture, Washington, D. C.

"Microfilm Copying of Documents"; T. R. Shellenberg, Washington, D. C.

12:30 p.m. *Continental Room;* **Informal Get-Together Luncheon.**

Addresses by:

Mr. J. Brylawski, *Vice-President,* M. P. T. O. A., New York, N. Y.

Mrs. Emily Newell Blair, *Consumers Representative,* Advisory Council, National Recovery Administration, Washington, D. C.

Hon. Sol Bloom, Member of Congress from New York.

Capt. John G. Bradley, *Chief,* Division of Motion Pictures and Sound Recording, National Archives, Washington, D. C.

2:00 p.m. *Little Theater;* **General Session. Capt. John G. Bradley, Presiding.**

"An Experimental Program in Visual Education"; F. H. Conant, Massachusetts Institute of Technology, Cambridge, Mass.

"Demonstration of Photography by Polarized Light"; J. W. McFarlane, Eastman Kodak Company, Rochester, N. Y.

"The Development and Use of Stereo Photography for Educational Purposes"; Prof. C. Kennedy, Smith College, Northampton, Mass.

"Is the Federal Government Interested in Educational Films?"; C. M. Koon, U. S. Department of the Interior, Washington, D. C.

"Further Studies in Motion Picture Theater Design"; B. Schlanger, New York, N. Y.

8:00 p.m. *Little Theater;* **Film Program.**

Exhibition of recent outstanding feature motion pictures and shorts.

"Demonstration of 16-Mm. Colored Motion Pictures with Synchronized Sound"; H. H. Jones, Buffalo, N. Y.

TUESDAY, OCTOBER 22nd

9:30 a.m. *Little Theater;* **Screen Brightness Symposium. Dr. L. A. Jones, Presiding.**

Report of Projection Screen Brightness Committee; C. Tuttle, *Chairman.*

"Screen Brightness and the Visual Functions"; E. M. Lowry, Eastman Kodak Company, Rochester, N. Y.

"An Experiment to Determine the Screen Brightness Requirements of the Public"; B. O'Brien, University of Rochester, and C. Tuttle, Eastman Kodak Company, Rochester, N. Y.

"A Review of Projector and Screen Characteristics, and Their Effects upon Screen Brightness"; A. A. Cook, Bausch & Lomb Optical Company, Rochester, N. Y.

"An Analysis of Theater and Screen Illumination Data"; S. K. Wolf, Electrical Research Products, Inc., New York, N. Y.

"Density Measurements of Release Prints"; C. Tuttle, Eastman Kodak Company, Rochester, N. Y.

"Photometry and Brightness Measurements"; R. P. Teele, U. S. Bureau of Standards, Washington, D. C.

"A Résumé of Methods of Determining Screen Brightness"; W. F. Little and A. T. Williams, Electrical Testing Laboratories, New York, N. Y.

2:00 p.m. *Auditorium;* **U. S. Bureau of Standards. Dr. Lyman J. Briggs, Director of the Bureau, Presiding.**

"The Measurement and Specification of Color"; K. S. Gibson, U. S. Bureau of Standards, Washington, D. C.

"Color Blindness and Anomalies of Vision"; D. B. Judd, U. S. Bureau of Standards, Washington, D. C.

"Physical Tests of Cellulose Films and Their Reproducibility"; S. E. Sheppard, P. T. Newsome, and S. S. Sweet, Eastman Kodak Company, Rochester, N. Y.

"Equipment for Developing and Reading Sensitometric Tests"; D. R. White, Dupont Film Manufacturing Co., Parlin, N. J.

"A Note on the Measurement of Photographic Density with the Barrier Type Photocell"; B. C. Hiatt and C. Tuttle, Eastman Kodak Company, Rochester, N. Y.

"The Brewster Color Process"; P. D. Brewster, Brewster Colorfilm Corp., Newark, N. J.

"Sixteen-Mm. Pictures in Natural Color with Third-Dimensional Effect"; L. C. Phillips, Los Angeles, Calif.

8:00 p.m. *Little Theater;* **Motion Pictures.**

Exhibition of recent outstanding feature motion pictures and shorts.

WEDNESDAY, OCTOBER 23rd

9:30 a.m. *Little Theater;* **General Session. Mr. J. I. Crabtree, Presiding.**

"The Real Need for Projection Departments in Theater Chains"; F. H. Richardson, New York, N. Y.

"Thyratron Reactor Theater Lighting Control"; J. R. Manheimer, E-J Electric Company, New York, N. Y.

