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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 best technical experts in the various research laboratories and other engineering branches of the industry in the country, as well as executives in the manufacturing and producing branches.

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.

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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THE NEW CINÉ-KODAK SPECIAL IN MEDICINE*

H. B. TUTTLE** AND R. PLATO SCHWARTZ†

Summary.—*The new Ciné-Kodak Special is briefly described, particularly in connection with its application to photographing surgical operations both in color and in black and white. In addition to the usual features of 16-mm. cameras, the advantages of being able to produce fades, dissolves, double exposures, multiple exposures, single-frame exposures and to use masks of various kinds, increase the facility with which the camera can be used for surgical instruction and records. The paper refers briefly to some of the work done at the University of Rochester with this camera.*

Progress in any field is dependent upon records. In medicine the first great men gave us written records of their work. The Science of Life as recorded by Sushruta in his *Samhita* is our source of information relative to Hindu surgery six hundred years before the Christian era. Two hundred years later, Hippocrates gave to the world his observations on the practice of medicine and surgery. But unfortunately, illustrations did not accompany their vivid and momentous descriptions.

With the development of art, drawings were used to visualize descriptions. And of necessity, these sufficed for many centuries until the progress of chemistry and physics gave rise to the science of photography. This situation is evidenced by the fact that as late as 1892 important books on medicine and surgery were published without a single photographic illustration. Today, however, most of the medical literature is profusely illustrated with photographs made with regular equipment for clinical still photography. And, as a result, the subjects are much more understandable.

The present importance of still photography to medicine is so obvious that it hardly needs mention. But despite this fact, in many situations its application has limits that can be exceeded only by the photographic records of motion. Pathology alters normal function, and treatment is prescribed to remove the limitations imposed upon

* Presented at the Spring, 1933, Meeting at New York, N. Y.

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

† School of Medicine, University of Rochester.

normal activity. It is at once apparent that motion pictures provide a very important means of supplying desirable records of (1) the patient's condition before treatment; (2) the method of treatment; and (3) the extent to which normal function is restored by the treatment.

Cinematography, the most modern servant of visual expression, first emerged usefully from the scientific laboratory of Thomas Edison in 1894. In less than forty years an industry has developed that is now vital to national and international understanding. Medicine has been one of the departments of human endeavor that has been influenced by the recording of motion.

To those who may not be familiar with the application of motion pictures to the medical field, it might be well to outline briefly its past history. From the advent of the motion picture, the possibility of applying it to the field of medicine, as an educational medium and a means of satisfactory record, has been recognized by the profession.

Since the 16-mm. motion picture camera was not introduced until 1923, all the early medical motion pictures were produced with 35-mm. equipment. In most instances it was necessary for the individual physician to bear the expense, a fact that undoubtedly retarded early constructive pioneering. However, the work progressed as various groups and institutions became increasingly interested in it.

The most influential event of this development was the comprehensive program begun in 1927 under the joint auspices of the American College of Surgeons, the Motion Picture Producers and Distributors of America, Inc., and Eastman Teaching Films, Inc., for an organized study[1] of the technic of making medical and surgical motion pictures. The films that were produced under the auspices of these groups were of excellent quality, and they represent to a large degree the recognized technic and practice of the majority of the profession. They also proved that 35-mm. originals, and 16-mm. reduction prints made from them, are entirely economical and highly satisfactory where a large number of prints are required.

As stated before, the 16-mm. camera—the Ciné-Kodak—made its appearance in 1923. Because of the relatively small cost of both the apparatus and the film, the possibility of recording medical subjects was greatly expanded. Individual physicians for the first time found it possible at little expense to film their unusual cases and technical methods for record and lecture purposes.

Each year has evidenced a steadily increasing effort to apply 16-

mm. motion pictures to the problems of medical photography. The degree of activity and the intensity of applications have increased despite the fact that the films produced have not equalled the technical quality of professional 35-mm. motion pictures. However, the advantages achieved were more than sufficient to overbalance the recognized deficiencies.

Ten years have passed since the announcement of the Ciné-Kodak; and the increasing number of physicians personally interested in the

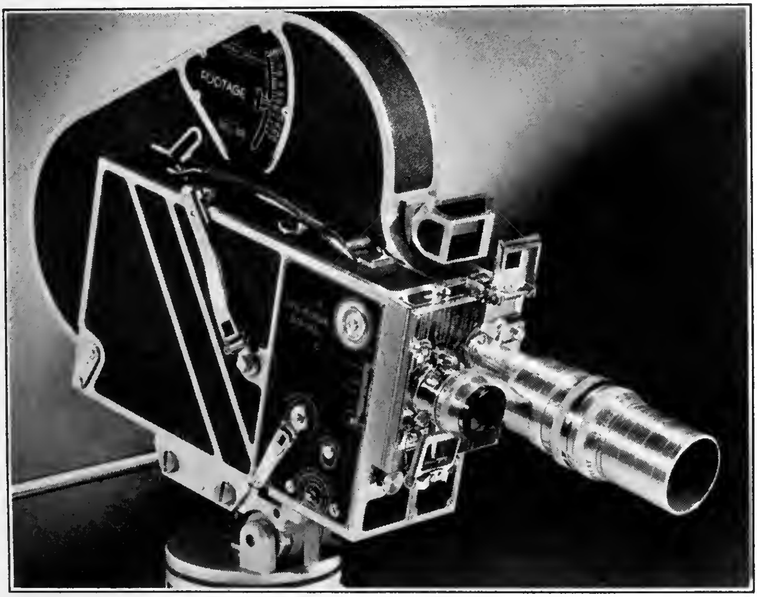

FIG. 1. The Ciné-Kodak Special.

application of motion pictures to their work has created a large number of highly competent operators of 16-mm. cameras. In addition, many new developments in films, lamps, and accessory apparatus have facilitated the taking of medical pictures.

Kodacolor[2] made it possible for the first time to film an operation in color.[3,4] Later, supersensitive Kodacolor film, together with photoflood lamps and a new type of ratio diaphragm cap, greatly extended the scope of medical films in full color. Supersensitive panchromatic film made possible black-and-white cinematography in the operating[5] room without additional lighting equipment.

Despite this widespread interest and the many advances, the medical films that have been made show that the limits of application of the regular 16-mm. camera render it impossible to attain results conformable to professional standards. Therefore, it is obvious that a special camera using 16-mm. film and capable of photographing any subject under the most exacting circumstances will fill a definite need.

The Ciné-Kodak Special (Fig. 1), recently announced by the Eastman Kodak Company, is such a camera. Among its features are a flexibility of operation and an accuracy of focusing and framing heretofore unavailable to 16-mm. camera users.

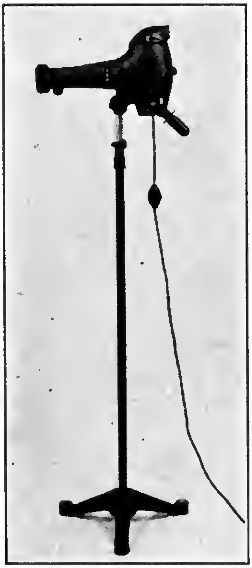

FIG. 2. The Eastman medical spotlight used with the Ciné-Kodak Special to produce Kodacolor pictures of surgical operations.

A reflex finder on the camera permits accurate framing and focusing with lenses of any focal length, at any distance. Supplementary lenses are available for focusing objects from 4 inches to 24 inches away; they permit close-up cinematography of small objects, with clear and sharp detail in the image. The spring motor drives 40 feet of film through the camera at one winding, and provision is made for attaching an electric motor. The lens turret on the front of the camera holds two lenses of selective focal length, and it can be turned quickly into position.

The film chamber is of the removable magazine type, which permits a rapid interchange from a 100-foot to a 200-foot chamber, or from Kodacolor to black-and-white film.

Fades "in" and "out," dissolves, double exposures, or multiple exposure effects can be produced by a built-in dissolving shutter. Provision is also made for exposing one frame at a time. With this feature, animation and time-lapse pictures can be made. Masks may also be used in front of the film aperture, so that many other effects can be produced.

The camera is geared so that changes of speed may be made while it is running. These speeds, varying from 8 frames a second to 64 frames a second, make possible slow-motion studies of subjects wherever such an effect is desired. The necessary adjustment in exposure can be compensated by the variable shutter while the camera is operating.

The appeal of the Ciné-Kodak Special is assured because the basic model includes all of these advantages. Moreover, it readily lends itself to practically all modifications essential to individual requirements.

The quality of work obtainable with this new camera is revealed in films made for William S. McCann, M.D., Professor of Medicine at Strong Memorial Hospital of the Rochester University School of Medicine. The work was done in minimum time, with four Kodaflectors and without the necessity of making retakes. The composition of the film reveals perfectly the sequence of procedures followed in determining lung capacities.

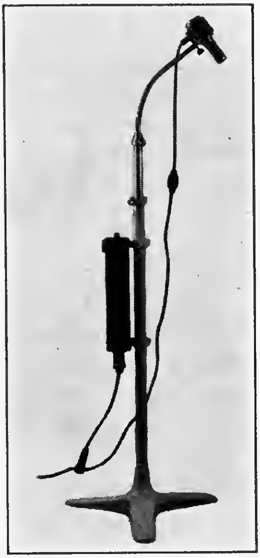

FIG. 3. The ophthalmic operating lamp; used as a source of illumination for making photographic studies of diseases of the eye.

Kodacolor motion pictures of a cataract extraction were made for John Gipner, M.D., of the same institution. An Eastman medical spot light (Fig. 2) was the only illuminant required. Another film was made to reveal various eye diseases. This work was done in black and white, as well as in color. For the black and white, a Bausch & Lomb ophthalmic operating lamp (Fig. 3) was found most satisfactory. In each instance the excellent quality of picture produced can be traced to the technical advantages of the new Ciné-Kodak Special.

A Kodacolor film for teaching purposes was made of an autopsy on an infant with a number of congenital deformities. This film provides the instructor with an excellent record that will be used from year to year to accompany lectures to students.

Another most difficult problem solved with this camera is the copying of radiographs. This task is now comparatively easy to accomplish. In order to obtain fine detail and good contrast, Ciné-Kodak panchromatic film was employed; all the detail and contrast in the original radiographs are recorded with exactitude. There are many possibilities in recording radiographs on motion picture film, especially in the study of bone and joint diseases, progress of disease processes, and other situations in which the bony structure of the human body is involved.

The results attained in all the previously mentioned instances have been so satisfactory that there is no hesitation in recommending the Ciné-Kodak Special to any worker in the medical or general scientific field. Its construction and design enable it to meet the most exacting requirements.

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PHOTOPLAY APPRECIATION IN THE NATION'S SCHOOLS*

W. LEWIN**

***Summary.**—As chairman of the Committee on Photoplay Appreciation of the National Council of Teachers of English, the author describes experimentation undertaken by the Council during 1932 and 1933 for the purpose of determining whether the movie habits of adolescents can be improved significantly through the medium of the English classroom; and desirable ideals and attitudes can be developed through the medium of well-selected current photoplays; and whether the neighborhood theater can serve in part as an educational laboratory working in direct relation to the public school.*

During the academic year 1932–33 the National Council of Teachers of English has been engaged in an experiment under the general supervision of Dr. Walter Barnes of New York University, president of the Council, to determine whether the movie habits of adolescent America can be improved significantly through the medium of the English classroom; whether, indeed, desirable ideals and attitudes can be developed through the medium of well selected current photoplays; and whether the neighborhood theater can serve, in part, as an educational laboratory working in direct relation to the public school, by providing enjoyable and worth-while "literature experiences" for boys and girls of junior and senior high school age.

The experiment was planned on the basis of suggestive units of instruction in photoplay appreciation. It is proposed to introduce these new units in the nation's schools as part of the revised course of study being prepared by the curriculum commission of the National Council of Teachers of English. This new development accords with the present emphasis on social criteria in secondary education, and is a phase of training in the right use of leisure.

Among the aims of the new instruction units are the development of appreciation of basic themes and conflicts in selected current photoplays, skill in retelling the stories of photoplays as a part of social con-

* Presented at the Spring, 1933, Meeting at New York, N. Y.

** National Council of Teachers of English, Newark, N. J.

versation, appreciation of the literary sources of photoplays, and the development of the vocabulary necessary to an elementary discussion of screen art and technic. It is hoped that, before graduating from the senior high school, students will be able to evaluate motives and character traits as revealed in the varying patterns of conduct found in popular screen dramas. It is hoped, too, that students will acquire some degree of skill in conversing about current photoplays in the light of definite critical standards.

The plan of the experiment has been to set up equivalent groups of students in each of a series of schools in a rather extensive network under the supervision of regional directors, in order to compare the reactions of instructed and uninstructed classes. The groups have been compared as to age, grade, sex, intelligence, home background, and initial appreciation of pictures. The procedure thereafter has been to arrange with local theater managers to admit both the experimental (that is, the instructed) groups and the control (that is, the uninstructed) groups in a body to see the same series of pictures at the same time. The control groups were merely to see the pictures without guidance and to have a good time. The experimental groups, on the other hand, were to be prepared for an appreciation of the pictures, and, after attending the theater, to evaluate the picture in the classroom under the guidance of the teacher.

To accelerate the growth of appreciation among the experimental groups, the activities in which they engaged included the discussion of such general topics as: What is the best photoplay you have ever seen? How would you decide which of two photoplays is the better? In how many ways may we consider levels of quality in photoplays? What are the fundamental themes of some photoplays you have seen? Story-telling "bees" were held, in which the plots of interesting photoplays were retold in brief talks. The experimental pupils were encouraged to start critical diaries of the photoplays they saw, and to record their impressions for later discussion. Some students were asked to start scrapbooks of newspaper clippings containing interesting bits of information about photoplay technics. Others made glossaries of motion-picture terms, with pictures pasted in, where possible, to illustrate the means of the terms. Classroom discussions considered how motion pictures were made, and pupils learned to use such terms as close-up, long shot, and camera angle.

When historical interest was shown by older pupils, they were asked to take notes on a formal talk prepared by the teacher on the development of the photoplay from its crude beginnings to its present status.

As the work progressed, the older experimental pupils prepared oral and written reports about the photoplays they were seeing, as bases for class discussions, with a view to pointing out striking examples of screen story treatment, strong and sincere direction, unusual camera work, subtle nuances of acting, and details of good sound recording.

As an approach to a more formal symposium by selected members of the more advanced classes, there were impromptu discussions of standards for judging photoplays and of methods of shopping for pictures to see. Out of the symposiums of pupils' points of view, class debates arose. The visits to the neighborhood playhouse were in the nature of theater parties, with natural emphasis on enjoyment.

Among the materials used with a view of accelerating appreciation and developing critical judgment were specially prepared study-guides and rating-scales. Suggestive mimeographed questions and work sheets were supplied for a number of specific pictures, including *I Am a Fugitive*, *Smilin' Through*, *Rasputin and the Empress*, *The Son-Daughter*, *Madame Butterfly*, *Rebecca of Sunnybrook Farm*, *Tom Brown of Culver*, and *Robbers' Roost*. In addition, a general study-guide was supplied in mimeographed form for use in discussing pictures for which no specific guides were provided. Standard questions were framed concerning the type and purpose of each photoplay seen, its setting or locale, its characters and their motives, the elements of the story, the logic of the ending, the best directed scenes, the scenes that might have been omitted, and the lessons about life to be drawn from the picture.

For example, the study-guide for *Madame Butterfly*, dealing with the consequences of an American naval officer's desertion of his Japanese wife, suggests that the restraint of brave little Cho-Cho-San be compared with the pathos of Oenone when deserted by Paris in Tennyson's poem *Oenone*, or contrasted with the furious passion of Dido when deserted by Aeneas in Virgil's great epic. Life-problems considered were: Should a girl marry a man she loves, even though he be of different race, with different ideas and customs? What should a girl do when deserted by the man to whom she entrusted all her happiness? How seriously should a naval officer take his romance with a geisha girl? What is the most touching scene? Is the picture convincingly directed?

In the study-guide for *I Am a Fugitive*, the marvelous effect of suspense was studied. In the guide for *The Son-Daughter*, the graceful acting of Helen Hayes and the subtle nuances in her use of the fan were mentioned, as well as the ideals of the character she portrayed.

Each teacher in the experiment was supplied with a manual on how to appreciate motion pictures, prepared by Dr. Edgar Dale, of Ohio State University. This manual is now being tried out intensively in Ohio under the auspices of the Payne Fund and in connection with special radio lectures by Dr. Dale. Radio, however, was not used in the English Council experiment. The manual was used in about fifty cities and is still being used in a few cities that have not yet reported.

A set of three experimental rating scales was used to obtain objective data as to the pupils' judgments. On these scales the student indicated whether he considered the fundamental idea of the picture trite or original; the story structure logical or illogical; the characters life-like or unnatural; the settings appropriate or inappropriate; the photography effective or crude; the dialog apt or dull; the acting sincere or artificial; the voices of the actors clear or blurred; the direction intelligent and imaginative or weak and uninspired; the social value of the production constructive or destructive. In judging the picture as entertainment, a weight of 50 per cent was given to basic story elements and 50 per cent to direction, photography, acting, and speech delivery.

To measure specific differences in appreciation, teachers and professional reviewers set up specific criteria by rating and ranking the photoplays involved in the experiment—about fifty pictures in all. Some of the newspaper critics objected that they were required to write practically an essay on every picture. The teachers did not feel that way. The ratings assigned by the pupils are being compared with the ratings assigned by the teachers and professional critics. Sectional differences are being noted, as well as age and sex differences.

To measure general growth in appreciation, the reactions of the various experimental and control groups to preliminary and concluding questionnaires are being tabulated. These questionnaires serve the purpose of initial and final tests of appreciation.

In the preliminary questionnaire the student was required to indicate which of ten worth-while photoplays of 1931, suitable for high school pupils, he had seen: *Tom Sawyer*, *A Connecticut Yankee*, *Huckleberry Finn*, *Spirit of Notre Dame*, *Merely Mary Ann*, *Skippy*, *Cimarron*, *Trader Horn*, *Street Scene*, and *Alexander Hamilton*. He was required to indicate which of the following things he was in the habit of doing before attending a photoplay: finding out who directed the picture; seeing whether the story is by a good author; reading what a critic says about the picture; asking a teacher about it (which is generally the last thing he thinks of doing); discussing it with a member of the family; and discussing it with a friend. He was asked also whether in his home the question of what photoplay to see was brought up at a family discussion at least once a month; whether he belonged to a photoplay club or similar group interested in motion pictures; whether he owned or had the use of a movie camera (it was found, incidentally, that this experiment has caused motion picture cameras to be purchased by the experimental groups, due to arousing their interest); whether he could mention a book in which he had become interested as a result of seeing a photoplay; whether he considered the director more important than the cameraman in making a photoplay; whether the story is more important than the star as a basis of choosing a photoplay to attend; whether he enjoys going to the movies so much that he considers it one of his favorite leisure occupations; whether he usually discusses with his friends the photoplays he has seen; whether he has ever prepared a theme or a talk on a photoplay in connection with school work; whether a photoplay, to be a good one, must end happily (in Utah, for example, a group overwhelmingly said, "Yes, it must end happily to be good;" in Brooklyn the opposite was the answer); and whether he could recall the names of any characters he had admired in photoplays for ideals of bravery, honesty, devotion, or self-sacrifice for a great cause.

In the final questionnaire the student was required to indicate his reactions to similar queries, with a few changes needed to maintain the validity of the test, and to make the final data comparable with the preliminary data. One interesting question added to the final questionnaire, "Can you mention a photoplay that has influenced your conduct in any way?" is providing very interesting data.

The reactions of 1500 representative boys and girls involved in the experiment are now being compiled by thirty teachers in sixteen states and the District of Columbia, representing nearly all sections of the country—California, Colorado, Florida, Georgia, Illinois, Indiana, Kansas, Michigan, Minnesota, Montana New Jersey, New York, Pennsylvania, Tennessee, Virginia, West Virginia, and Washington, D. C.

The results of the experiment will be formally announced at the annual convention of the English Council at Detroit, next November. Meanwhile, it is safe to say that comparative data now being assembled indicate significant trends. One of the outcomes of the project has already been the establishment of a strong national previewing committee of teachers, with Dr. Stella S. Center, past president of the Council, as chairman. The function of this Committee is to determine what current productions are worthy of consideration in the classroom. For such productions study-guides will be prepared.

Not the least interesting observation to be made meanwhile is that progressive teachers everywhere are enthusiastic about doing careful research work in this field and are eager to continue the experiment.

After all, the motion picture, whether it be in the theater or in the classroom, does not concern the English teacher alone. All knowledge is interrelated. Any given picture may be viewed from many angles. The teacher of social sciences, the teacher of geography, the teacher of physical sciences, looking at a picture, sees it from his point of view. The home-room teacher, the parent, the principal, the board of education member, by the same token, looks at the motion picture from his angle. Each seeks not only cleaner pictures, but also better pictures. Therefore it is evident:

(1) That visual education must widen the scope of its activities so as to include a consideration of the neighborhood theater and its programs as a community problem. This problem is destined to become less and less a problem and more and more an opportunity as time goes on. The problem has already been defined by the National Council of Teachers of English. A problem well defined and well understood is already half solved. Visual educators, at any rate, can not escape this cinema problem. They must face it squarely and constructively, with a view of arriving at some consensus which will lead to united effort.

(2) That the visual education movement must accept research and experimentation as part of its daily work. Education is an on-going, creative evolution. It is not enough that we teach our teachers how to use charts, slides, and films. We must teach our teachers how to do research. It is at once the advantage and the disadvantage of visual education that visual aids are in a continual state of obsoles-

cence. Engineers, it seems, have found a way of inventing inventions, so that a problem need but be defined, and lo, its solution is but a matter of time. The classroom teacher must keep abreast of science. She must learn how to evaluate her methods, her materials, her equipment. The English Council experiment demonstrates that progressive teachers enjoy motion picture research work. Let us give them more of it.

(3) That progress for the director of visual instruction lies in making his job less and less a physical problem and more and more a mental problem. The work of distributing charts, slides, and films, and caring for machines no longer presents any real problems. The machines have been simplified until now they are so easy to operate that even children can handle them. In high schools, boys and girls enjoy learning how to show slides and films. The work of classifying and distributing pictures and objects should be part of the training of every good library assistant. Slides and films should, furthermore, be correlated with books by a unified system like the Dewey decimal system.

The director of visual instruction needs time to devote himself to the major problems of selecting the best visual aids, planning experiments in methodology, and organizing the many interesting activities that teachers and pupils enjoy and that are of practical benefit to the community. It should not be the function of the English specialist to take the initiative in regard to motion picture theaters, but rather of the visual educator, who can see the problem in all its phases.

(4) That visual education must embrace radio, as is done by Dr. Charters and Dr. Dale in teaching photoplay appreciation in Ohio, because inevitably visual and auditory aids will be merged in the classroom through the medium of television.

REPORT OF THE NON-THEATRICAL EQUIPMENT COMMITTEE*

The Non-Theatrical Equipment Committee is one of the newest committees of the Society, having been formed a little more than a year ago. Its function and purpose are to investigate all matters relating to 8- and 16-mm. film cameras and projectors, 35-mm. film portable and semi-portable projectors, stereopticon and film slide projectors, and accessories such as screens, film splicers, reels, *etc.* It is the function of the Committee also to investigate proposals of standardization for submittal to the Committee on Standards and Nomenclature on matters that can be more advantageously studied by this Committee because of its close contact with the non-theatrical field.

The word "equipment" in the name of the Committee is definitive of the real purposes of the Committee; although a few of the members have felt that the Committee should concern itself also with matters relating to visual education and other non-theatrical activities. The personnel of the Committee includes representatives of practically all the manufacturers of non-theatrical motion picture equipment.

The Committee is now engaged with the problems relating to the standardization of 8-mm. film, stereopticons employing very large slides, advantageous in the projection of color plates, and a further study of the entire field.

The large variety of types of projection lamps and the general lack of standardization, due to the rapid growth of this field, have been perplexing problems for some time for both the equipment and lamp manufacturers. The matter was dealt with at considerable length by E. W. Beggs[1] at the Washington, D. C., Convention. Owing to the great activity in this connection, particularly in the field of 8- and 16-mm. film projectors, the Committee felt it imperative to direct its activities toward an improvement of existing conditions.

While, of course, the development of a suitable group of projection lamps is largely the problem of the lamp manufacturers, nevertheless coöperation of the Committee members has greatly facilitated the results that have been achieved. A line of projection lamps has been

* Presented at the Spring, 1933, Meeting at New York, N. Y.

made available which includes interchangeable high and low priced lamps for ordinary and super service, fewer voltage ratings, and 25-hour life for the newer lamps. All may be operated on either a-c. or d-c. circuits.

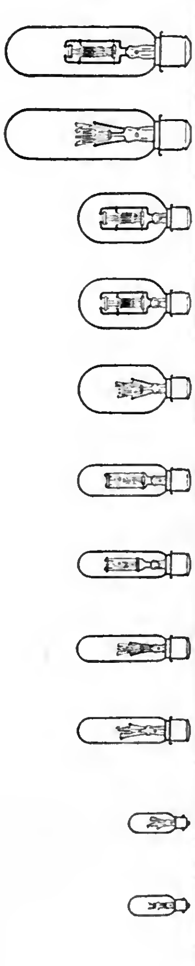
In analyzing the problem of projector lamp standardization, the equipment now in service was considered as well as that yet to be designed. The particular point of distinction between the two groups is that the older projectors are only moderately well ventilated, whereas the newer ones are greatly improved in this respect, and contain also improved optical trains. Thus, lamps designed to utilize these advantages can not be used in projectors now in service. The following types of projectors must be considered in developing a group of projection lamps:

8-Mm. motion picture	
16-Mm. motion picture	home application semi-professional
35-Mm. motion picture	portable semi-portable
Film slide projector	pocket size large size
Lantern slide projector	low power high power

Fortunately, it has been found that equipment of more than one type can be served by a single lamp, thus somewhat reducing the number of types necessary.

Fig. 1 shows briefly the essential data pertaining to a group of lamps now available for use in non-theatrical equipment. Referring to the item "service," it will be noted that in most cases two types of equipment are given, the upper of which is the more important, the lower being of secondary importance. It will be noted that all lamps are of the 100-volt class, obviating the expense and weight of auxiliary transformers or large resistances used in the past with low-voltage lamps. It appears that except on the lower-priced projectors the practice will become general of using 100-volt lamps in series with a small resistance and in combination with a voltmeter, which will permit the adjustment of the resistance so that the lamp will receive 100 volts on all circuits. Thus the full advantage of the highlight output of the lamps will be combined with satisfactory lamp performance.

The three short *T-20* bulb lamps, namely, the 500-, 750-, and



SERVICE: Type of Projectors	Film Slide 8mm & 16mm M.P.	8mm & 16mm M.P. Film Slide	Film Slide 16mm M.P.	16mm M.P. Film Slide	16mm Motion Picture	16mm Motion Picture	Stereopticon 35mm Portable M.P.	35mm Portable M.P. Stereopticon	35mm Portable Motion Picture	Stereopticon 35mm Semi-Port. M.P.	35mm Semi Port. M.P. Stereopticon
Required Ventilation	Natural	Natural	Natural	Moderate Forced	High Degree Forced	High Degree Forced	Natural	Moderate Forced	High Degree Forced	Natural	Natural
Watts	50	100	200	300	500	750	500	750	1000	1000	1000
Volts	100, 105, 110, 115, 120	100, 103, 110, 115, 120	100, 105 110, 115, 120	100, 105, 110, 115, 120	100*	100*	100, 105, 110, 115, 120	100*	100*	100, 105, 110, 115, 120	100*
Bulb	T-8	T-8	T-10	T-10	T-10	T-12	T-20	T-20	T-20	T-20	T-20
Base	S.C. Bay. Cand.	S.C. Bay. Cand.	Med. Pre.	Med. Pre.	Med. Pre.	Med. Pre.	Med. Pre.	Med. Pre.	Med. Pre.	Mog. Pre.	Mog. Pre.
Average Rated Life-Hours	50	50	50	25	25	25	50	25	25	50	25
Filament Construction	Monoplane	Monoplane	Monoplane	Monoplane	Biplane	Biplane	Monoplane	Biplane	Biplane	Monoplane	Biplane
Initial Output-Lumens	790	1870	4000	7500	12500	19500	13150	19500	27600	27000	27600
Light Center Length-Inches	$1\frac{3}{8}$§	$1\frac{3}{8}$§	$2\frac{3}{16}$†	$2\frac{3}{16}$†	$2\frac{3}{16}$†	$2\frac{3}{16}$†	$2\frac{3}{16}$†	$2\frac{3}{16}$†	$2\frac{3}{16}$†	$3\frac{7}{16}$†	$3\frac{7}{16}$†
Max. Overall Length-Inches	$3\frac{1}{8}$	$3\frac{1}{8}$	$5\frac{3}{4}$	$5\frac{3}{4}$	$5\frac{3}{4}$	$5\frac{3}{4}$	$5\frac{3}{4}$	$5\frac{3}{4}$	$5\frac{3}{4}$	$9\frac{1}{2}$	$9\frac{1}{2}$

These tubular-bulb lamps are designed for operation in the vertical position—base down.

* 100-volt lamps—recommended for use with voltmeter and small variable resistance. Also available at 105, 110, 115, and 120 volts.

§ The light center of this lamp is measured from center of light source to top of base pins.

† The light center of this lamp is measured from center of light source to top of base fins.

(§, †) These are average figures for which such lamps are designed and are subject to manufacturers' tolerances.

FIG. 1. Projection lamps recommended for motion picture and stereopticon service.

1000-watt lamps, form an interesting group. The 500-watt lamp is the original member of the group, and was intended for 35-mm. portable projectors as well as for lantern slide projectors. It was found possible to use a 750-watt filament in this bulb, and with the ventilation available in most 35-mm. portables the performance of the lamps is satisfactory. If the projection machine manufacturers are desirous of increasing the illumination still further and are willing to improve further the ventilation in the lamp house, there is available a 1000-watt lamp. The medium powered lantern slide projector must continue to use the 500-watt lamp, since the ventilation of such projectors is not forced; hence, the retention of this lamp in the group.

The two 1000-watt long *T-20* bulb lamps are another interesting pair. The lamp at the left is the original member, and was intended for both 35-mm. semi-portable and high powered lantern slide projec-

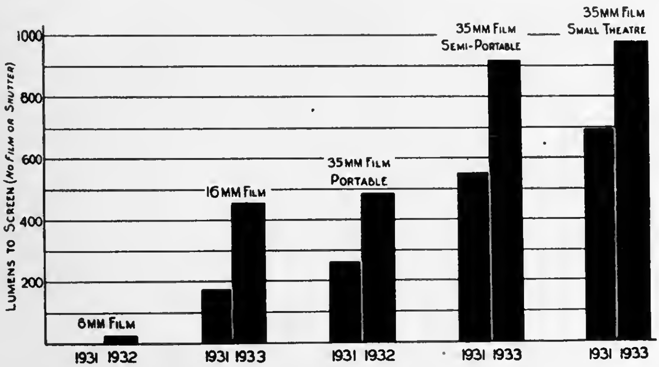


FIG. 2. Screen illumination from best available lamps and best motion picture projectors.

tors; the lamp at the right provides about 40 per cent more light in motion picture projectors because of its greater efficiency and concentration of its source. This source concentration is of little value when used with a stereopticon optical system; hence the user of such equipment should not be penalized by having to pay the higher price of the biplane filament lamp.

The three *T-10* bulb lamps and one *T-12* bulb lamp form another important group. The 300-watt lamp will replace many lamps now used in the moderately priced 16-mm. projectors, such as the 250-watt, 20- and 50-volt types; and affords better screen illumination when used in place of the 200-watt lamp.

The 200-watt lamp is retained for film slide projector service, as the substitution of a 300-watt lamp in many of these devices will cause the film to blister. With adequate ventilation, as in the case with many 16-mm. projectors now in use, the 500-watt lamp can be used. The 750-watt lamp is available for manufacturers of 16-mm. equipment who require still more light and are willing to provide the special optical system and ventilation necessary to obtain the 30 per cent increase of illumination possible as compared with the 500-watt lamp.

It is thus apparent that this move toward projector lamp standardization has made it possible to comply with practically all projector requirements with eleven lamps, and at the same time to produce increases in available screen illumination, as shown in Fig. 2, when used in the improved equipments and with the better optical elements that the industries have provided.

R. E. FARNHAM, *Chairman.*

A. A. COOK	E. R. GEIB	J. H. KURLANDER
W. B. COOK	N. B. GREEN	R. P. MAY
H. A. DEVRY	H. GRIFFIN	R. F. MITCHELL
E. GALE	L. A. JONES	A. SHAPIRO

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[1] BEGGS, E. W.: "Standardization of Projection Lamps," *J. Soc. Mot. Pict. Eng.*, **XIX** (July, 1932), No. 1, p. 817. MILI, J. T.: "Biplane Filament Construction—A High Intensity Incandescent Lamp Light Source for Motion Picture Projection," *J. Soc. Mot. Pict. Eng.*, **XIX** (July, 1932), No. 1, p. 829.

DISCUSSION

MR. E. W. BEGGS: In his presentation, Mr. Farnham referred to my last year's paper on standardization of lamps, and perhaps some will think of the Westinghouse Lamp Company as being entirely responsible for this revolutionary change in lamps. I should like to emphasize that it is a joint venture of the General Electric Company and the Westinghouse Lamp Company.

Some projector manufacturers have recently designed projectors around a 400-watt biplane filament lamp, which is omitted from the new list. However, the 400-watt lamp will always be available for those who need it. The number of projectors that can not use a 500-watt type, but can use a 400-watt, is small.

This line of lamps that the Committee has presented represents a goal. It is the duty of projector manufacturers to adhere to it. A line presented here will do no good unless the projector manufacturers use it fully.

About a year ago one large manufacturer said to me, "How can I standardize my projectors when every year or every six months the lamp manufacturers bring out a new and improved device? Can we ever hope to adhere to one design or standard line?" As to the answer: the design features of these lamps are such as to indicate a stopping point beyond which marked improvements can not be made within a short period of time. We have reached a point where we can stand on the merits of the achievement, possibly, for some years.

SOME PROPERTIES OF TWO-BATH DEVELOPERS FOR MOTION PICTURE FILM*

J. I. CRABTREE, H. PARKER, JR., AND H. D. RUSSELL**

Summary.—*It is well known that the properties of developers change during use as a result of depletion of the developing agents and accumulation of reaction products. This change is greatest for low-energy developers such as those of the borax type, and results in (1) a reduced development rate, and (2) a lowering of effective emulsion speed. These two effects may be offset to some extent by increasing the development time and by adding booster solutions to revive the developer. Another method of securing a more uniform degree of development throughout the life of a developer consists in using two developer baths in succession.*

Three types of two-bath developers have been investigated, as follows: (1) bath A contained all the developing agents plus sodium sulfite; bath B, all the alkali plus the balance of the sulfite. (2) Both baths contained developing agents. (3) Both baths were of identical composition, the first bath being replaced by the second as it became exhausted. The results of the investigation showed that Type I is the most satisfactory developer combination and with this method it is possible to obtain an almost constant gamma with only a slight loss of emulsion speed over a fairly wide range of time of development. A formula is also suggested for the development of variable density sound negatives. The application of two-bath developers to machine, and rack and tank systems is described.

The idea of developing a photographic image by successive immersions in two separate solutions is by no means new. A large number of workers have investigated the effect of starting development in a weak developer and then, according to the manner of appearance of the image, continued the development in either a restrained, normal, or very active developer.[1] In the case of negatives exposed under widely varying conditions of lighting, such a method appears to have merit.

Other workers[2,3] have claimed that in the case of an underexposed negative of a contrasty subject, if the negative is first immersed in a developing solution which does not contain alkali (A), and is then placed in a second solution containing only alkali and sulfite (B), the

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* Presented at the Spring, 1933, Meeting at New York, N. Y.

** Eastman Kodak Co., Rochester, N. Y. Communication No. 517 from the Kodak Research Laboratories.

quantity of developer absorbed by the film in *A* is sufficient to assure adequate development of the shadows in *B;* whereas in the case of the highlights, the developing power of the developer is exhausted before full development is attained. In this way, good shadow detail is obtained while the highlights are not overdeveloped.

At the outset it was considered that the two-bath method of treatment might permit the development of motion picture film to a fixed degree of development or gamma irrespective of the time of development beyond a certain critical value; that is, if the gelatin emulsion absorbed a definite volume of developer in the first bath, this portion would only be sufficient to develop the image to a definite maximum contrast in the second bath, provided the latter contained enough alkali.

So far as is known, the two-bath method of development has been given very little consideration by motion picture laboratories, although some of the advantages of this method have been pointed out by Dundon, Brown, and Capstaff.[4] The merits of this method as applied to motion picture film, therefore, seemed worthy of more thorough investigation.

I. EXPERIMENTAL PROCEDURE

General methods of testing the photographic properties of developers have been described by one of the authors,[5] and the interpretation of results obtained by the sensitometric method of Hurter and Driffield (H&D) has been discussed by Jones and Crabtree,[6] and more recently by Jones.[7]

The sensitometric measurements in this investigation were made with Eastman motion picture supersensitive panchromatic negative film, exposed through step tablets on a Bell & Howell continuous printer to a tungsten light source diffused with ground glass for an exposure time of $^1/_{32}$ second, thus receiving an intensity-scale exposure.

Development was carried out in a miniature duplicate of the rack and tank apparatus used for the commercial development of motion picture film. Small racks holding six 10-inch strips of motion picture film were placed in glass battery jars containing one-half gallon of developer, which jars were immersed in a water bath to control the temperature. It has been found that with the proper manipulative technic this method of development gives more consistent results than any of the other usual small-scale processing methods.

For the exhaustion and graininess tests, 50-foot lengths of motion picture film were developed in 1-gallon tanks of solution, and the fine-grain developer formula *D-76* was used as the standard with which the various experimental developers were compared.

II. TYPES OF TWO-BATH DEVELOPERS INVESTIGATED

This investigation has been limited to a study of three types of two-bath developers as follows: (1) Those of Type I, in which the first bath contained all the developing agents plus sodium sulfite, while the second bath contained all the alkali plus sodium sulfite; (2) those of Type II, in which both the first and the second

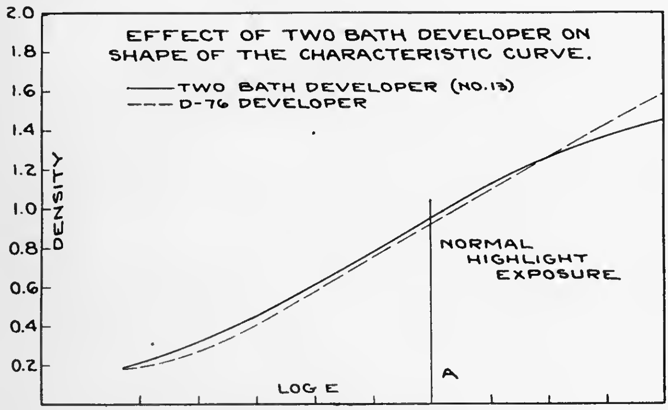

FIG. 1. Effect of two-bath developer on shape of the characteristic curve.

baths contained developing agents; and (3) those of Type III, in which the first and second baths were complete developers having identical compositions.

A few of the developer formulas investigated which represent the various types are given in Table I. The concentrations of the constituents are given as grams per liter, and the relative speed and fog values were measured at a gamma of approximately 0.7.

III. PHOTOGRAPHIC CHARACTERISTICS OF DEVELOPERS OF TYPE I

A. Shape of the Characteristic H&D Curve

At the outset it was considered that by the two-bath method of development it might be possible to increase the steepness of the toe gradient of the characteristic H&D curve, which would result

TABLE I

Developer Formulas
(65° F.)