"The Conquest of Color"; H. Ketcham, New York, N. Y.

"The Elementary Theory of the Cathode Ray Tube"; W. F. Diehl and E. D. Cook, RCA Manufacturing Co., Camden, N. J.

"Motion Pictures as Government Archives"; Capt. J. G. Bradley, National Archives, Washington, D. C.

"The Motion Picture Collection at the National Museum"; A. J. Olmstead, Smithsonian Institution, Washington, D. C.

Report of the Standards Committee; E. K. Carver, *Chairman.*

"A Non-Theatrical International Service Organization—The Amateur Cinema League"; Col. R. W. Winton, Amateur Cinema League, Inc., New York, N. Y.

"Condenser for 16-Mm. Optical Systems"; G. Mili, Westinghouse Lamp Company, Bloomfield, N. J., and A. A. Cook, Bausch & Lomb Optical Co., Rochester, N. Y.

"World Motion Picture Markets"; N. D. Golden, U. S. Bureau of Foreign and Domestic Commerce, Washington, D. C.

1:30 p.m. Motor-Bus Tour.

Stops made at the Library of Congress, Smithsonian Institution, and the National Archives.

8:00 p.m. *Continental Room;* **Semi-Annual Banquet.**

Presentation of Scroll of Honorary Membership to Thomas Armat, Washington, D. C.

Presentation of S. M. P. E. Journal Award to Dr. Loyd A. Jones and Dr. Julian H. Webb.

Presentation of S. M. P. E. Progress Medal to Dr. Edward C. Wente.

10:30 p.m.

Address by Hon. Will H. Hays, *President,* Motion Picture Producers and Distributors of America, Inc., New York, N. Y. Broadcast through the courtesy of the National Broadcasting Company.

THURSDAY, OCTOBER, 24th

9:30 a.m. *Little Theater;* **Sound Session. Dr. J. G. Frayne, Presiding.**

"A New Method for Increasing the Volume Range of Talking Motion Pictures"; N. Levinson, Warner Bros.-First National Studios, Burbank, Calif.

Report of the Sound Committee; P. H. Evans, *Chairman.*

"Reversed Mechanical Bias on Light-Valve Recordings"; E. H. Hansen and C. N. Faulkner, 20th Century-Fox Film Corp., Hollywood, Calif.

"Elimination of Splice Noise in Sound-Film"; E. I. Sponable, 20th Century-Fox Film Corp., New York, N. Y.

"Contributions of Telephone Research to Sound Pictures"; E. C. Wente, Bell Telephone Laboratories, New York, N. Y.

"A Non-Directional Moving-Coil Microphone"; L. W. Giles, Bell Telephone Laboratories, New York, N. Y.

"Principles of Measurements of Room Acoustics"; E. C. Wente, Bell Telephone Laboratories, New York, N. Y.

2:00 p.m. *Little Theater;* **Apparatus Symposium and Laboratory Session. President H. G. Tasker, Presiding.**

"The Debrie 16-Mm. Professional Projector"; H. R. Kossman, André Debrie Corp., New York, N. Y.

"RCA PB-141 Optical Reduction Printer"; M. E. Collins, RCA Manufacturing Co., Camden, N. J.

"RCA Photophone Reproducing Equipment"; J. Frank, Jr., RCA Manufacturing Co., Camden, N. J.

Report of the Committee on Laboratory Practice; D. E. Hyndman, *Chairman.*

"Primary Considerations in the Design and Production of Theater Amplifiers"; T. D. Cunningham, RCA Manufacturing Co., Camden, N. J.

"Air Conditioning"; J. G. Patterson, Bryant Heater Company, Cleveland, Ohio.

"Air Filtration in the Production of Motion Pictures"; H. C. Murphy, American Air Filter Company, Louisville, Ky.

"A Versatile Processing Machine"; M. Ricker, United Research Corp., Long Island City, N. Y.

"Motion Pictures and the Air Corps"; Capt. J. M. Goddard, *Director*, Photographic Department, Army Air Corps, Chanute Field, Rantoul, Ill.

"Recent Progress in Motion Pictures in the U. S. S. R."; V. I. Verlinsky, Amkino Corp., New York, N. Y.

"Technical Advances in Soviet Russia"; A. F. Chorine, Central Laboratories, All-Union Electrical Trust, Moscow, U. S. S. R.