	First Bath					Second Bath					Time in First Bath (Min.)	Gamma			Relative Speed	Fog	*p*H	
Exp. No.	Elon	Hydro-quinone	Sodium Sulfite		Borax	Elon	Hydro-quinone	Sodium Sulfite	Borax	Boric Acid		(Time in Second Bath) 6	10	12	(Gamma = 0.7)	(Gamma = 0.7)	First Bath	Second Bath
1	2	5	100		2	Single Solution					.	0.40	0.60	0.66	100	0.17	...	8.7
Type I																		
2	10	..	100		..	.	.	100	4	..	8	0.70	0.77	..	100	0.14	7.6	8.9
					Sodium Bisulfite													
3	10	..	100		10	.	.	100	10	..	8	0.56	0.61	..	76	0.10	7.3	9.6
4	4	10	100		..	.	.	100	8	8	8	0.60	0.65	..	72	0.12	7.9	8.4
5	5	..	100		..	.	.	100	4	..	8	0.58	..	..	...	..	7.8	8.9
										Sodium Carbonate								
6	5	..	100		..	.	.	100	..	5	8	0.64	0.64	..	100	0.18	7.8	11.0
7	5	..	100		..	.	.	100	..	50	8	0.66	0.66	..	130	0.23	7.8	12.0
8	5	..	100		..	.	.	100	25	..	8	0.66	0.66	..	100	0.14	7.8	10.0
				Sugar														
9	5	5	100	100	5	.	.	100	..	10	4	0.70	..	..	110	0.18	7.8	11.4
10	5	5	100	100	5	.	.	100	..	50	4	0.90	..	..	100	0.24	7.8	12.0
11	5	10	100	...	..	.	.	100	10	..	6	0.64	0.68	..	100	0.14	7.8	9.6
12	6	3	100	...	..	.	.	100	10	..	6	0.63	0.64	..	100	0.16	7.7	9.6
13	5	2	100	100	5	.	.	100	..	10	4	0.52	..	..	140	0.15	...	..

Type II—Class A

				Borax													
14	5	..	100	..	.	5	100	10	..	6	0.76	0.95	..	100	0.14	7.8	9.6
	Class B																
15	2	..	100	5	2	5	100	2	..	3	0.58	..	0.72	100	0.16	9.4	8.7
16	5	..	100	10	2	5	100	2	..	3	0.50	..	0.74	100	0.16	8.8	8.7
17	2	..	100	20	2	5	100	2	..	3	0.50	..	0.74	100	0.15	9.4	8.7
18	2	..	100	20	2	5	100	2	..	3	0.54	..	0.74	100	0.16	9.0	8.7
Type III																	
19	2	5	100	2	2	5	100	2	..	2	0.53	0.66	0.78	100	0.18	8.7	8.7

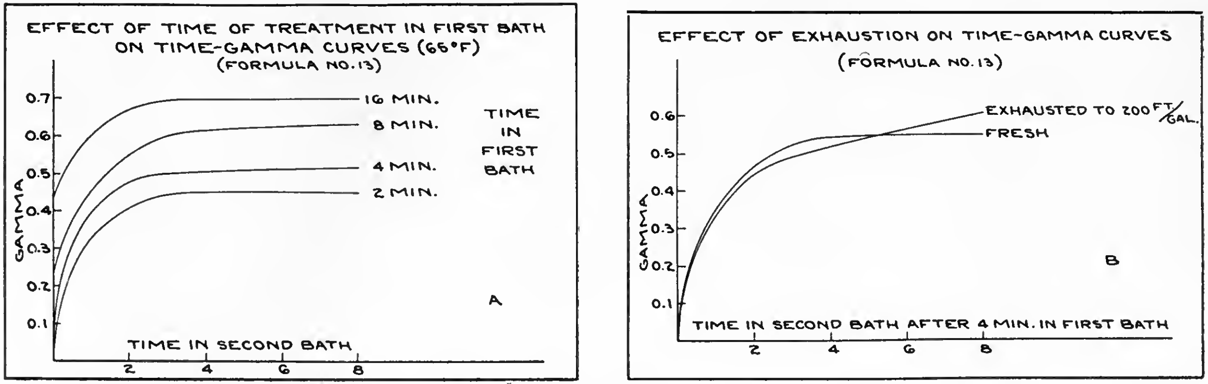

FIG. 2. (a) Effect of time of treatment in first bath on time-gamma curves (65°F.) (Formula No. *13*); (b) effect of exhaustion on time-gamma curves (Formula No. *13*).

in greater picture shadow detail and an increase in the effective emulsion speed. Tests showed that the developers with a high concentration of alkali in the second bath gave slight increase in speed, but the increase was not great enough to be noticeable in camera exposures.

In order to test the effect on the latitude, strips of film were given comparatively heavy exposures through the step tablets, and developed in two-bath developers and in the single-bath developer *D-76*.

As illustrated in Fig. 1, the strips treated in the two-bath developer (formula *13*) showed a suggestion of a shoulder at the upper end of the curve while those treated in the *D-76* developer were perfectly straight. However, since the highlight exposures in an average normally exposed camera negative were equivalent to an exposure value *A*, which is well down on the straight-line portion of the curve, it would require more than eight times the normal exposure before this effect could be detected in a picture negative. For this reason, the slight loss in latitude is of very little practical importance.

B. Effect of Various Times of Treatment in the First Bath on Time-Gamma Curves

The effect of varying the times of immersion in both the first and second baths of formula No. *13* at 65°F. is shown in Fig. 2 at *A*. The shape of these time-gamma curves is characteristic for all developers of Type I, although the increase in gamma with increasing times of treatment in the first bath varies with the different formulas, and is a minimum with those containing restraining agents.

From the curves it is seen that for a short time of immersion in the first bath the degree of development increased rapidly during the first 2 minutes of treatment in the second bath, but increased only very slowly between 2 and 4 minutes and became practically constant after 4 minutes. As the time of treatment in the first bath increased, there was less and less increase in the degree of development after immersion in the second bath; that is, the time-gamma curve for the second bath became more nearly flat. In all cases there was little increase in the degree of development after 2 minutes in the second bath. This means that this method is not suitable in cases where it is desired to control the gamma over a considerable range, but that it is advantageous where, as is normally the case in modern laboratory practice, a fixed gamma is desired.

C. *Effect of Restraining Agents in the First Bath on the Time of Appearance of the Image*

With an ordinary developer, its properties change during use as a result of the accumulation of the by-products of the development reaction. With two-bath developers it is not necessary that any development reaction occur in the first bath but only that the emulsion absorb enough developing agents to carry out the development process when placed in an alkaline second bath. Under such conditions the solution of the first bath should last indefinitely, requiring only the addition of enough liquid to replace that carried

TABLE II

Effect of Restraining Agents on the Time of Appearance of the Image

Restraining Agent	Quantity (Grams per Liter)	Time of Appearance
None		2 Min.
Sodium sulfate (desiccated)	5	2 Min.
Sodium sulfate (desiccated)	25	3 Min.
Sodium sulfate (desiccated)	100	6 Min.
Cane sugar	5	2 Min.
Cane sugar	25	2 Min.
Cane sugar	100	3 Min.
Cane sugar	200	4 Min.
Cane sugar Sodium bisulfite	100 5	5 Min.
Cane sugar Sodium bisulfite	100 10	7 Min.

out by the film. However, developers containing elon, either with or without hydroquinone, and a high concentration of sodium sulfite, were quite active and produced an image in less than 2 minutes. From practical considerations it appeared that the film should remain in the first bath at least 4 minutes, and an attempt was therefore made to increase the time of appearance of the image of a normally exposed negative to at least 4 minutes by the addition of restraining agents.

When sodium bisulfite was added to decrease the alkalinity of the first bath of formula No. *5*, it was found that 10 grams per liter, which decreased the alkalinity to a *p*H of 7.6, were necessary to delay the appearance of the image sufficiently. This concentration of bisulfite, however, gave low speeds when the second bath of the developer had a low alkalinity; and in all cases it tended to lower the alkalinity of the second bath on exhaustion, and so cause an excessive change in the photographic properties. Other restraining agents were tested, therefore, which gave the results shown in Table II. The developer used was No. *12* (Table I).

Sodium sulfate reduced the solubility of the developing agents, and the addition of only 25 grams per liter caused a slight precipitation of the developing agents at 65°F. The effect of glycerin was found to be practically identical to that of sugar, which was considered preferable for economic reasons.

For the succeeding tests the following formula was used with variations in the concentrations of developing agents and alkali and the addition at times of other substances, such as antifogging agents. It is formula No. *13* in Table I.

Two-Bath Developer, Formula No. 13

	First Bath	Second Bath
Elon	5 grams	
Hydroquinone	2 grams	
Sodium sulfite (desiccated)	100 grams	100 grams
Sodium carbonate (desiccated)		10 grams
Sugar	100 grams	
Sodium bisulfite	5 grams	
Water to make	1 liter	1 liter

D. *Effect of the Alkalinity of the Second Bath on the Maximum Gamma, Fog, and Emulsion Speed*

The relation between the alkalinity of the second bath and the maximum gamma, fog, and emulsion speed was determined for elon developers with formulas Nos. *5*, *6*, *7*, and *8*, and for elon-hydroquinone developers with formulas Nos. *9* and *10*.

From the data in Table I it is seen that for the pure elon developers the maximum gamma was independent of the concentration and nature of the alkali present in the second bath, but when hydroquinone was present the alkalinity of the second bath had a decided influence on the maximum gamma. Tests on numerous other developers showed that this was due to the hydroquinone rather than to the restraining agents, which were also present in the developers listed.

In general, an increase in the alkalinity of the second bath had a tendency to increase the emulsion speed, but it also caused an increase in the fog. A number of antifogging agents such as potassium bromide, potassium iodide, and several organic compounds[8] were tested; and it was found that for the developers containing 10 grams per liter of sodium carbonate, the addition of 0.5 gram of potassium bromide and 0.01 gram of potassium iodide to each liter of the second bath reduced the fog sufficiently without affecting the speed excessively. For the higher gamma developers containing 50 grams per liter of carbonate in the second bath, it was desirable to double these quantities.

E. Effect of Temperature of Baths on Gamma and Speed

Since the gamma obtained by this method of development depends on the quantity of developing agents absorbed by the emulsion, which is determined by the degree of swelling, it was desirable to ascertain the relation between the temperature and the degree of development. The data in Table III show that with developer No. *13* the change in gamma with temperature, at least between 55° and 75°F., is not excessive.

TABLE III

Effect of Temperature on Maximum Gamma

Temperature	Maximum Gamma after 3 Min. in First Bath	Maximum Gamma after 5 Min. in First Bath
55°F.	0.39	0.43
65°F.	0.48	0.55
75°F.	0.56	0.63

The variations in temperature also caused variations in the emulsion speed, a temperature rise of 1 degree raising the speed about 2 per cent, but this increase was not sufficient to make the higher temperatures desirable.

F. Method of Controlling the Degree of Development

With the ordinary single-bath developers, the degree of development is controlled by varying the time of treatment. Two-bath developers of Type I, however, were so designed that variations in the time of treatment would have a minimum effect on the degree of development. For this reason, the usual method of controlling the gamma was not applicable to the two-bath developers, and it was necessary to seek some other means of regulating the gamma obtained. Temperature changes and changes in the degree of agitation caused variations in the degree of development, but the range covered was too narrow to be of practical use. Variation in the concentrations of the developer constituents caused a wide variation in the gamma obtained. Since in the cases where this type of development would be applicable the gamma desired is known definitely in advance, it was considered that control of gamma by adjustment of the composition of the solutions would be quite satisfactory.

The following variables in the formula directly affect the gamma:

(*a*) The concentration of elon.
(*b*) The concentration of hydroquinone.
(*c*) The alkalinity of the second bath.

The data in Table IV show the effect of changes in these three factors with developer No. *13* as a base.

TABLE IV

Relation between Concentration of Developing Agents, Alkalinity of Second Bath, and Maximum Gamma

Elon (Grams per Liter)	Hydroquinone (Grams per Liter)	Maximum Gamma: 10 Grams per Liter Carbonate in Second Bath	Maximum Gamma: 50 Grams per Liter Carbonate in Second Bath
2	0	0.25	0.27
2	1	0.34	0.44
2	5	0.62	0.73
2	10	0.69	0.83
5	2	0.50	
5	5	0.70	0.90

Changes in the alkalinity of the second bath had little effect on the pure elon developer as noted above, but had an increasing effect as the quantity of hydroquinone increased. Increase in the elon concentration caused the gamma to increase by an amount which was apparently independent of the hydroquinone concentration. Increasing the hydroquinone concentration from 0 to 5 grams per liter caused a large increase in gamma, but an increase from 5 to 10 grams per liter caused little further change. For practical work, satisfactory concentrations would be: for gammas from 0.5 to 0.7, 5 grams per liter of elon, 2 to 5 grams per liter of hydroquinone, and 10 grams per liter of carbonate; and for gammas from 0.7 to 0.9, the same elon and hydroquinone concentrations with 50 grams per liter of carbonate in the second bath.

G. *Effect of Exhaustion on the Time-Gamma Curve, Emulsion Speed, and Fog*

Practically all the changes occurring in a developer of Type I on exhaustion take place in the second bath. The first bath changes slightly by virtue of the solvent action of the sodium sulfite on the silver bromide in the emulsion and the reduction of this silver bromide to metallic silver. From practical considerations, however, these changes are negligible. In the second bath, however, a number

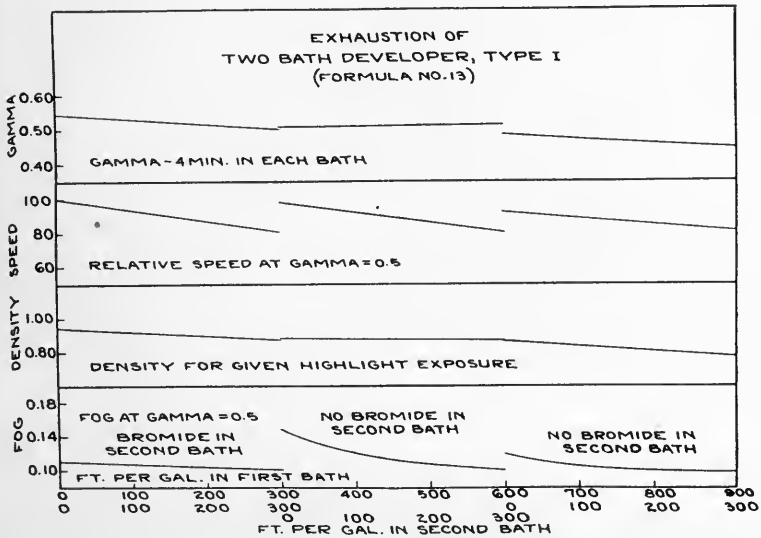

FIG. 3. Chart showing exhaustion of two-bath developer, Type I (Formula No. *13*).

of important changes occur. There is an accumulation of bromide and iodide and of the oxidation products of the developing agents which are by-products of the development reaction, and these products tend to restrain development.[9] On the other hand, there is a gradual accumulation of the excess developing agents carried over by the film from the first bath, which tends to continue the development after the developing agents absorbed by the emulsion have been exhausted. These two opposing effects cause a change in the shape of the time-gamma curve. During the first few minutes of treatment in the second bath the effect of the restraining forces predominates, and the time-gamma curve falls below that for the fresh developer; but later the accumulated developing agents prevent the flattening of the curve, so it continues to rise and crosses the curve for the fresh developer. In order to maintain the most uniform properties in the developer, the quantity of developing agents carried into the second bath should therefore be kept as low as possible. In Fig. 2 are given the time-gamma curves obtained at two stages in the exhaustion of the baths of formula No. *13* containing 0.5 gram of potassium bromide and 0.01 gram of potassium iodide per liter in the second bath.

Data showing the changes in other properties of this developer are given in Fig. 3, where the gamma, relative emulsion speed, density, and fog are plotted against the number of feet of film developed per gallon of developer. The exhaustion was carried out in a small tube developing machine, and the film squeegeed by means of cotton as it left the first bath so as to reduce the volume of the first bath carried over into the second. The film was flashed to give a uniform density of 0.9 in this developer. The first bath was exhausted with 900 feet of film per gallon and the only revival was the addition, every 300 feet, of sufficient fresh solution to replace that carried out by the film. The second bath was changed every 300 feet per gallon, and the bromide and iodide were omitted after the first 300 feet had been processed.

It is seen from Fig. 2 at *B* that over a developing range of 4 to 6 minutes in the second bath the gamma changed only from 0.52 to 0.56, even after exhaustion with 200 feet of film per gallon. With the fresh developer there was no change in gamma. It is considered that with air squeegeeing, the change in gamma on exhaustion would be even less than indicated above. From Fig. 3 it is seen that the speed loss was only 20 per cent of the original speed after exhaustion with 300 feet of film per gallon, and that the first bath was practically unaffected, since the renewal of the second bath brought the speed back almost to the original value. After 600 feet per gallon had been processed, the first bath began to be affected, as is shown by the slight drop in gamma.

II. Use of Two-Bath Developers with Sound Recording Films

For the development of variable density sound records, relatively low gammas (around 0.5) are required for the sound negatives, and relatively high gammas for the combined picture and sound positives. With regard to the latter, even with the use of caustic alkalies in the second bath, it was not possible to obtain sufficiently high gammas (around 2.0) with existing sound recording films.

Preliminary tests indicated that in general the factors to be considered in the development of sound recording films were similar to those which applied in the case of picture negative films, although since the former as a class are relatively fine grained, the concentration of the sulfite in the developer solutions was found to be important.

High sulfite concentrations caused distortion of the characteristic curve of Eastman motion picture films, emulsions Nos. *1301* and *1359*, manifested by the total absence of a straight-line portion. When the sulfite concentrations were lowered to 10 grams per liter in the first bath and 25 grams per liter in the second bath, this distortion disappeared, and these sulfite concentrations were sufficient to prevent excessive aerial oxidation. The following formula was chosen for further tests:

	First Bath	*Second Bath*
Elon	7 grams	
Sodium sulfite (desiccated)	10 grams	25 grams
Sodium carbonate (desiccated)		10 grams
Sodium bisulfite	2 grams	
Sugar	100 grams	
Water to make	1 liter	1 liter

With the above formula, the following properties were investigated:

(*1*) *Time-Gamma Characteristics.*—Table V shows the gammas obtained for various times of treatment in the second bath after 3 minutes in the first bath, and also the gammas obtained with the same film in *D-76*. Practically no action occurred during the time of treatment in the first bath but immediately on immersion in the second bath, the development proceeded rapidly and was practically complete within 1 minute.

TABLE V

Comparison of the Effect on the Gamma of Negative Sound Records of Varying Times of Development in D-76 and in a Type I Two-Bath Developer

Two-Bath Developer Time of Treatment			*D-76*	
First Bath	Second Bath	Gamma	Time	Gamma
3 Min.	0 Min.	0.0	2 Min.	0.29
3 Min.	1 Min.	0.49	3 Min.	0.49
3 Min.	3 Min.	0.52	4 Min.	0.64
			5 Min.	0.74

(*2*) *Effect on Latitude and Resolving Power.*—There was very little difference between the latitudes obtained in the *D-76* and the two-bath developers, although a slightly greater speed was obtained with the two-bath formula. The resolving power was equal to that observed with formula *D-76*.

(*3*) *Changes during Exhaustion.*—Fig. 4 shows the changes in gamma, speed, and highlight density during the exhaustion of *D-76* and of the two-bath developers with Eastman motion picture film, emulsion No. *1301*. The *D-76* exhaustion was carried out in a small tank apparatus, while the two-bath developer was exhausted in a small tube developing machine in which the film was squeegeed

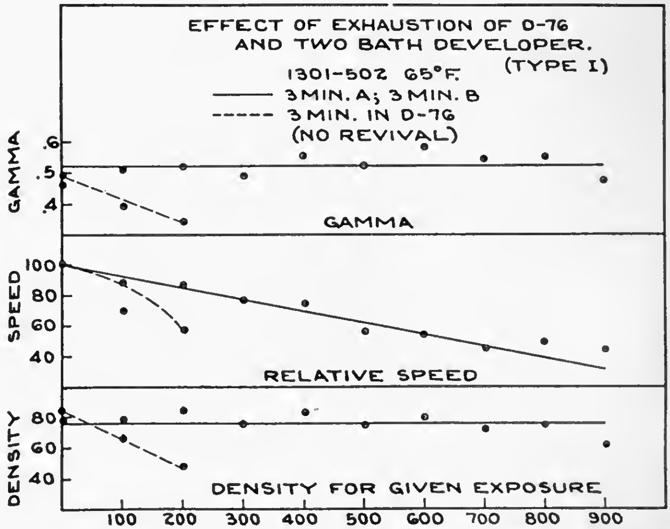

FIG. 4. Effect of exhaustion of *D-76* and two-bath developer (Type I).

between the first and second baths. The sensitometric strips were developed in the machine.

In the *D-76*, the speed, gamma, and density all dropped rapidly on exhaustion, while in the two-bath developer, the gamma and density remained approximately constant and the speed dropped gradually.

(*4*) *Control of Gamma.*—Table VI shows the effect on gamma of changes in the concentrations of developing agents. Gammas up to 0.6 are readily obtained with elon alone, but for gammas above 0.6 it becomes advisable to reduce the elon concentration and add hydroquinone.

IV. PHOTOGRAPHIC CHARACTERISTICS OF DEVELOPERS OF TYPE II

Developers of Type I were considered suitable when a definite predetermined gamma was required, but in order to be able to vary the degree of development in the case of negatives exposed under widely varying conditions, a further study was made of developers of Type II which contained developing agents in both baths.

The two-bath developers of Type II were divided into two classes, *A* and *B*. Those of class *A* contained developing agents and sodium sulfite in both baths with all the alkali in the second bath, and those of class *B* contained developing agents, sodium sulfite, and alkali in both baths but in different proportions. Although with developers of class *A* such as No. *14* it was possible to control the degree of development in the second bath, the emulsion speed decreased

TABLE VI

Effect of Varying Elon and Hydroquinone Concentrations on the Gamma of a Two-Bath Sound Record Developer

Elon Concentration (Grams per Liter)	Hydroquinone Concentration (Grams per Liter)	Gamma
5	0	0.44
7	0	0.52
10	0	0.60
5	2	0.69
5	4	0.81
5	10	1.05

rapidly on exhaustion for gammas less than 0.5. For this reason, the class *A* developers of this type were not investigated further.

Previous experiments[9] have indicated that the by-products of development which accumulate during exhaustion of the *D-76* developer rapidly decrease not only the effective emulsion speed but also the rate of development. In order to prevent to a certain extent this change in the photographic properties of the developer, it was recommended that after 80 feet per gallon of motion picture panchromatic negative film had been processed, the bath should be revived with one-half the original quantities of elon, hydroquinone, and borax dissolved in hot water, with the addition of enough sodium sulfite to make its concentration in the reviving solution equal to 10 per cent. By this procedure it was possible to maintain the rate of development fairly constant, and also to maintain a higher emulsion speed than without revival, but there was an inevitable loss in speed as the developer aged. At the outset, it was considered that the emulsion speed could be maintained by the two-bath method of development according to the procedure suggested by Dundon, Brown, and Capstaff,[4] and that possibly the rate of development could be maintained constant by so adjusting the composition of the first bath that the developer carried over into the second would serve as a replenishing solution for the latter. Accordingly, developers of Type II, class *B*, were compounded.

A. Factors Influencing the Choice of Formula for First Bath

In the choice of a formula for the first bath, it was necessary to consider the following:

(1) The quantity of developer carried over by the film.
(2) The limiting solubility of the constituents.
(3) The formula of the second solution.
(4) The restraining action of the reaction products accumulated in the second bath.

A consideration of these factors indicated that the first bath which is to act as a replenisher for the second should increase the alkalinity and concentration of the developing agents in the second bath during exhaustion. On the other hand, it should not be so concentrated that any considerable degree of development occurs during the time of treatment in the first bath, since in such a case the first bath itself would become exhausted too rapidly. Also, since it is desirable to be able to use desensitizers in the first bath, and since the presence of hydroquinone tends to cause the precipitation of many desensitizers, this reducing agent was omitted from the formulas tested. The study of developers of this type was also limited to those in which the first bath contained elon, borax, and sulfite, while the second bath consisted of the regular *D-76* formula.

B. Exhaustion Tests with Type II Developers

In the following exhaustion tests sensitometric strips were developed in the fresh baths and after every 50 feet of film per gallon had been processed. The baths were exhausted by developing lengths of motion picture panchromatic negative film, flashed so that a density of 1.0 was obtained when developed for 12 minutes in fresh *D-76*. The film was bathed for 3 minutes in the first bath, and for the remainder of the time in the second.

In order that the results might be compared with those obtained with the *D-76* developer under the most favorable conditions, the

D-76 developer was revived in a manner similar to that recommended in a previous investigation[9] described above.

The chief factors considered in comparing the properties on exhaustion included (1) the change in the gamma and shape of the characteristic curve; (2) the loss in emulsion speed and change in fog for a given gamma; and (3) the decrease in density for a given exposure.

The effects of exhaustion of the single-bath *D-76* developer with

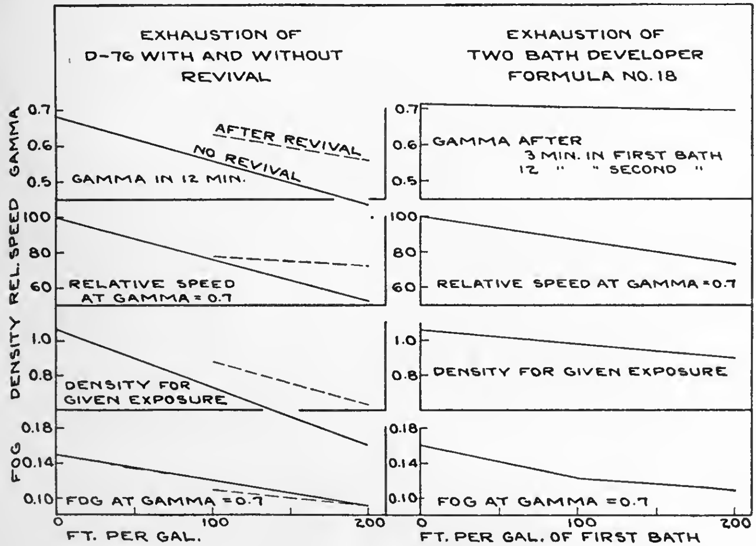

FIG. 5. FIG. 6.

FIG. 5. Chart showing exhaustion of *D-76* with and without revival.
FIG. 6. Exhaustion of two-bath developer, Type II (Formula No. *18*).

motion picture negative film are shown in Fig. 5. The results indicate, as has been previously shown,[9] that the products of exhaustion rapidly affect the photographic properties of the developer. The properties are revived by additional quantities of developing agents and alkali, but even then they decrease rapidly on further exhaustion.

The effect of exhaustion to 200 feet of negative film per gallon on several two-bath developers is shown in Table VII. The constituents in grams per liter are given for the first bath only, since *D-76* was used as the second bath in all cases. The first bath was compounded with 100 grams per liter of sodium sulfite, and throughout the exhaustion the film was bathed for 3 minutes in the first bath and for the remainder of the time of development in the second bath.

Since very little development occurred in the first bath, it did not exhaust rapidly, and therefore furnished a fresh supply of developing agents to the second bath.

A study of the results in Table VII indicates that it was necessary to increase the concentration of both the developing agents and alkali in the second bath in order to maintain the rate of development constant, and in no case was it possible to obtain a constant emulsion speed. Other experiments were made to obtain a developer with which the emulsion speed did not decrease on exhaustion, but this was not possible with the use of elon-borax formulas tested for the first developer.

TABLE VII

Exhaustion of Two-Bath Developers, Type II (65°F.)

Formula No.	First Bath*		Fresh Developer			Exhausted Developer			Time of Bathing
	(Grams per Liter) Elon	Borax	Gamma (12 Min.)	Relative Speed (at Gamma = 0.7)	Fog	Gamma	Relative Speed (at Gamma = 0.7	Fog	(First Bath)
15	2	5	0.72	100	0.16	0.64	72	0.12	3 Min.
16	5	10	0.74	100	0.15	0.62	60	0.12	3 Min.
17	2	20	0.74	100	0.16	0.66	71	0.10	3 Min.
18	5	20	0.74	100	0.16	0.70	71	0.11	3 Min.

* Second bath = *D-76*.

The change in photographic properties of formula No. *18* (Table VII) on exhaustion is shown in detail in Fig. 6. A comparison of the curves with those in Fig. 5 shows that except for the loss in emulsion speed, the photographic properties of this developer are maintained more uniformly than those of the *D-76* developer revived. The loss in the emulsion speed is practically equal in both cases.

V. PHOTOGRAPHIC CHARACTERISTICS OF DEVELOPERS OF TYPE III

The only experiments made under this classification were with two baths of formula *D-76*. Dundon, Brown, and Capstaff[4] have stated that the loss in emulsion speed in an exhausted developer is due to the solvent action of the sulfite on the latent image during the period of induction, which is greatly lengthened by the presence of accumulated bromide. If this is so, there should be no loss in emulsion speed if development is started in a fresh developer until the image appears and is then continued in an exhausted or bromided developer. Since tests made in the above investigation seemed to

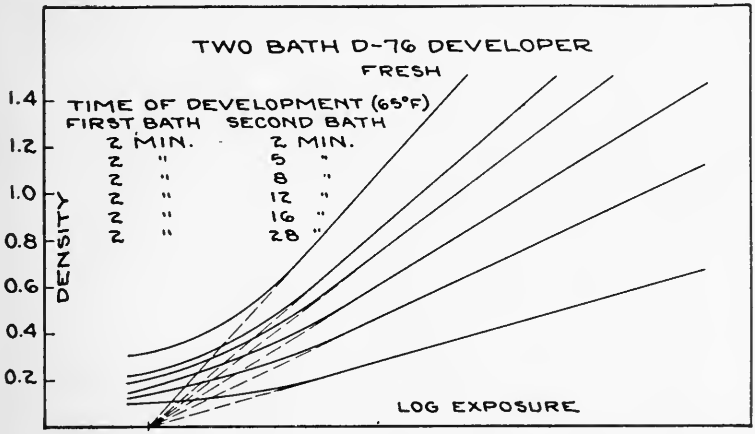

FIG. 7. Characteristic curves of motion picture panchromatic negative film with two-bath *D-76* developer, neither bath being bromided.

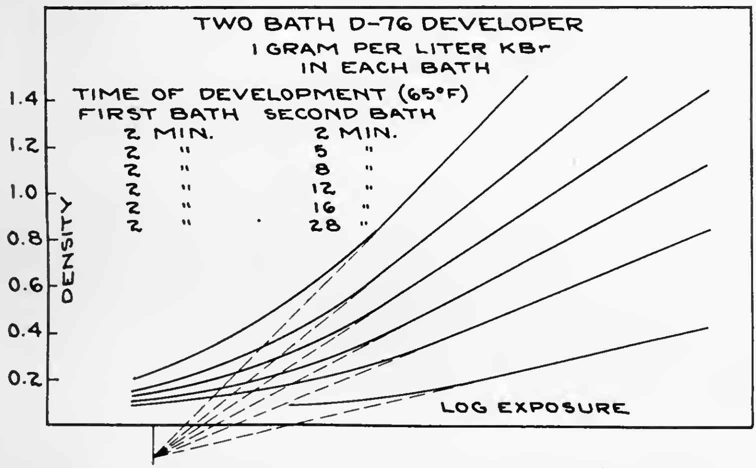

FIG. 8. Characteristic curves of motion picture panchromatic negative film with two-bath *D-76* developer, the two baths being bromided to the same degree.

substantiate this conclusion, further practical tests of the method were undertaken.

A. Effect of Bromide in Two-Bath Developers

Since the changes in the properties of a developer during exhaustion are undoubtedly due largely to the influence of bromide, iodide, and other reaction products of development rather than to an actual

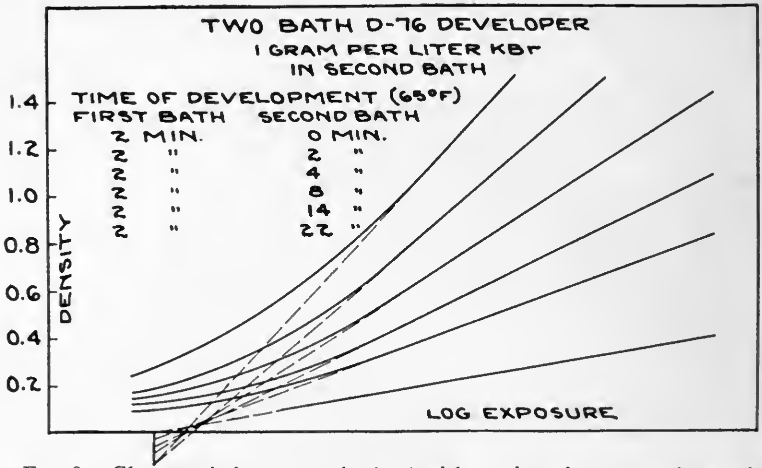

FIG. 9. Characteristic curves obtained with motion picture panchromatic film, the development being started in an unbromided developer and completed in a bromided developer.

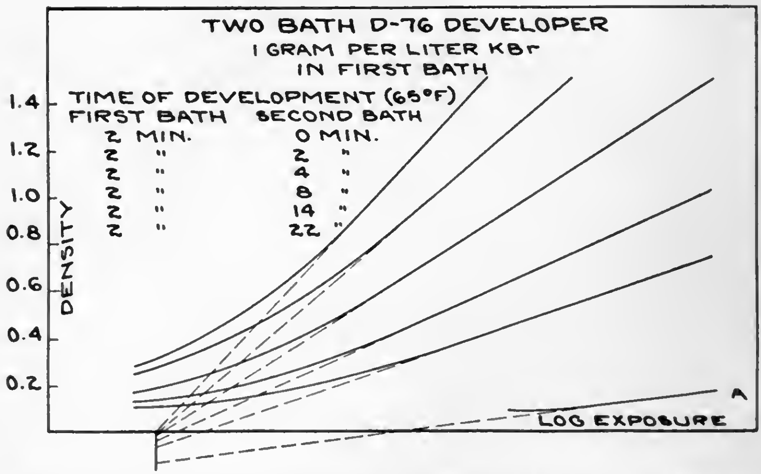

FIG. 10. Characteristic curves obtained with motion picture panchromatic negative film, the development being started in a bromided developer and completed in an unbromided developer.

exhaustion or oxidation of the developing agents, and since the effect of bromide in single-bath developers has been carefully investigated, a study of the effect of bromide in two-bath developers was undertaken.

Previous investigators[10] have found that with certain emulsions and certain unbromided developers, the tangents to the straight-line portions of a series of characteristic curves for various times of development meet in a common point of intersection on the log E axis. The addition of bromide to the developer causes a downward displacement of this intersection point. Motion picture panchromatic negative film, with developer *D-76*, gives curves of this type. Similar results are obtained with two-bath developers when both baths are unbromided and when both baths are bromided to the same degree, as is shown by the curves in Figs. 7 and 8. The effects on this displacement of the intersection point when (*a*) development is started in an unbromided developer and completed in a bromided developer, and (*b*) when development is started in a bromided developer and completed in an unbromided developer, are shown in Figs. 9 and 10. The curves in Fig. 9 were obtained when the film was first placed in a *D-76* developer for 2 minutes and then transferred to a *D-76* developer containing 1 gram per liter of bromide for the completion of development. It is seen that the tangent to the straight-line portion of the curve for the strip treated only in the plain developer intersects the log E axis at the normal point, but the strips which were treated for increasing times in the bromided second bath gave tangents showing a progressive lowering at this value of log E, until a maximum depression was obtained equal to that obtained with full development in a bromided developer. In Fig. 10, curve A shows the density lowering due to bromide, while the curves for longer times show a progressive elevation of the intersection point with the above log E value until, for long times of development, the effect of the bromide practically disappears. This shows that the effect of the bromide is not permanent, as it would be if a destruction of the latent image were involved, but is rather in the nature of a mass action effect where the bromide lowers either the solubility or degree of ionization of the silver bromide, thus retarding development. Tests were made with different concentrations of bromide and with developers of Type II, and all gave curves similar to those illustrated.

Several series of tests were then made, using fresh and exhausted *D-76* developers for the two baths. Except for slight deviations which were no greater than normal experimental error, all these tests gave results similar to those obtained with the bromided and unbromided developers. The results obtained in one of these series are given in Table VIII. One series of tests was conducted in 120-gallon tanks with developers which had been exhausted in the routine processing of motion picture film, and gave results parallel to those given in Table VIII.

B. Advantages of First Immersing the Film in a Fresh Bath

From the data in Table VIII it is seen that there is only a slight loss in emulsion speed if a fresh developer is used during part of

TABLE VIII

Effect of Using Fresh and Exhausted Developers in Two-Bath Development

Solutions		Time in First Bath	Gamma in Total Development Time				Total Time for Gamma of		Relative Speed at Gamma of	
			8 Min.	12 Min.	15 Min.	20 Min.	0.5	0.7	0.5	0.7
Fresh *D-76* (I)			0.54	0.70	0.78	0.91	7 Min.	12 Min.	100	100
D-76 Exhausted to 200 feet per gallon (II)				0.55	0.64	0.78		17 Min.		58
First Bath	*Second Bath*									
II	I	2 Min.	0.49	0.71	0.78	0.91	8 Min.	12 Min.	76	85
II	I	4 Min.	0.45	0.60	0.73	0.85	9 Min.	14 Min.	68	85
II	I	6 Min.	0.48	0.69	0.77	0.90	8 Min.	12 Min.	49	66
I	II	2 Min.		0.60	0.65	0.78	9 Min.	16 Min.	72	74
I	II	4 Min.	0.51	0.64	0.67	0.78	8 Min.	15 Min.	78	78
I	II	6 Min.	0.46	0.64	0.70	0.79	8 Min.	15 Min.	89	79

the development time. The question arises as to whether the fresh bath should come first or last. The table shows that for short times of treatment in the first bath, there is a slight advantage in using the exhausted bath first. Practical considerations, however, make it desirable that the fresh solution be used as the first bath. When the film is transferred from the first bath to the second, it carries a considerable quantity of the solution with it. Therefore, if an exhausted bath were used first, the bromided developer would be carried into the fresh second bath, which would therefore rapidly become exhausted. The fresh bath should be exhausted no more rapidly than necessary, because when the exhausted bath is discarded, the partially exhausted developer may be used with a fresh bath through another exhaustion cycle. Also, if the fresh developer is used as the first bath, the portion of it carried into the exhausted bath will have somewhat of a reviving action and retard its exhaustion. For these reasons, in all the exhaustion tests made with this type of developer the fresh developer was used as the first bath.

C. Comparison of Properties of Two-Bath Type III Developers with a Single-Bath Developer on Exhaustion

Exhaustion tests were made to compare the behavior of developers using two baths of formula *D-76* with that of a single bath of *D-76*.

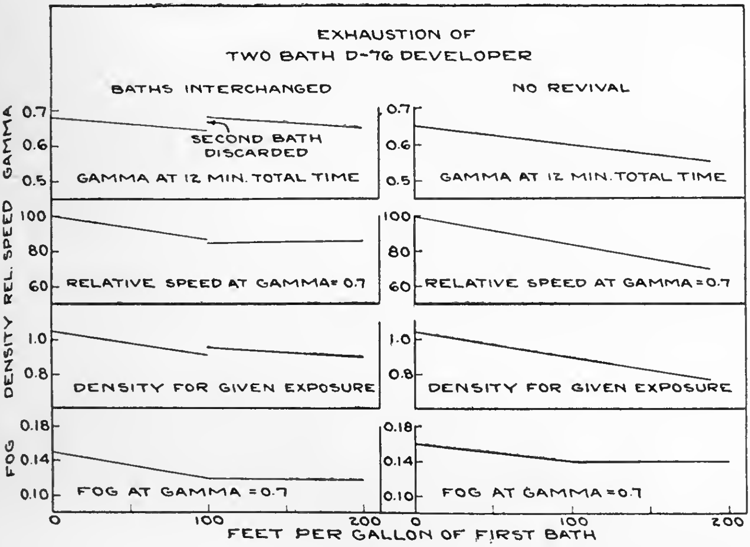

FIG. 11. FIG. 12.

FIG. 11. Chart showing exhaustion of two-bath *D-76* developer, the baths being interchanged. FIG. 12. Chart showing exhaustion of two-bath *D-76* developer, with no revival.

In all the two-bath tests the film was treated for 2 minutes in the first bath, then transferred to the second bath for the completion of the development. The procedure used during the exhaustions has been described under the discussion of developers of Type II.

Three different sets of tests were made as follows:

(1) Two baths of formula *D-76* were exhausted with 100 feet of

film per gallon. The second bath was then discarded, the first bath used as the second, and a fresh solution supplied for the first bath. This procedure was repeated every 100 feet per gallon.

(2) The second exhaustion test was similar to the above, but each set of solutions was exhausted to 200 feet per gallon before they were changed.

(3) In the third exhaustion the solutions were changed every 200 feet per gallon, but the second bath was revived after 100 feet per gallon, in a manner similar to that used with the single *D-76* bath. Figs. 11 and 12 show the changes in photographic characteristics during the first two of these exhaustions.