SOCIETY ANNOUNCEMENTS

BOARD OF GOVERNORS

At a meeting of the Board of Governors at the Wardman Park Hotel, Washington, D. C., on October 20th, plans for the current Convention were completed, the results of which are described in detail in this issue of the JOURNAL in "Proceedings of the Semi-Annual Banquet at Washington" and "Highlights of the Washington Convention," on pp. 467 and 545, respectively.

Several amendments of the Constitution and By-Laws were approved for presentation to the Society in Convention on the following day. These amendments, and the actions taken thereupon, are described below.

The report of the Financial Vice-President indicated that the Society was operating within its budget and that the financial situation was satisfactory. In addition, other matters, described below, such as the Society Awards and the Spring, 1936, Convention, were discussed and acted upon.

SPRING, 1936, CONVENTION

At the meeting of the Board of Governors, on October 20th, Chicago was selected for the next Convention of the Society, the dates being April 27th–30th, inclusive. The Edgewater Beach Hotel will be the Convention Headquarters again, and Mr. William C. Kunzmann, *Convention Vice-President,* has already begun to make arrangements. Full details will be announced later in the JOURNAL.

AMENDMENTS

The following amendments of the Constitution and By-Laws were proposed at the meeting of the Society on October 21st:

Article IV (of the Constitution). The officers of the Society shall be a President, a Past-President, an Executive Vice-President, an Engineering Vice-President, an Editorial Vice-President, a Financial Vice-President, a Convention Vice-President, a Secretary, and a Treasurer.

The term of office of the President and Past-President shall be two years; of the Engineering, Editorial, Financial, and Convention Vice-Presidents, two years; and of the Executive Vice-President, Secretary, and Treasurer, one year. Of the Engineering, Editorial, Financial, and Convention Vice-Presidents, two shall be elected alternately each year or until their successors are chosen. The President shall not be immediately eligible to succeed himself in office.

By-Law III, Sec. 4. The Board of Governors, when making nominations to office, and to the Board, shall endeavor to nominate persons, who in the aggregate are representative of the various branches or organizations of the motion picture industry, to the end that there shall be no substantial predominance upon the Board, as the result of its own action, of representatives of any one or more branches or organizations of the industry.

By-Law V, Sec. 6. Each officer of the Society, upon the expiration of his term of office, shall transmit to his successor a memorandum outlining the duties and policies of his office.

By-Law VII, Sec. 4 (new second sentence). All Honorary Members, Fellows, and Active Members in good standing, as defined in Sec. 5, may vote or otherwise participate in the meetings.

The proposed amendments of the By-Laws, given above, were approved at the Washington meeting and are therefore immediately effective. The proposed amendment of Article IV of the Constitution was discussed upon the floor, and, according to Constitutional procedure, must be voted upon by letter-ballot. Transcripts of the discussions and the ballots will be mailed to the voting membership of the Society shortly.

RESULTS OF ELECTION

At the Washington Convention on October 21st, the ballots for the election of officers for 1936 were counted, and the results announced as follows:

President: H. G. TASKER*
Executive Vice-President: E. HUSE*
Engineering Vice-President: L. A. JONES
Financial Vice-President: O. M. GLUNT
Secretary: J. H. KURLANDER
Treasurer: T. E. SHEA
Governor: A. S. DICKINSON
Governor: H. GRIFFIN
Governor: A. C. HARDY

The terms of those indicated by asterisks expire December 31, 1936; of those not so indicated, December 31, 1937. Other officers and governors of the Society not listed above are listed upon the reverse of the Contents page of the JOURNAL, their terms expiring December 31, 1936.

SOCIETY AWARDS

Details concerning the Progress Medal Award and the Journal Award to Dr. E. C. Wente, and to Drs. L. A. Jones and J. H. Webb, respectively, are given in "Proceedings of the Semi-Annual Banquet at Washington" on p. 467 of this issue of the JOURNAL.

ATLANTIC COAST SECTION

The initial Fall Meeting of the Section was held at the Hotel Pennsylvania, New York, N. Y., October 17th. Mr. S. K. Wolf, Director of the Acoustics Division of Electrical Research Products, Inc., presented a paper on "Recent Advances in Acoustics." The meeting was well attended, and an interesting discussion followed the paper.

MID-WEST SECTION

At a meeting of the Section on October 17th, Mr. H. A. Hartt, Laboratory Manager, Eastman Kodak Company, Chicago, presented an interesting paper on the subject, "Laboratory Practice in 16-Mm. Reversal Film Processing." The next meeting of the Section is scheduled for November 1st.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

AUTHOR AND CLASSIFIED

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