When the second bath was discarded every hundred feet, very uniform properties were obtained. The gamma obtained in 12 minutes varied between 0.70 and 0.64, while the greatest speed drop was to a value equal to 85 per cent of the original. These values should be compared with a gamma change from 0.68 to 0.55 and a speed drop to 72 per cent for the single-bath *D-76* developer with revival.

As explained above, the quantity of chemicals added during revival of the *D-76* developer was equal to one-half the original weight used except for the sulfite, so that the total quantity of chemicals used to develop 200 feet of film by this method was one and one-half times the quantity in the original formula.

Using the two-bath method, when the solutions were changed every 100 feet per gallon, the quantity of chemicals required for each 200 feet was equal to twice the weight of the chemicals in the original formula. Therefore, the two-bath method used only one-third more chemicals than the single bath, and gave much more uniform properties.

When the second bath was discarded every 200 feet per gallon, the drop in the rate of development and the loss in emulsion speed were of the same order as those obtained with the single-bath *D-76* developer revived, but the quantity of chemicals required to develop 200 feet of film by this method was equal to that in the original formula, and thus was one-third less than that required by the *D-76* developer revived.

When the second bath was revived after 100 feet of film had been processed per gallon very little, if any, advantage was obtained over the two-bath developer without revival, while the consumption of chemicals was increased.

VI. PRACTICAL APPLICATIONS

One of the most important problems confronting motion picture processing laboratories is that of securing a constant degree of development, especially with sound-on-film records. Formerly it was possible to compensate for variations in the gamma of the negative by varying the gamma of the positive print, but present practice requires that sound negatives be developed to a fixed gamma ranging from 0.40 to 0.7 in the various laboratories.[11] This determines the gamma for the projection positives at values ranging from 1.8 to 2.3, which, in turn, determines the gamma of the picture negative. The absolute gamma aimed at varies in the different laboratories, but this is immaterial so long as the product of the gamma of the negative and that of the positive sound record is approximately 1.2. Any considerable departure from the standardized gammas will cause a loss in quality of either the picture or the sound or both, and for uniform results they must be maintained.

All developers undergo changes in their characteristics during use as a result of the exhaustion of the developing agents and the accumulation of reaction products such as sodium bromide, which tends to restrain the development. This change is greatest for the low energy developers, such as those of the borax type, because they have much less power to resist the effect of bromide. These changes in properties are evidenced in two ways: (*a*) the rate of development is reduced, and (*b*) the effective emulsion speed is lowered.

In practice, these changes may be partially offset either by lengthening the time of development so as to obtain the desired gamma, or by adding booster solutions to revive the developer. The first of these methods requires frequent tests to determine the necessary time of development, while it does not compensate for the speed loss. The second method could, theoretically, with the proper control, maintain uniform results. In practice, however, it is difficult to hold the ratio between the quantity of booster added and the quantity of film processed at the proper value, with the result that the processing is not always absolutely uniform.

A. Two-Bath Developers

In no case is it possible to obtain absolutely uniform development properties throughout the life of a developer, but by the use of two-bath developers this condition is approached much more nearly than with single-bath developers which are suitably revived. The two-bath developers give a practically constant gamma throughout their life, and the emulsion speed loss is less than with single-bath developers. Since the properties of the various types of two-bath developers differ considerably, each type will be considered separately.

(*1*) *Two-Bath Developers of Type I.*—The outstanding characteristic of the two-bath developers of Type I is their ability to give an almost constant gamma over a wide range of time of development.

A satisfactory formula for a developer of this type designed to give a gamma between 0.5 and 0.55 with Eastman motion picture supersensitive panchromatic negative film is as follows:

Two-Bath Developer for Supersensitive Panchromatic Negative Film
(Formula SD-4)

	Avoirdupois		Metric
Solution A—First Bath			
Elon	5	lbs.	5.0 grams
Hydroquinone	2	lbs.	2.0 grams
Sodium sulfite, desiccated (E. K. Co.)	100	lbs.	100.0 grams
Sugar	100	lbs.	100.0 grams
Sodium bisulfite (E. K. Co.)	5	lbs.	5.0 grams
Water to make	120	gallons	1.0 liter
Solution B—Second Bath			
Sodium carbonate, desiccated (E. K. Co.)	10	lbs.	10.0 grams
Sodium sulfite, desiccated (E. K. Co.)	100	lbs.	100.0 grams
Potassium bromide	1/2	lb.	0.5 gram
Potassium iodide	70	grains	0.01 gram
Water to make	120	gallons	1.0 liter

The purpose of the sugar and the sodium bisulfite in the first bath is to restrain development and prevent the appearance of an image, thus greatly reducing the effect of exhaustion on the bath. If the sugar is decreased, the time of appearance of the image is decreased, while if the sodium bisulfite is decreased, the *p*H of the solution increases and the time of appearance of the image is decreased. It is not desirable that any image should appear during the period of treatment in the first bath as it would cause the more rapid exhaustion of the bath.

When the film is immersed in the first bath, the emulsion absorbs a definite volume of the solution containing the developing agents; and when the film is transferred to the second bath, the alkali acts on the developing agents in the emulsion, causing a fairly rapid rate of development. The developing agents held in the emulsion are soon exhausted by the reaction or by diffusion into the surrounding solution, so that after 3 or 4 minutes in the second bath no further developing action occurs. This effect is shown by the time-gamma curves in Fig. 2 at *A*. The curves also indicate that variation of the time of treatment in the first bath has only a slight effect on the gamma obtained.

Control of Gamma.—Since it is not practicable with these developers to vary the gamma by changing the time of treatment, the gamma

TABLE IX

Effect of Variation in the Composition of Type III Two-Bath Developers on the Gamma with Constant Time of Development

Gamma	First Bath	Second Bath	Time of Treatment First Bath	Time of Treatment Second Bath
0.5	*A*	*B*	4 Min.	4 Min.
0.7	*A* with 5 grams per liter of hydroquinone.	*B*	4 Min.	4 Min.
0.7	*A*	*B* with 50 grams per liter of sodium carbonate and double quantities of bromide and iodide.	4 Min.	4 Min.
0.9	*A* with 5 grams per liter of hydroquinone.	*B* with 50 grams per liter of sodium carbonate and double quantities of bromide and iodide.	4 Min.	4 Min.

must be varied by altering the composition of the baths. The gamma obtained with a given formula will vary slightly with different processing conditions, so that the exact composition for any desired gamma must be determined by trial. Table IX indicates the results obtained with various concentrations of developing agents and alkali.

The formulas in Table IX are only suggestions, since the same gammas can be obtained with other combinations. An increase of the elon and hydroquinone concentrations, separately or together, increases the gamma. Increasing the alkalinity of the second bath increases the gamma if there is hydroquinone in the first bath, but this has little effect if elon is the only developing agent present.

Since the developing action is dependent on the developing agents carried in the emulsion from the first bath, very heavily exposed portions of the film tend to exhaust the developing agents before the full density is reached. This effect is shown on the characteristic H&D curve by the appearance of a slight shoulder in the over-exposure region, as shown in Fig. 1. This effect is not of practical importance, however, since it could not be detected in an ordinary picture unless it were given at least eight times the normal exposure.

Graininess.—Experiments have shown that the above two-bath developer gives images, the graininess of which is of the same low order of magnitude as that given by the borax type of developer, which is as would be expected since the concentration of sulfite and the times of development are approximately equal with both types of developers.

Effect of Temperature.—The effect of temperature on this developer is not great, a 5-degree rise in temperature causing only a 10 per cent increase in gamma and a 10 per cent increase in speed.

Life of Baths.—Although this developer, by virtue of its constant gamma characteristics, has advantages over the single-bath developers when the solutions are fresh, its greatest advantage is realized on exhaustion. Since almost no development occurs in the first bath, it is exhausted only very slowly. The second bath accumulates sodium bromide and other restraining agents, but it also accumulates developing agents which are carried in by the film. The restraining agents slow down the development during the first part of the treatment in the second bath but the developing agents, in turn, accelerate the development during the latter part of the treatment. This effect is shown in Fig. 2 at *B*. If the quantity of developing agents added is kept at a minimum by thoroughly squeegeeing the film between the first and second baths, the gamma obtained with 4 minutes' treatment in each bath remains practically constant during exhaustion, and the emulsion speed loss is low. The behavior on exhaustion is shown in Fig. 3. The first bath was exhausted with 600 feet of film per gallon before it began to be affected sufficiently to lower the gamma. The second bath was discarded and replaced by a fresh bath after every 300 feet of film per gallon had been processed. With more thorough squeegeeing, as with an air squeegee, it should last even longer. Comparison of Fig. 3 with Fig. 5, which gives the characteristics of the single-bath borax developer *D-76*, shows that the two-bath developer can process three times as much film with an approximately equal speed loss and with practically no change in gamma.

Use with Sound Recording Films.—Two-bath developers of Type I are equally satisfactory for use with sound recording films where low gammas are required. The following formula is satisfactory:

Two-Bath Developer for Variable Density Sound Negatives (Formula SD-5)

	Avoirdupois	Metric
Solution A—First Bath		
Elon	7 lbs.	7.0 grams
Sodium sulfite, desiccated	10 lbs.	10.0 grams
Sodium bisulfite	2 lbs.	2.0 grams
Sugar	100 lbs.	100.0 grams
Water to make	120 gallons	1.0 liter
Solution B—Second Bath		
Sodium sulfite, desiccated	25 lbs.	25.0 grams
Sodium carbonate, desiccated	10 lbs.	10.0 grams
Water to make	120 gallons	1.0 liter

Manipulative details have been given on p. 32.

(*2*) *Two-Bath Developers of Type II.*—For those cases where it is desirable to be able to vary the gamma by varying the time of treatment, two-bath developers of Type II have several advantages.

With these developers the first bath acts as a booster solution for the second bath, which has the same composition as an ordinary single-bath borax developer. Since this booster solution is carried into the second bath by the film itself, the quantity added is proportional to the quantity of film processed. If the first bath is properly compounded to fit the particular conditions of use, with this procedure the rate of development will be maintained absolutely uniform. The speed loss will not be eliminated but it will be diminished. Fig. 6 shows the change in properties of a developer of this type during exhaustion. It is seen that the gamma remained uniform, while the emulsion speed gradually dropped.

(*3*) *Advantage of Type III Developers.*—The two-bath developers of Type III consist of two baths of an ordinary single-bath formula. Their advantage lies in the fact that the film is treated for only a short time in the first bath, which therefore remains comparatively fresh. The short treatment in this fresh bath prevents the gamma and emulsion speed from dropping as they would for total treatment in an exhausted developer. Also, when the second bath becomes completely exhausted, the first solution which is only slightly exhausted may be used as the second bath with a fresh first bath. Figs. 11 and 12 show the properties on exhaustion of two baths of the *D-76* formula.

B. Application of Two-Bath Developers to Machine and Rack and Tank Systems

(*1*) *Machine Systems.*—In machine development two systems are in common use for handling the developer solutions: (*a*) the recirculating system, and (*b*) the continuous flow system.

(*a*) *Recirculating Systems.*—In the recirculating system, a large volume of developer is held in a storage tank and circulated by means of pumps from this tank through the tubes or tanks of the machine and back to the storage tanks. If the developer is revived, the booster solution may be added continuously at some point in the system or it may be added at intervals to the storage tank.

With this system, the two-bath developers of Type I retain all their advantages, giving constant gamma with variations in time, constant gamma on exhaustion, and low speed loss on exhaustion. The only precaution necessary is to see that the film is well squeegeed between the first and second baths.

Developers of Type II and Type III retain their advantages of a small gamma change and low speed loss on exhaustion. The developers of Type II give a constant gamma without increasing the time of development, but the developers of Type III are somewhat more economical of chemicals, since the first bath is not discarded but is merely shifted to be used as the second bath. Also, there is a less abrupt change in the developing power when the shift is made to a fresh first bath. Neither of these types, however, has as long an exhaustion life as Type I.

(*b*) *Continuous Flow Systems.*—In the continuous flow system, fresh developer is allowed to flow in continuously at one end of the machine and to overflow continuously at the other end.

With this method, the developers of Type I retain all their advantages of constant gamma and long life, but the advantages of Types II and III are of doubtful value. This system itself might be considered as a multiple-bath developer with an infinite number of changes. When the ratio between the quantity of developer used and the length of film processed is held constant, an equilibrium is reached with fresh developer at one point, exhausted developer at another point, and various degress of exhaustion in between. The degree of exhaustion at any point in the system remains constant and therefore there is no change in the properties of the developer.

Disadvantages of Two-Bath Developers with Machine Systems.—There are also certain disadvantages connected with the use of two-bath developers in machines. These are briefly:

(*a*) Extra storage tanks, pipes, and pumping equipment are required for handling the extra bath.

(*b*) It is necessary to compound two solutions rather than one, but this is somewhat compensated for by the fact that the solutions last longer.

(*c*) With developers of Type I, it is necessary to squeegee the film between baths.

(*d*) With developers of Type III it is necessary to shift the slightly exhausted solution from the first tank into the second tank. This shift could be accomplished quickly by means of valves if each storage tank were connected to both sets of developing tubes or tanks.

(*c*) *Rack and Tank Systems.*—With the rack and tank system, when the rack is removed to the next bath, a considerable quantity of solution is carried along, not only on the film but also on the surface of the racks. This is a disadvantage with developers of Type I because it causes the rapid exhaustion of the second bath. This property is utilized by the developers of Type II, however, to prevent the exhaustion of the second bath, and in this case a constant rate of development can be maintained. With developers of this type it is possible to use desensitizers.

Developers of Type III may be used and have the same processing characteristics as when used in machines. The process of shifting the first bath is relatively simple since it is merely necessary to change the order of immersion of the racks.

The disadvantages of the two-bath method are practically the same with rack and tank processing as they are with machine processing, namely, additional tank space is required, additional solutions must be made up and handled and, in addition, any increased amount of handling of the film on the racks subjects it to danger of injury from careless manipulation and tends to reduce the output of each operator.

VII. SUMMARY

(1) The photographic characteristics of two-bath developers when used with Eastman supersensitive motion picture negative film have been investigated. The developer solutions were placed in two separate tanks, and the film immersed in the first bath for a definite time and then transferred to the second bath where the development was completed.

(2) Three types of two-bath developers were investigated, as

follows: Type I, in which all the developing agents were contained in the first bath and all the alkali in the second bath; Type II, class *A*, in which only developing agents and sulfite were contained in the first bath, while both developing agents and alkali were in the second bath; class *B* in which developing agents, sulfite, and alkali were present in both baths but in different proportions; and Type III, in which both baths were complete developers having identical compositions.

(3) With developers of Type I, in which the first bath was restrained with sugar and sodium bisulfite, a practically constant gamma was obtained with times of treatment varying from 3 to 5 minutes in the first bath and from 4 to 8 minutes in the second bath. Control of gamma was obtained by varying the concentrations of developing agents and alkali in the baths. Exhaustion tests showed that the restrained first bath had a very long life, while the life of the second bath was limited because of the accumulation of developing agents carried in by the film. With 4 minutes' treatment in each bath, practically constant gammas were obtained throughout the life of the baths, and the speed loss was low even after exhaustion with 300 feet of film per gallon of developer.

(4) The developers of Type II, class *A*, were unsatisfactory because of the rapid loss in emulsion speed on exhaustion.

(5) The developers of Type II, class *B*, in which the first bath was compounded to act as a booster solution for the second bath, had very satisfactory exhaustion properties with a constant rate of development, and only a small speed loss resulted after exhaustion with 200 feet of film per gallon of the first bath.

(6) When the film was treated even for only a small fraction of the total development time in a fresh developer and for the remainder of the development time in an exhausted developer, the gamma and emulsion speed obtained were only slightly lower than those for complete development in a fresh solution.

Tests have indicated that the use of two successive baths of the same developer (Type III) has the following advantages:

(*a*) A more uniform degree of development can be maintained on exhaustion.

(*b*) The loss in emulsion speed during exhaustion is less than with a single solution of the same volume as the combined volumes of the two-bath developer.

(*c*) A greater quantity of film can be processed satisfactorily per unit volume of developing solution.

(7) The two-bath principle is applicable also to the development

of negative sound records, although a developer is required which contains a lower concentration of sulfite than that for picture negatives. In view of the extremely low gammas usually required, it may be necessary to use borax in the second bath in place of carbonate.

It has not been possible to compound a practical two-bath formula which will give sufficiently high gammas for picture and sound negatives.

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SENSITOMETRIC CONTROL IN THE PROCESSING OF MOTION PICTURE FILM IN HOLLYWOOD*

EMERY HUSE**

Summary.—*It is the purpose of this paper to present a résumé of the current methods involved in the application of sensitometry to motion picture film processing today in the major laboratories in Hollywood, Calif. During the past decade very rapid progress has been made in the general technic of handling motion picture film of all kinds in a variety of processes. This paper, however, discusses only that phase of the handling that deals with the actual chemical development processes.*

Ten years ago the development of motion picture film in Hollywood was entirely a manual operation, being accomplished with the aid of the well-known rack and tank system. During the last ten years much work has been done, and a few papers written on the general subject of machine development of motion picture film; with the result that at the present time, with the exception of one or two smaller laboratories, all film developed in Hollywood is handled by machines. With machine development, one can feel assured that the actual conditions under which film is developed are much more stable than those conditions which existed under the now almost obsolete rack and tank methods. In discussing sensitometric control in the motion picture laboratories in Hollywood, therefore, it must be remembered that such laboratories as Paramount, Metro, Fox, Warners, Consolidated, Horsley, *etc*., use developing machines, operating at speeds in the neighborhood of 90 feet per minute.

Prior to the actual use of the classical Hurter and Driffield method of sensitometry in motion picture practice, certain less accurate control methods were in use. However, until recently no precise sensitometric control instruments were available. All control was accomplished by visual judgment of the operator in actual charge of the development processes. By the rack and tank method of development, densities were matched and picture quality was obtained solely as a

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result of visual comparison. Naturally a procedure of control which is dependent upon personal judgment lent for no standardization of results. It was possible to establish a procedure, such as specifying a certain number of shakes to the rack at certain stated intervals of time during development but the developing solutions were not taken care of from the replenisher standpoint with anywhere near the precision which now takes place with machine development and the accompanying circulating and conditioning systems.

HURTER AND DRIFFIELD SENSITOMETRY

The first thing to be considered in discussing the Hurter and Driffield system of sensitometry is the instrument with which a series

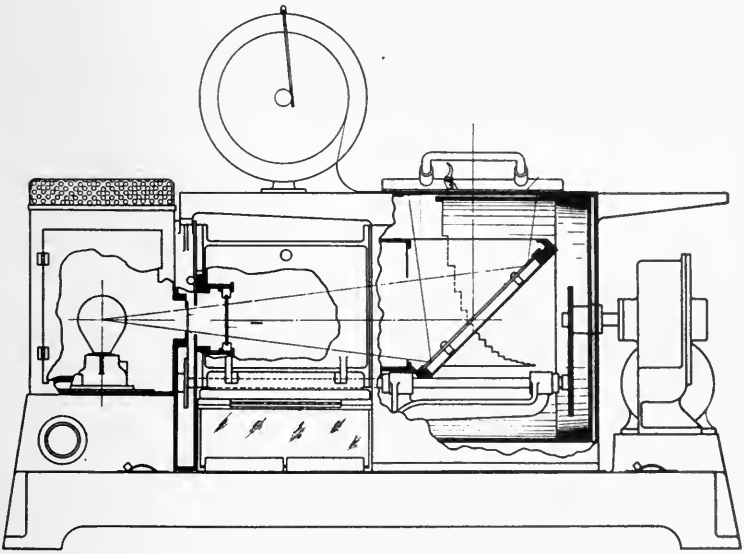

FIG. 1. A partial vertical section through the optical axis of the Eastman Type IIb sensitometer.

of exposures can be impressed upon a piece of film under known conditions of light quality, light intensity, and exposure time. It can readily be seen that an ordinary picture does not allow for a complete technical analysis. It is not possible to determine the absolute brightnesses which cause each of the different densities in the negative; and although the time of exposure given in a camera is fairly well established it is still impossible to obtain a correct technical estimate of the total value of exposure as expressed by the simple equation $E = It$. In a mechanical instrument designed for impressing uniform exposures one is not confronted with a series of densities which are distributed heterogeneously throughout the film. With the aid of a properly designed instrument it is possible to obtain a series of uniformly exposed areas differing as a result of a known ratio of exposures. A strip of film containing a series of uniform areas of density gives a means by which certain technical analyses may be made of both the film and the developer. The first problem, therefore, to be considered in setting up a sensitometric control is the establishment of this exposure instrument, called a sensitometer, which must be able to make exposures which can be definitely repeated. The Eastman Kodak Company built and placed on the market for general sale about two years ago an instrument which is called the Eastman Type IIb sensitometer. This instrument operates on the time scale

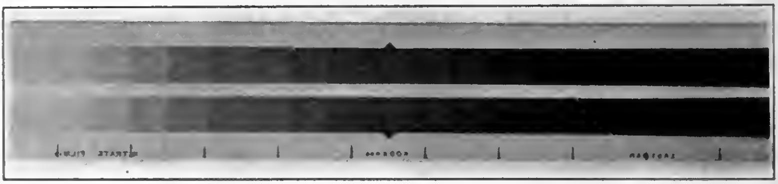

FIG. 2. A typical sensitometric record made with the Type IIb sensitometer.

principle and makes use of precisely calibrated tungsten lamps as the light source. This device has been adequately described by L. A. Jones,[1] who designed and supervised the building of the instrument.

The Eastman Type IIb sensitometer was designed especially to meet the need of the modern motion picture film laboratory. It provides a precise and rapid means of making routine sensitometric tests for the control of development processes. Fig. 1 shows a partial vertical section through the optical axis of the sensitometer. This instrument impresses on the film under test an accurately predetermined scale of exposures which may be maintained constant from test to test over long periods of time. The exposure scale consists of 21 steps produced by exposures equal in illumination and ranging from 1 to 1024 in relative times, each exposure being 1.414 (square root of 2) times as long as the next shorter. This constant factorial difference between steps permits the density readings to be spaced at equal intervals along the log exposure axis in constructing an H&D (density-log E) curve. Fig. 2 shows an actual sensitometric record made with this instrument. Tables I and II herewith submitted show the actual set-up of the instrument for the exposure of positive and negative films, respectively.

TABLE I

Positive Exposure

Lamp	72-watt, 6-volt locomotive headlight, calibrated for 2600°K.
Filter	78 *B*, correcting to 3000°K.
Intensity	27 meter-candles
t max.	4.99 seconds, at 50 cycles
log E max.	2.13

TABLE II

Negative Exposure

Lamp	36-watt, 6-volt locomotive headlight, calibrated for 2360°K.
Filter	79, correcting to 5400°K.
Intensity	0.75 meter-candle
t max.	4.99 seconds, at 50 cycles
log E max.	0.57

It is with this instrument that practically all sensitometric control in the processing of motion picture film in Hollywood is accomplished. At the time of this writing there are nine of these instruments in use there. It is interesting to note at this point that at the Annual Awards Banquet of the Academy of Motion Picture Arts and Sciences in November, 1932, this instrument was given official recognition by being awarded an honorable mention by the Committee on Awards on Scientific and Technical Achievements.

After the development of the sensitometric strip made on the Type IIb sensitometer it is necessary, in order to attain the desired technical results, to find a means of measuring the densities of the various deposits. A photometric instrument of one type or another is used for this work. Such an instrument in common use in most of the laboratories in Hollywood is the Eastman densitometer which has been described by Capstaff and Purdy.[2] At the present time there are approximately 25 of these instruments in use in Hollywood, both in laboratories and in sound departments. Some of these departments make use of polarization photometers such as those made by Schmidt and Haensch or by the Bausch & Lomb Optical Company.

The Eastman densitometer, which is shown in Fig. 3, is designed to fulfill several conditions, namely: the ability to read densities from 0.00 to 3.00; to measure very small areas ($^1/_2$ sq. mm.) utilizing the same source of light for the illumination of the density to be measured and furnishing the light for the comparison beam; calibrated to read direct diffused density; and designed to be portable, compact, and inexpensive. It has been shown in actual practice that this instrument fulfills these requirements. The West Coast Laboratory of the Eastman Kodak Company maintains a continual service in checking the densitometers in the field for their physical condition as well

FIG. 3. Eastman densitometer.

as their photometric ability, calibrations being made against standard densities originally calibrated in the Research Laboratories in Rochester.

Inasmuch as the actual conditions of exposure of the sensitometric strip are known, *i. e.*, the time of exposure and the intensity and quality of the exposing radiation, it is possible, with the values of density available, to construct the characteristic density-log E curve. As the exposure increases so the density increases until upon completion of the plotting of the curve a graph, such as is shown in Fig. 4, is obtained. There are three distinct portions to this curve, namely:

the toe, which is that portion indicated between A and B; the straight line, between B and C; and the shoulder, between C and D. It is quite well known that these three portions of the characteristic curve are referred to respectively as the regions of underexposure, correct exposure, and overexposure. It is of value, therefore, in the application of sensitometry to motion picture film processing to know the characteristic curve resulting from the development of sensitometric exposures in the negative, positive, and sound track developing solutions. Quite naturally the negative developer is studied in terms

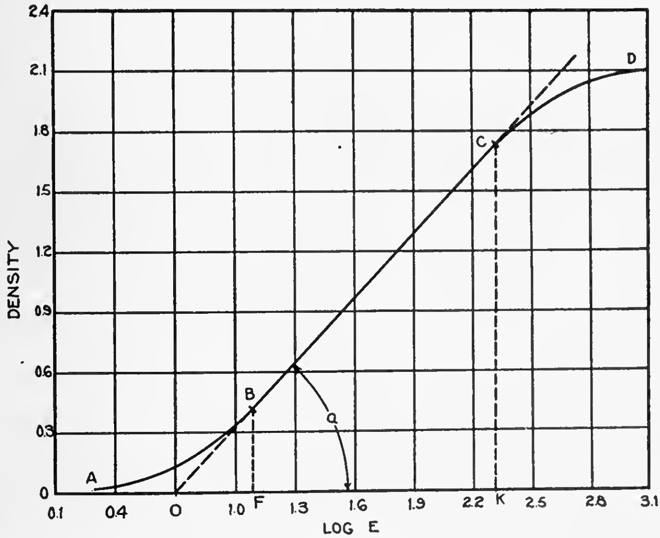

FIG. 4. Typical H&D curve.

of exposures made on negative film, the positive developer in terms of exposure made on positive film, *etc.*

GAMMA

There are in the Hurter and Driffield system of sensitometry several constants regarding which data are desired. From the standpoint of motion picture control, by far the most improtant characteristic is the slope of the straight-line portion of the curve, which is commonly referred to as "gamma." Gamma is defined as the tangent of the angle formed by the straight-line portion of the H&D curve and the log E axis, and is an indication of the degree of development.

It is, of course, a constant of the emulsion itself; but for a given emulsion developed in a given solution, gamma is a numerical specification of the degree of development in that solution. It is important, furthermore, to know that as development time increases, gamma increases, meaning that the straight-line portion of the curve forms increasingly greater angles with the log *E* axis as development time progresses. This is an extremely important fact.

Probably the best way to determine for a given emulsion the reaction which a developing solution will give is by a study of the rate at

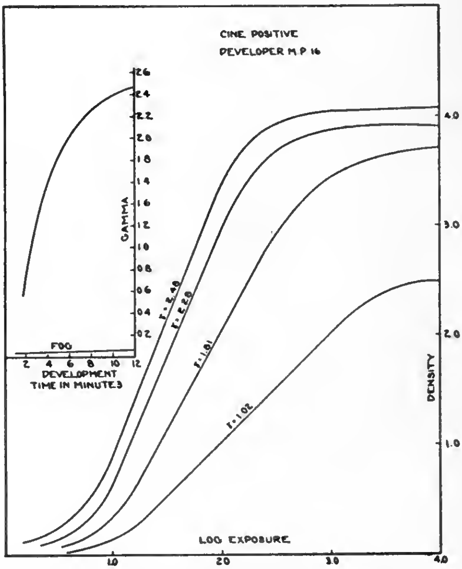

FIG. 5. A series of H&D curves for identical exposures but different times of development.

which gamma builds up with development time. Fig. 5 shows a series of H&D curves, all of which had identical exposures in an Eastman Type IIb sensitometer, but each strip of which received a different time of development under a constant developing condition. After the determination of gamma for each of these curves, these values were plotted as ordinates against the times of development as the abscissa. A new curve is thus obtained which definitely shows the relationship existing between gamma and development time and this curve is referred to as the time-gamma curve. From the sensitometric standpoint this curve tells a great deal about the condition, or rather the reaction, of that developer to that particular type of film. It is now very easy to see that regardless of whether negative or positive film is to be developed, the determination of a time-gamma curve for negative film in the negative solution and for positive film in the positive solution is very essential. In actual practice complete series of H&D curves for a variety of development times are not obtained because with practice it is readily determined what the probable range of development times will be and it is therefore only necessary to construct time-gamma curves over the range which is within that used practically. There are several other sensitometric constants which, while important both from a technical and practical standpoint, do not necessarily occupy the same important niche as that filled by gamma. Reference is made to the constants speed, latitude, and fog.

SPEED

Speed as a sensitometric constant has been subjected to many interpretations. From the standpoint of the practical photographer, speed and density mean much the same thing, for the reason that if two samples of film are exposed simultaneously to the same quantity and quality of light and then developed for the same time, that sample showing the greatest density is considered the fastest. From the standpoint of the Hurter and Driffield method of sensitometry, speed has a little different meaning and it is arbitrarily defined as the reciprocal of the inertia multiplied by a constant, *i. e.*,

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

The inertia i is defined as the exposure value at the point where on the log E the straight-line portion of the H&D curve (Fig. 4), extended, cuts that axis. The value of the constant k should be so chosen that it is sufficiently large so that values of speed for various commercial emulsions are of convenient magnitude for practical use. Speed determinations made by this method on the Eastman Type IIb sensitometer make use of the value 10 as the constant k. Speeds as thus determined are not of any particular value to the practical laboratory man. This method of speed determination has been discussed because it is technically important and, furthermore, it was desirable to acquaint the reader with the fact that this constant exists.

LATITUDE

Latitude is a constant which has to do with the range of brightnesses which can be adequately rendered by a photographic emulsion. The numercial specification of latitude is derived from the H&D curve, such as is shown in Fig. 4. That portion of the curve with which we are interested in the determination of latitude is the straight-line portion. If from the limits of the straight-line perpendiculars are dropped to the log E exposure axis, a simple determination can then be made of the exposure value where each of these perpendiculars hits the axis. The ratio between the two exposure values thus determined gives a measure of the latitude. Quite a little consideration is given to the latitude of an emulsion in the processing of sound records on film. A thorough appreciation of the importance of latitude as it affects negative and positive picture quality has not been attained.

FOG

Fog is an important constant in that it gives definite information regarding the final results of the developed photographic images. Fog may be considered as an actual density which has arisen from sources other than intentional exposure to light. It may be considered under two general headings, inherent fog and development fog. Inherent fog may be the result of certain of the silver grains being made developable by the chemical processes involved during the manufacture of the emulsion. It may also be due to slight exposure to light during some stage of the handling, either prior or subsequent to its final and intentional exposure.

Development fog arises from various causes such as the action of fogging agents or reaction products in the developer, aerial oxidation, *etc.* Fog is not detectable until after development. From a purely practical standpoint no particular attention is paid to fog unless it gets outside of accustomed grounds. For example, in the development of positive film, a fog value of 0.03 to 0.05 is quite normal; and unless fog builds up beyond this limit it is disregarded, other than to record it. However, excess fog, which is readily detectable visually, plays a detrimental part in both picture and sound quality. Precaution is continually exercised to prevent fog of either the inherent or the development type.

CONTRAST AS DISTINGUISHED FROM GAMMA

One very important item, which should be well understood in the practical application of sensitometry to the control of the development of motion picture negative film, is the fact that a sensitometric strip which has been made under precisely controlled conditions of time and intensity can only give data as to the degree of development obtained. Thus, such a sensitometric strip developed with an exposed picture negative will show a definite gamma value for the strip but will not give any precise information as to the contrast of the picture negative developed along with it. Contrast in the negative is not only a function of gamma but also of the lighting balance in the set at the time of exposure. If at all times the brightness balance would be maintained constant in the various scenes to be photographed, then the sensitometric strip would give a true indication of the contrast of those scenes after development. However, this is not possible. Each and every scene of different subjects has an inherent brightness contrast characteristic of its own and upon controlled development the resultant densities in each scene indicate the contrasts which were in those scenes. The point which is being stressed is the fact that, because picture negatives are developed in a solution which gives a definite value of gamma from the sensitometric control strip, it does not follow that these negatives have the same degree of contrast as shown by the gamma value of that strip. They bear a very definite relationship to each other and under certain conditions can be used synonymously; but this condition does not always hold. If we refer to Fig. 4, it will be readily observed that the straight-line portion of the H&D curve from which gamma is determined exists only between points *B* and *C*. This straight-line portion contains only part of the various densities which go to make up the complete curve. This being the case the densities which are beyond either extreme of the straight line must play some part in the photographic rendering of subject or scene. When one looks at a motion picture on the screen and studies it for contrast, all thoughts of gamma disappear. What the observer is looking at is the relationship existing between the highlights and shadows. Sensitometrically this refers to the toe and shoulder portions of the H&D curve. Therefore, it seems evident in studying contrast sensitometrically that densities which lie on the toe and shoulder must be considered. In evaluating contrast it is necessary to determine the density at some fixed point on the toe and shoulder and contrast can then be expressed in terms of a density value. The difference between the density chosen on the toe and that on the shoulder gives these data. It has been sensitometric practice to consider the extremes of the curve as the density at those points on the toe and shoulder where the slope is equal to 0.20. From the curve as shown in Fig. 4, a 0.20 gradient on the toe and shoulder would be slightly above point *A* and slightly below point *D*. The word "gradient" signifies the slope of the curve at any given point. However, along the straight-line portion of the curve the gradient is constant and is equal to gamma.

As was previously indicated, there is one instance in practical sensitometry where gamma and contrast can be used synonymously and that is in the sensitometric control of sound track. Inasmuch as the exposures on the track are based upon the straight-line portion of the H&D curve, and for most recordings densities in the actual track fall within the limits of the straight line, then in this instance where the maximum and minimum densities recorded are completely included in the straight line, it is quite simple to see that contrast and gamma are identical.

Every major studio or commercial laboratory in Hollywood is adequately equipped with, or has access to, the instruments which have been described in the early part of this paper. Furthermore, each laboratory has a man, or several men, taking care of the sensitometric routine. It can be stated rather strongly that with the advent of sensitometric control motion picture film processing has attained a degree of perfection which has not hitherto been possible. Of course all of the current quality should not be laid to sensitometric control because during the past several years much has been accomplished from the standpoint of improved machine development, photographic emulsions, developers, and processes which have aided in this improvement. However, it is the candid opinion of the author that sensitometric control has revealed deficiencies in the processing systems which have not heretofore been observed, or, if observed, were not properly taken care of because there was no technical control available to indicate the direction in which improvement should be made.

In attempting to convey clearly a concise picture of the actual control methods in use it is felt that the subjects of control for negative, positive, and sound track should be treated individually. Furthermore, that this paper might contain more than the opinion of the author, data will be presented from actual production laboratories, which data will show clearly the degree of consideration which is given to sensitometric control.

Before discussing the actual laboratory data, consideration should be given to the development of negative film. In Hollywood there are two distinctly different methods by which negative film is developed. One method is that of a constant time of development. The other method is that which is colloquially termed the test method. According to the constant time method the developing solution is maintained at a definite control gamma, as shown sensitometrically, and exposed negatives of all types, except very special effect shots, are developed under this standard predetermined condition. By the test method, it is necessary that the cameraman photograph an extra portion of each scene to be used as a test for development. These tests are developed for a constant time, which time has been predetermined as normal for correct exposures. After the development of these tests the responsible person in the laboratory examines them and determines the time of development which in his opinion would be best suited for each take. When one considers a large production company with several individual companies in production, the number of tests which go through by this system is appreciable. Over a period of time it is found that many of these scenes receive normal development. The remaining scenes may vary from plus or minus one-half to several minutes from the normal. In many instances, where scenes were shot under adverse conditions, their photographic quality is materially improved by this method of negative development. The time consumed is greater and the work slightly more involved, but in view of the results obtained the quality is very favorable.

The author after having observed over a five-year period the results of the development of negatives by either of these two systems is convinced that both have their merits and can be and are productive of excellent results. From the standpoint of pure sensitometric control, the developing solution itself is studied before any production work goes through it. One of the first things done when a new developer is put into the system is to run a sensitometric control, which consists of the development of a group of sensitometric strips all made under a set condition. It is determined from the results of these developed strips just what time of development is necessary to give the desired control gamma. Once this is established, then, regardless of which of the two systems of negative development is to be employed, that time becomes the standard for that machine operating at a definite speed under a definite condition of developing solution and temperature. If the laboratory is operating purely on the time basis, then all of the negative to be developed goes through that solution, for the time which the tests indicate produces the desired control gamma. The sensitometric control which is applied to this system consists of periodic tests, such as at half-hour intervals, which give data showing whether or not the degree of development was greater or less than that determined by the original test. With knowledge as a result of practice which now exists in the laboratories it is a simple procedure to determine the rate at which a replenisher must be added to the developing solution to maintain it at its predetermined controlled developing power. Naturally, during the course of development by either system the developing strength of the solution changes as increased footage goes through it. It is necessary to find a means of maintaining the fixed development condition, whether it be by altering the time of development or the chemical replenishment.

In some laboratories samples of a test negative are developed along with their sensitometric strips. This test negative is usually a close-up of a girl. Many laboratory men still feel that they can see more in the picture than they can be told about that picture from the data indicated by the sensitometric analysis. By developing both sensitometric and practical tests a double check is made. It is remarkable to observe the fine details of density and contrast which can be seen by the experienced laboratory man in the examination of the test picture negative. All laboratory men are becoming more thoroughly educated in the art of sensitometry, and are becoming quite able in determining from the sensitometric data the cause of any differences which might occur and show themselves between two successive tests. There are still in existence in Hollywood one or two smaller laboratories operating by the rack and tank method. Their system of sensitometric control is quite similar to that applied to machine development. With very carefully laid down manipulative procedures good results can be, and are being, obtained. One laboratory in particular uses the rack and tank method for the development of all film, including picture negative and positive, and sound track. However, inasmuch as we are more particularly interested in the modern methods of control, we shall not deal further with any system except one which makes use of developing machines.

All of the foregoing, under the general heading of negative development, has dealt with the procedure involved. Nothing has been said quantitatively about the results obtained. During the past five years there have been some rather definite changes in what is desired from the standpoint of negative quality. In 1928 the author had occasion to measure sensitometrically the control gammas of the solutions used by the various major laboratories in Hollywood. This was before any sensitometric methods were in use in these laboratories. The film which was used was panchromatic negative which was then in style. The sensitometric exposures were made on a time-scale sensitometer in the West Coast Laboratories of the Motion Picture Film Division of the Eastman Kodak Company. This instrument was a duplicate of the time-scale sensitometer in use in the Research Laboratories in Rochester. The gamma values resulting from exposures made on this instrument were of the same general order as those obtained currently with the Type IIb sensitometer. At the time of these tests, the average negative picture gamma was very close to 0.80, although some laboratories used higher values. A few years later, particularly after the introduction of the high-speed supersensitive type of film, it was found that the trend in general negative quality was toward a lower degree of contrast, which exhibited itself from the sensitometric data made at the time. Measurements of negative gamma from 0.55 to 0.65 were quite normal. At the present time, 1933, the average negative gamma has increased somewhat, and measurements show negative gammas between 0.60 and 0.75, with the average being very close to 0.67. It is not within the scope of this paper to explain why this trend has taken place even if it were possible to do so adequately, although it can be stated in brief that as the details of the photographic method of recording sound were improved, changes were necessitated in the entire processing system of both sound and picture films.

NEGATIVE CONTROL DATA

It was previously discussed in some detail that there are in existence in Hollywood two different methods of developing negative film: namely, the constant time method and the test system. Under this general heading of negative control such data will be discussed as applies to the constant time of development method. For that purpose the writer has obtained from one of the major Hollywood laboratories an exact copy of the sensitometric operations in the development of their production negative during an entire night. The procedure which will be described here is a nightly occurrence.

It is the procedure of this laboratory to begin production negative development around 5:30 P.M. Early in the afternoon the circulatting system of the negative developing machines is turned on. After the developer has had time to recirculate thoroughly, which usually takes about an hour, sensitometric control strips are developed, consisting of exposures on negative film of the same kind and type as used for picture work and exposed in the Type IIb sensitometer under the negative set-up conditions. These strips are put through to determine the time of development necessary to produce the predetermined negative control gamma. If these first strips give values which depart from the desired condition, another series of strips is then developed under slightly altered conditions. Once the desired gamma is attained the time of development which was necessary to produce this gamma is considered the normal time of development for that night's run. At intervals of approximately one-half hour, together with the production work, further sensitometric control strips are developed. This procedure is followed during the course of the night. If at any stage during the development, gamma increases or decreases to any marked degree, the time of development is altered or replenisher is added to compensate for the change.

The laboratory in question submitted data obtained during the production run on March 29, 1933. The first two tests which were put through after the circulating system had been in operation for a while were developed for the time which had been normal on the previous night. In this instance, the time was 10 minutes, 37 seconds. These first two tests went through the developing machine at 3:00 P.M. It so happened that these tests gave, upon plotting, a gamma value of 0.62. If the gamma value obtained in such a test falls between the limits of 0.60 and 0.65, the time of development required to do this is selected as normal. Inasmuch as these first two tests at 3:00 P.M. gave a gamma of 0.62 and a further test at 5:26 P.M. likewise gave the same gamma, production negative was immediately fed into the machine, and the night's run was begun. From 5:26 P.M. until 12:00 M. sensitometric strips were put through the system at half-hour intervals, together with production and likewise with a sample of test negative made under conditions as described earlier in this paper. In Table III are given the exact data obtained sensitometrically during the night, including the densities of each individual strip together with the gamma obtained and also the amount of footage which was developed between successive tests. These data when plotted gave curves of the type indicated in Fig. 6. For

TABLE III

Negative Control Strips

Step	3:00	3:00	5:26	6:05	6:20	7:05	7:35	8:20	8:50	9:35	10:05	10:50	11:25	12:00
1	1.44	1.44	1.40	1.40	1.40	1.40	1.40	1.38	1.38	1.39	1.38	1.38	1.36	1.36
2	1.40	1.40	1.36	1.34	1.34	1.32	1.34	1.30	1.31	1.30	1.30	1.30	1.30	1.30
3	1.30	1.32	1.28	1.26	1.24	1.22	1.26	1.24	1.22	1.22	1.24	1.22	1.22	1.22
4	1.24	1.22	1.22	1.20	1.20	1.16	1.20	1.16	1.16	1.16	1.16	1.16	1.14	1.16
5	1.15	1.16	1.14	1.10	1.12	1.06	1.10	1.08	1.09	1.07	1.06	1.08	1.04	1.04
6	1.08	1.08	1.04	1.00	1.00	0.97	1.00	0.98	0.97	0.98	0.98	0.96	0.96	0.96
7	0.98	0.98	0.94	0.92	0.92	0.88	0.92	0.91	0.90	0.92	0.90	0.90	0.90	0.89
8	0.89	0.88	0.86	0.82	0.82	0.90	0.82	0.82	0.80	0.82	0.81	0.80	0.79	0.81
9	0.76	0.77	0.74	0.73	0.73	0.70	0.72	0.72	0.70	0.72	0.70	0.70	0.70	0.70
10	0.68	0.69	0.66	0.64	0.63	0.62	0.63	0.62	0.60	0.62	0.60	0.62	0.62	0.62
11	0.60	0.60	0.58	0.55	0.54	0.52	0.53	0.52	0.51	0.54	0.52	0.52	0.54	0.52
12	0.50	0.50	0.49	0.44	0.44	0.42	0.44	0.42	0.42	0.44	0.44	0.42	0.42	0.42
13	0.40	0.42	0.38	0.36	0.34	0.34	0.36	0.34	0.34	0.36	0.36	0.34	0.33	0.34
14	0.33	0.32	0.32	0.28	0.26	0.24	0.28	0.26	0.26	0.28	0.28	0.27	0.26	0.26
15	0.26	0.26	0.22	0.20	0.20	0.19	0.21	0.20	0.20	0.20	0.21	0.20	0.18	0.20
16	0.22	0.20	0.19	0.16	0.16	0.16	0.16	0.18	0.16	0.17	0.18	0.18	0.16	0.18
17	0.17	0.16	0.16	0.14	0.14	0.12	0.13	0.14	0.12	0.14	0.15	0.16	0.14	0.14
γ	0.62	0.62	0.62	0.62	0.63	0.61	0.62	0.61	0.61	0.60	0.60	0.60	0.60	0.60
Footage	Test	Test	0	1,400	3,500	4,600	6,700	9,850	12,300	15,450	17,550	20,700	23,150	24,900

the sake of brevity, the two curves shown represent the strips which went through at 5:26 P.M. and 12:00 M. These were the first and last strips developed. It will be observed that there is a difference of 0.02 in gamma between these two tests, the 12:00 M. curve showing the lower value. From the standpoint of density if one individual step of the H&D strip is chosen, for example, step *11*, it will be observed that there is a maximum density change of 0.08. During that night approximately 30,000 feet of negative were put through the solution. These data are for one of the two negative developing machines which are normally in operation each night at this laboratory.

From the standpoint of replenisher, an average of eight gallons per

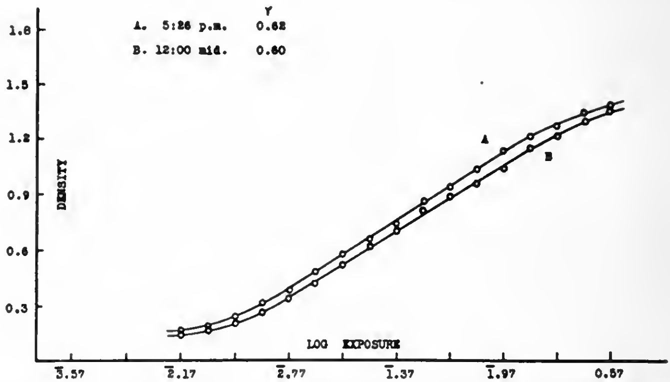

FIG. 6. Characteristics of negative control strips showing the variation of gamma and the degrees of density with operating time.

hour of double-strength developer, minus bromide, was fed into the system. If, at any stage during the development, gamma or density had dropped appreciably, one of two things would have happened, either the time of development would have been increased, or the rate of replenishment increased. Inasmuch as the maximum density change amounted to only 10 per cent, which is equivalent in speed to approximately one Bell & Howell printer point, and furthermore, inasmuch as gamma had changed less than 5 per cent, the same time of development and the same rate of replenishment was maintained throughout the night.

This sample of data from the laboratory in question represents an average condition. These data were not selected to represent either a good or bad night's work. The slight development differences which existed between negatives developed during this night required very little unnecessary manipulation in timing or printing. Naturally, all scenes of all cameramen did not print alike, but all negative was well within the normal printing range.

Again it must be borne in mind that by this system of development the solution was maintained constant within very narrow limits to produce the same degree of development. The contrasts that were exhibited by the various negatives were the result of the various brightness contrasts in the scenes photographed. Inasmuch as it is the practice of this laboratory to develop the bulk of its work for a fixed time of development, the cameramen realize that any change they make in their exposure conditions will be evidenced in their negatives.

By the test system of development it is necessary first to construct a short time-gamma curve, similar to the one shown in Fig. 5. From that curve it is possible to determine the time required to give the normal gamma. In this system the time is varied, dependent upon the judgment of the man in charge of the negative development; and because each laboratory accurately records all sensitometric data it is quite possible to determine just what control gamma is obtained at any time of development other than normal. This is done, of course, by referring to the time-gamma curve previously established. The system of control of the solution over a period of time, when the test system is used, is done in a manner identical to that which is described above for the constant time of development method.

The developers in general use for the development of picture negatives are modifications of the standard E. K. *D-76* borax formula. They are modified to fit the needs of the various types of developing machines. Quite naturally, all laboratories do not use the same formula, even though there is a similarity in the machines used. Differences of opinion as to photographic quality and differences in the recirculation and agitation of solutions are factors which enter into the question of developer formula differences. In the final analysis, there is not a great deal of difference between the various negative formulas in use in the various laboratories in Hollywood. It is desirable, however, to include in this paper a typical machine negative developer formula. Developers of this general composition are in use today and produce excellent results. The formula quoted in Table IV shows the chemical composition of such a developer.

TABLE IV

Picture Negative Formula

	Avoirdupois	Metric
Elon	1 lb. 15 ozs.	1.93 grams
Sodium sulfite, desiccated	96 lb.	96.0 grams
Hydroquinone	4 lb. 13 ozs.	4.82 grams
Borax	1 lb. 12 ozs.	1.75 grams
Water to make	120 gals.	1.0 liter

POSITIVE CONTROL DATA

From the standpoint of positive control the procedure followed is very similar to that described for negative film. The final positive print contains both picture and sound track records. It is important

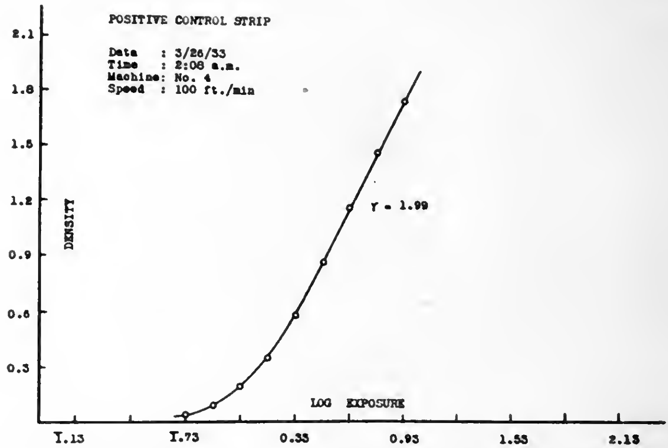

FIG. 7. A typical H&D curve having a gamma of approximately 2.00.

from the standpoint of the sound that positive gammas be specified and maintained. For that purpose rigid control is applied to positive film development so that the predetermined positive gamma may be maintained consistent throughout. This is particularly true in release print development.

From another major studio, laboratory control data have been obtained for a period of one day. This laboratory submitted all of their data on positive control for March 26, 1933. This consisted of each individual sensitometric curve for every machine in operation during that day, at intervals of about one hour. During the day's work there were five developing machines in operation, each machine having in its system the same chemical formula. At this laboratory a positive control gamma of 2.00 is desired. By preliminary sensitometric tests, which consist of the development of Type IIb positive sensitometer exposures on the positive film emulsion which is in use, gamma determinations are made before any production work goes through. With these data it is possible to determine the time of development to give this desired gamma value. This time is controlled by the machine speed. In Fig. 7 is shown a typical positive H&D curve giving an approximate gamma of 2.00, as obtained at this laboratory in one of the machines on the day in question. From

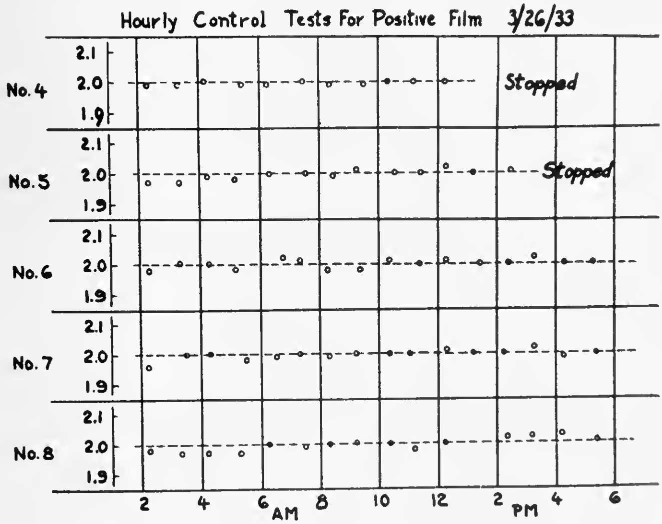

FIG. 8. Curve showing the variation of gamma from hour to hour on several machines.

this graph the general density range covered by the sensitometric strip, as well as the general shape of the curve, is readily seen. Once the time is determined to give this desired gamma, production starts and hourly thereafter a pair of sensitometric exposures are sent through. Each strip is then read for density and plotted. Upon the completion of the work, a final curve is obtained showing gamma plotted against the time interval of development. Naturally there are some tests which show values greater or less than the desired value. Certain tolerances are, of course, allowed, usually a plus or minus 0.05 deviation from the normal. In the data which are presented in

Fig. 8 the actual variations are readily observable for each machine. The work during this day was not representative either of a good or a bad day, but did show a perfectly average set of conditions. For any given machine, for example, machine No. 8, there is only a 0.06 maximum variation between the highest and lowest gamma strips. If all of these values of gamma were averaged, a numerical gamma of 1.995 would be obtained. The maximum deviation, considering all machines, was only 0.07.

In the event that any general trend is shown by successive tests, then slight alterations are made in the actual time of development to compensate for that trend. It is the function of the foreman in charge of the positive developing machines to maintain the desired gamma of 2.00. From the data presented from this laboratory it can be seen that the results are excellent.

Although the purpose of this paper is to describe the sensitometric routine in vogue and to show the results obtained, it is only fair to state that the results shown from this laboratory on their positive film control is indicative of the type of work obtained by all of the laboratories in Hollywood.

As was the case with negative developer formulas, differences exist also among the positive formulas. To complete this section on positive film control the tabulation of an average positive formula is considered necessary. Table V gives such a formula.

TABLE V

Picture Positive Formula

	Avoirdupois	Metric
Elon	12 ozs.	0.75 gram
Sodium sulfite, desiccated	40 lb. 8 ozs.	0.5 grams
Hydroquinone	4 lb. 14 ozs.	44.87 grams
Sodium carbonate, desiccated	26 lb.	26.0 grams
Potassium metabisulfite	1 lb. 7 ozs.	1.43 grams
Potassium bromide	10 ozs.	0.63 gram
Potassium iodide	178 grains	0.025 gram
Water to make	120 gals.	1.0 liter

SOUND CONTROL DATA

A complete discussion of the sensitometric control for sound film development would be extremely voluminous. In the discussion of this subject in this paper no attempt will be made to give actual data from any individual studio. The control methods are similar to those described for positive and negative film, but are much more detailed in many respects.

There are at the present time two major sound recording methods in vogue, the RCA and the Western Electric systems. A brief discussion is necessary for each of these two methods. They differ appreciably and should be discussed separately. The RCA system makes use of a variable width sound track, while the track of the Western Electric system is of the variable density type.

VARIABLE WIDTH SYSTEM

The particulars regarding this system of recording sound are very well known and this paper will give only the necessary details to describe the sensitometric requirements which are submitted to their licensees by the RCA Victor Co. They are quite simple, and are readily maintained in the processing laboratory.

The specification laid down by RCA Victor engineers for negative gamma is that the negative sound track should be developed to give a control gamma of from 2.00 to 2.20. The unmodulated track density, and in this instance reference is made to the symmetrical track, should fall within the density range of 1.40 to 1.50. The sensitometric set-up necessary to follow these specifications requires that the laboratory determine the time of development on the film being used for the recording to give a gamma within the limits just prescribed. It is then necessary for the recording unit to provide an exposure which will give a density upon development within the density limits cited above. The RCA Victor Company recommends for positive control gammas between 2.00 and 2.20, similar to the negative, while the positive track densities should be from 0.15 to 0.20 less than the negative density. For example, if the negative unmodulated track density at the proper gamma is 1.45, then the positive track density should be within the limits of 1.25 to 1.30. Naturally, during the course of processing, solution control must be maintained, and this is accomplished in a manner very similar to that previously described under positive film. Once the sensitometric conditions are determined, both from the exposure and development standpoints, then it is the function of the laboratory to maintain those conditions in their developing procedure. The developer normally used for this type of work is the regular picture positive formula, an example of which was cited under the heading of positive film.

VARIABLE DENSITY TRACK

In the consideration of the Western Electric system of recording, a much more detailed sensitometric discussion is necessary. In processing variable density sound records which utilize the straight-line portion of the H&D curve, it is necessary that the over-all gamma characteristic, as determined by plotting projection densities *versus* the logarithm of light valve openings, be held to the ideal value of unity. This might also be expressed by saying that the product of the positive and negative gammas multiplied by the projection factor should be 1.00.

Before specifying numerical values for positive and negative gamma, several factors entering into this computation should be explained. The gamma value obtained from a series of exposures on a light valve recorder and plotted against the logarithm of the light valve openings will be designated as the light valve gamma, $LV\gamma$. The gamma valve obtained on the control strip, which has been exposed on the Type IIb sensitometer and developed with the light valve gamma strip, will be called the negative control gamma and designated as $NC\gamma$.

In the measurement of positive gamma it is necessary to measure the apparent printer gamma, which is obtained by printing the negative control strip on a printer and developing this print with the positive sound track print. This value will be called $AP\gamma$. When the positive control strip, which has been exposed on the Type IIb sensitometer is plotted, its gamma will be designated as $PC\gamma$.

Furthermore, as the positive sound track will be scanned in projection by a photoelectric cell, it is necessary to determine experimentally the difference in gamma as determined by visual measurement of the diffuse densities and the quasi-specular measurements of the photo-cell. This factor has been measured for standard projection conditions and found to be 1.30.

The conditions for correct reproduction, as recommended by representatives of Electrical Research Products, Inc., are given in the following data:

$$\text{over-all gamma} = LV\gamma \times AP\gamma \times \text{projection factor} = 1 \qquad (1)$$

$$\text{If } LV\gamma = a \times NC\gamma \text{ and} \qquad (2)$$

$$AP\gamma = b \times PC\gamma, \text{ then} \qquad (3)$$

$$\text{over-all } \gamma = NC\gamma \times PC\gamma \times a \times b \times \text{projection factor} \qquad (4)$$

It is customary to assume that the factor $a = 1$; *i. e.*, the difference between the negative control gamma and the light valve gamma is negligible. In practice, the light valve gamma is found to vary by plus or minus 5 per cent from this. The printer factor, b, is usually measured daily in most laboratories; at least such a procedure is recommended. While the printer factor may be as much as 10 per cent, it is found in practice that this value is approximately equal to the factor a, and opposite in direction, so that the two tend to cancel each other.

Omitting these factors, then, from equation (*4*) we have

$$\text{over-all gamma} = NC\gamma \times PC\gamma \times \text{projection factor} \tag{5}$$

and substituting

$$1 = NC\gamma \times PC\gamma \times 1.30, \text{ or} \tag{6}$$

$$NC\gamma \times PC\gamma = 0.76 \tag{7}$$

In other words, any combination of negative and positive control gammas which gives a product approximating 0.76 would be correct for straight-line recording.

Tests have been made in four Hollywood studios, listed below by letter, of the Type IIb sensitometer negative and positive gammas. In Table VI these data are given.

TABLE VI

Studio	Negative Gamma	Positive Gamma	Visual Product
A	0.42	2.10	0.88
B	0.35	2.15	0.75
C	0.36	2.00	0.72
D	0.38	2.40	0.91

It will be observed that the maximum variation from 0.76 is +0.15 higher. One studio at the time these tests were made operated slightly lower than the desired 0.76, their visual product being 0.72. A mean exposure of the light valve that will permit 90 per cent modulation without going into the toe of the negative H&D curve is recommended. This results in an average density numerically equal to the negative gamma plus the toe density. By toe density is meant that value of density at which the toe departs from the straight-line characteristic of the sound negative H&D curve.

Thus if the Type IIb negative gamma equals 0.40 and the toe density equals 0.15, then the correct operating density would be 0.55.

In the case of positive density a value that will not permit much operation into the toe region is recommended. This depends upon the shape of the toe of the printer H&D curve. Experience has shown that a visual print density in the neighborhood of 0.70, for a gamma approximating 2.00, is usually satisfactory. Some studios that fail to obtain a correct over-all gamma of unity have recourse to lighter prints, varying in density from 0.50 to 0.60. Based on observations, the following specifications cover most processing of light valve records.

Negative Gamma	0.35 to 0.40
Negative Density	0.50 to 0.60
Positive Gamma	1.80 to 2.20
Positive Density	0.65 to 0.75

Before any recommendations for processing are made to any studio by the Western Electric Co., or its subsidiary, Electrical Research Products, Inc., the entire sensitometric control set-up, from light valve to photoelectric cell, is examined. All the above recommendations regarding Western Electric track control are quoted from data obtained from representatives of Electrical Research Products, Inc., in Hollywood.

In considering developers for sound track work, it is necessary to realize that recordings are made on film which contains an emulsion of positive characteristics. As can be seen from the specifications quoted above, the gammas desired are very low. It becomes necessary, therefore, that a developer of low contrast characteristic be used. Quite often, use is made of the picture negative formula. However, slightly better results are obtained with a developer quite similar to the picture negative formula but with a smaller quantity of sodium sulfite. A typical formula used for the development of sound negative of the variable density type is given in Table VII.

TABLE VII

Sound Negative Developer

	Avoirdupois	Metric
Elon	1 lb.	1.0 gram
Sodium sulfite, desiccated	46 lb. 8 ozs.	46.5 grams
Hydroquinone	2 lb. 3 ozs.	2.2 grams
Borax	1 lb.	1.0 gram
Water to make	120 gals.	1.0 liter

It is quite obvious that the formula used for developing the positive sound track is identical with that for the positive picture, inasmuch as the final print contains both the picture and the sound track.

In closing the author would like to express his appreciation to the individual representatives of practically every studio and laboratory in Hollywood, as well as representatives of the major sound units, for the assistance which they rendered in the compilation of the data presented in this paper.

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DISCUSSION

MR. L. A. JONES: The author has stated in this paper that the characteristic curve completely specifies the contrast of the material. To avoid misunderstanding on the part of the reader it might be mentioned that the word "contrast" as used by most of us can refer to any of several quite different things. For instance, when we speak of the "contrast of a negative" we refer to the extreme density difference or to the highlight-shadow brightness ratio. Obviously the characteristic curve of the negative material does not specify "contrast" in this sense.

MR. J. COFFMAN: It would be interesting for Mr. Huse to explain exactly how he reconciles the control of processes that are essentially intensity-scale processes, such as printing and negative developing, with the use of a time-scale instrument such as the IIb sensitometer.

MR. HUSE: All our sensitometric tests are a means of solution control. The sensitometer does not give us a picture of the entire photographic process, but of solution control, primarily.

MR. COFFMAN: I should like my own attitude to be understood. The IIb sensitometer is well designed, if we accept its compromise principle. I also agree that it is possible to establish an arbitrary control in which data obtained with a time-scale instrument such as this are related to film printing characteristics. But it would seem desirable, before proceeding too far in standardization, to determine whether it is not possible to design an instrument that will be more closely related to the processes that we wish to control. I do not want to put obstacles in the way of standardizing, because standardization of sensitometric technic and terminology is very desirable. But I do feel that it is too early to take steps to standardize time-scale instruments. All tests that we have made have tended to show that reciprocity and various other factors enter into the situation; and while approximate control can be achieved with a time-scale sensitometer, I do not believe that absolute control can be achieved with it. And while there is no perfectly satisfactory intensity-scale sensitometer, yet I believe Mr. Huse and the members of the Kodak Research Laboratory, if they will concentrate on the idea, can probably turn out an intensity-scale instrument that will be more satisfactory than the IIb sensitometer.

MR. JONES: Mr. Coffman's statement is one with which we all must sympathize from the purely academic point of view. The intensity-scale sensitometer is ideal for use with an intensity-scale process. We have such an instrument in the laboratory, and have described it to the Society. It is very expensive, and is difficult to reproduce from specifications.

In our design of the IIb sensitometer it was our purpose to lay down a structure that could be accurately reproduced in any machine shop; an instrument that would combine maximum precision with minimum cost. We think this instrument is entirely adequate for the purpose for which it was built—namely, the control of processing. Now, in the control of variable density sound processes there are factors built into the instrument that do take care of reciprocity failure in a practical manner.

If sensitometry is to be applied to the *theoretical* study of a tone reproduction problem, it is desirable to have an intensity-scale instrument. Moreover, this instrument should reproduce the time and intensity and quality of radiation used in the process.

Unfortunately, when one considers the multiplicity of practical problems—the picture problem, the sound recording problem, the printing problem, each with its many variations in different organizations and even within the same organization—he is faced with the necessity for a multiplicity of sensitometers. I do not see any way of building a single instrument of the intensity-scale type that could meet all the requirements.

Therefore, it seems to me we should add confusion by attempting to meet those conditions. Instead of one instrument at least four or five would be required, and the result would be chaos.

The time-scale instrument results can for practical purposes be applied to other problems by using arbitrary conversion factors. For the present I think this type of instrument offers the best chance at standardization of sensitometric procedure.

MR. T. E. SHEA: Is the work of the Sub-Committee on Sensitometry leading toward standardization of any particular type of instrument for practical work?

MR. JONES: I do not feel that I can speak with the authority of the Committee on that point because we have not perhaps had sufficient discussion of the subject to reach any conclusion. The proposals toward standardization in sensitometry that can be made at the present time are rather limited. I think it would be a mistake to set up too hastily and too arbitrarily sensitometric technics that we all recognize are perhaps forcedly artificial. I do not believe it is the intent of the Committee to propose that any particular instrument be adopted as standard.

However, there are certain rather basic things that can be established. For instance, I think the Society should establish at once, or recognize at once, the international unit of photographic intensity.

MR. COFFMAN: All I am asking for is a sense of values as related to the industry as a whole. Everybody in the motion picture industry must pay a tremendous amount of credit to the sound technicians who first forced sensitometry on the industry. At the same time, sensitometry, as now practiced by the industry, is not altogether a problem of sound and its control. As a matter of fact, I believe that we realize today that we need sensitometric control for pictorial quality far more than we need it for sound quality. And while the time-scale sensitometer seems for most practical purposes well adapted to the control of variable density sound negative processing, let us not forget that by far the greater amount of footage used by the industry is represented by prints; and that for every negative, either sound or picture, that is turned out, we are turning out at least a hundred prints.

For the purposes of print control, all studies that we have made seem to indicate that there are several variable factors that tend to upset systems of control based upon time-scale sensitometric indications. And I believe that we should study the matter quite carefully before we let the practice of the industry become crystallized.

This is an industry that tends to follow the leader; sometimes even rushing violently ahead of the leader. I do not believe that you would go as far as some of your technicians have in approving this IIb sensitometer for general use. But if we simply continue to use the IIb, trying other methods, and finally determine what is the best system of control for each kind of process, then I believe we shall be rendering a real service to the industry.

MR. JONES: I disagree somewhat with Mr. Coffman's apparent feeling that the IIb sensitometer can not be used satisfactorily for the control of pictorial quality. I think it can. Any such instrument properly calibrated, when proper conversion factors have been determined, can be applied to the control of pictorial quality as well as it has been used for the control of sound quality. It is the old story of learning the possibilities and limitations of a tool.

MR. R. F. MITCHELL: In checking some of the sensitometric controls in connection with our new printer, we ran into a rather interesting situation. Reference was made in Mr. Huse's paper to the girl test favored by many technicians. We investigated that rather carefully and found a considerable lack of agreement between different machines and between different laboratories in what they got from the same girl test. We checked back, and instead of using the girl-test negative, we used a clear film as a negative and made exposures at different printer steps, say, every alternate step. A sensitometric exposure was made on a piece of the same film and the two films developed together. The sensitometer strip gave the gamma and that part of the H&D curve for which the sensitometer was set. By taking the densities of the printer test and coördinating with the H&D curve, we obtained a graphical representation of the relative exposures at different printer steps. As far as the printer is concerned, specifically the Model D, we found that the placement of the printer light in the printer itself affected the difference in density obtained between different steps of the printer. There was considerable variation between any two steps on different printers, which seemed to be dependent on the placement of the light on the printer itself. That means of checking back on the printers, and on the testing machines used for making girl tests, provides a very desirable check for that type of control.

MR. COFFMAN: I believe that we have a sufficient volume of data available to state positively that if we use a time-scale instrument we must have conversion factors for every type of printer that we use. Mr. Mitchell has doubtless found that he will get different results with the new printer from those obtained with the old one.

MR. MITCHELL: That is partly due to that factor that I mentioned. It is also due to the fact that in the Model *D* we have more or less of an arithmetical progression of the printer steps, whereas the new printer is designed to give a geometric exposure progression.

MR. JONES: Mr. Coffman said we must have a number of conversion factors if we use a time-scale instrument for various types of photographic procedure. I personally feel that it is better to have a series of conversion factors with one standardized instrument, than to have several different intensity-scale sensitometers to represent each one of these procedures. I frankly think that the setting up of intensity-scale sensitometers to match all these conditions is going to be very much more confusing and much less economical than sticking to one sensitometer with a series of conversion factors.

MR. COFFMAN: Not every laboratory has all these various kinds of work to do. If we think of an experimental plant in which work of all kinds is done, that is one situation. If we think of plants in which the work is strictly specialized, then specialized instruments for those plants are obviously correct.

MR. JONES: I can not help feeling that the attempt to build sensitometers to duplicate all the various practical conditions would mean that in the industry we would have a very much larger number of sensitometers. Perhaps instead of nine or ten in Hollywood, as we have now, we would have forty or fifty of these, of several varieties. And I really believe that that would introduce more confusion than the course we are now following.

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SOCIETY ANNOUNCEMENTS

PROJECTION PRACTICE COMMITTEE

At a meeting of the Projection Practice Committee, held on June 15 at the Paramount Building, New York, N. Y., the final form of the targets, used in the test reel developed by the Committee and presented at the convention last April, was agreed upon. New targets were presented for detecting the presence of travel-ghost and for testing for aberration of projection lenses.

Among the items included in the agenda of the Committee for the coming season are the problems of monitoring the reproduction of sound in theaters, of the increasing importance of maintaining the highest quality of projection, and of exercising the greatest care in handling, shipping, storing, and cleaning the "wide range" and "high fidelity" films now being used. Defects in these processes are glaringly evident with recordings of the newer types, and, if allowed to persist, will nullify the benefits expected of the increased range of frequency of the recordings.

STANDARDS COMMITTEE

At a meeting of the Standards Committee, held on June 2 at the General Office of the Society, work was continued on the revision of the standards booklet, which it is expected will be published in the Fall. The work has been completed with the exception of bringing up to date the table of sprocket dimensions.

The Committee also investigated the question of standardizing the dimensions of motion picture reels, and of adopting the recommendations of the International Congress of Photography as regards the unit of photographic intensity for negative materials and the use of a non-intermittent exposure in making sensitometric measurements. The following motion was passed:

> "Resolved that the unit of photographic intensity adopted by the International Congress of Photography for negative materials, and the principle of non-intermittency in making sensitometric measurements, be adopted as recommended practice."

As regards the standardization of the perforations used in 35-mm. film, the following resolution was passed after considerable discussion:

> "Resolved that a single perforation be adopted for all 35-mm. film, and that this perforation be the present standard positive perforation, to be known hereafter as the standard S. M. P. E. perforation."

BOARD OF GOVERNORS

The next meeting of the Board of Governors will be held on July 14 at New York, N. Y. Consideration will be given to the financial problems of the Society, the question of reducing the annual dues, and various administrative matters. Officers for the year beginning October, 1933, will also be nominated.

PACIFIC COAST SECTION

At a meeting of the Pacific Coast Section, held in the auditorium of the Bell & Howell Co., Hollywood, Calif., on June 15, the following papers were presented:

"A New Development in Arcs for General Set Lighting," by Mr. E. C. Richardson.

"The Lumenarc—A Mazda Lamp-Gaseous Tube Unit for Daylight Quality," by Mr. R. M. Maxwell.

"A New Development in Incandescent Lamps for Motion Picture Lighting," by Mr. R. E. Farnham.

SUSTAINING MEMBERS

Bausch & Lomb Optical Co.
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Burnett-Timken Laboratories
Eastman Kodak Co.
Electrical Research Products, Inc.
National Carbon Co.
RCA Victor Co., Inc.

HONOR ROLL
OF THE
SOCIETY OF MOTION PICTURE ENGINEERS

By action of the Board of Governors, October 4, 1931, this Honor Roll was established for the purpose of perpetuating the names of distinguished pioneers who are now deceased:

LOUIS AIMÉ AUGUSTIN LE PRINCE
WILLIAM FRIESE-GREENE
THOMAS ALVA EDISON
GEORGE EASTMAN
JEAN ACME LE ROY

PAMPHLETS, BOOKLETS, AND CATALOGUES

Manufacturers of motion picture equipment and supplies are requested to send to the General Office of the Society copies of their descriptive pamphlets, booklets, and catalogues as issued. Notices of the issuance of this material will be published in the JOURNAL, advising the readers that the material may be obtained free of charge by addressing the manufacturers named. This editorial service has been established in order to acquaint readers of the JOURNAL with the commercial developments of the motion picture industry as quickly as they occur.

EMPLOYMENT ADVERTISEMENTS

In order to assist members of the Society who desire to obtain positions, the Board of Governors has authorized the establishment in the JOURNAL of an "Employment Page." Advertisements will be available to members of the S. M. P. E. who desire positions and to manufacturing concerns seeking trained men. Material for publication is subject to editing, and must be sent to the General Office of the Society by the 10th of the month prior to publication.

Each employment advertisement shall not exceed one-sixth page in length; a charge of $2.00 will be made for a single insertion, or $5.00 for three consecutive insertions.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

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SYLVAN HARRIS, EDITOR

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REPORT OF THE PROJECTION PRACTICE COMMITTEE*

Projection provides the industry's closest contact with the public, whose continued patronage is dependent largely upon the quality of the projected picture and the reproduced sound—the finished product which embodies the work of all other branches of the industry. Acceptance of the foregoing fact leads naturally to a consideration of the means available for maintaining at all times a high standard of quality. The Committee feels that every facility that aids, even remotely, in maintaining a high standard of projection should willingly be provided.

TEST REEL

A serious deficiency in the projection field heretofore has been the lack of an efficient test medium that would enable the speedy and convenient detection and correction of various defects common to both visual and sound apparatus. To meet this requirement, the Committee, in collaboration with the RCA Victor Company, Inc., has devised a test reel that serves two distinct purposes in that it provides an accurate means of checking both the visual and the sound equipment. This film is suitable for use on all makes of equipment arranged for projecting films that conform to the specifications of the Standard Release Print.

The test reel is about 1000 feet long, of which about 500 feet are devoted to various targets (test objects) to be used for detecting optical defects, the remaining 500 feet providing various means of testing sound quality. The latter section has sound tracks on both margins of the film, thus providing an effective test footage of approximately 1000 feet.

Optical Test Section

The "optical" section of the test film will be considered first. It contains five test targets with appropriate descriptive legends in the following order:

(1) Travel-ghost.

---

* Presented at the Spring, 1933, Meeting at New York, N. Y.

(2) Picture-jump.

(3) Vertical lines for testing marginal and radial aberration of the projection lens.

(4) Horizontal lines for testing the marginal and radial aberration of projection lens.

(5) Small squares for checking focus.

(1) *Travel-Ghost Target* (Fig. 1).—Unless the shutter is properly adjusted and timed, "travel-ghost" will be evidenced by the blurring of the bright portions of the screen into the dark portions, with a resulting loss of detail in the vertical direction. The target consists of

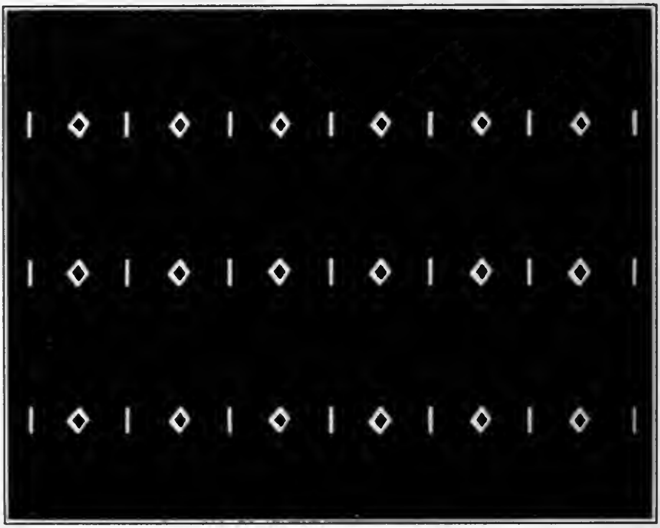

FIG. 1. Travel-ghost target.

white geometric forms on a black field. Travel-ghost may be considered to have been eliminated when the outlines of these white forms are clearly and sharply defined on the screen against the black field.

(2) *Picture-Jump Target* (Fig. 2).—This target consists of two rows of white rectangles placed corner to corner along the diagonals of the screen image, against a black field. The amount of picture-jump can be measured with a ruler held against the screen at the top or bottom of any of these rectangles. By holding the ruler to the vertical side of any of these rectangles, the amount of side-motion, or weave, may be determined.

(3) *Vertical Line Target* (Fig. 3).—This target consists of a series of white vertical lines against a black field. Projection of this image in sharp focus *over the entire area of the screen* by a lens in one position, in this and in the following test, stamps the lens as one that is commonly referred to as having a "flat field." If, on the other hand, marginal aberration is present, it will be indicated by a blurring of the lines at the sides of the screen. Radial aberration will be indicated by a blurring of the lines at the top and bottom of the screen.

(4) *Horizontal Line Target* (Fig. 4).—This target serves the same purpose as the preceding target, except that it is partly intended to compensate for visual deficiency (astigmatism) of the observer.

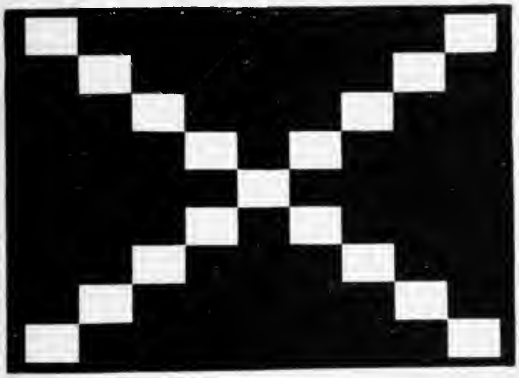

FIG. 2. Picture-jump target.

(5) *Small Square Target for Checking Focus* (Fig. 5).—This target consists of numerous white squares, arranged and numbered in vertical and horizontal rows, against a black field. The position of the lens for which the greatest possible number of squares are projected in sharp focus is the most desirable lens position. The numbering of the squares provides a means for making comparative tests of lenses.

Sound Test Section

The remaining portion of the test film, some 500 feet long, is recorded on both edges, as previously stated. On one side of the film are recorded the following tests with suitable accompanying announcements:

(1) Buzz track for checking the position of the scanning light relative to the sound track.

(2) 6000-cycle and 9000-cycle constant frequency tracks for checking the focus of the sound optical system.

(3) Selected frequencies for ascertaining the over-all characteristics, as follows: 50, 100, 200, 300, 500, 1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000, and 10,000.

(1) *Buzz Track.*—This consists of a 300-cycle and a 1100-cycle frequency recording, respectively, just outside the boundaries of the standard sound track area, one on each side. When the 1100-cycle

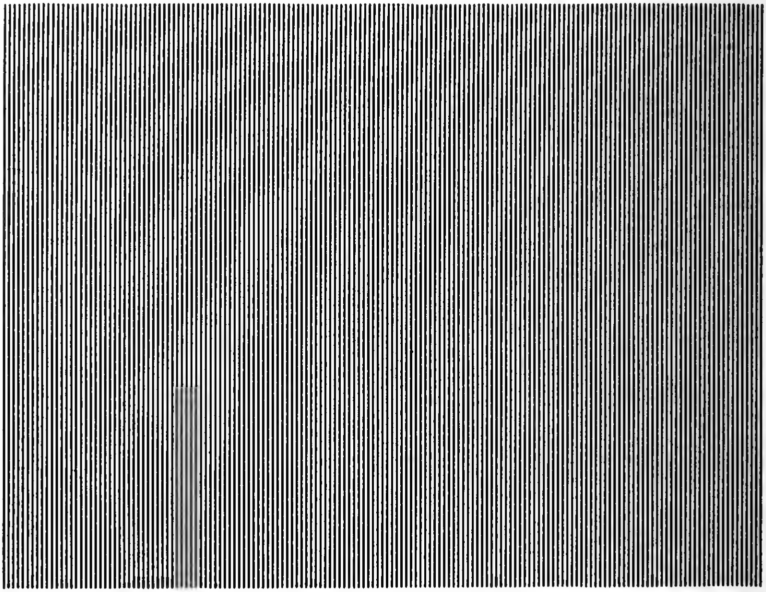

FIG. 3. Vertical line target for testing aberration of projection lens.

note (the higher pitched note) is heard, it indicates that the film is passing the light slit too closely to the sprocket hole margin. When the 300-cycle note (the lower pitched note) is heard, it indicates that the film is passing the light slit too closely to the picture margin. When both notes have been eliminated by properly adjusting the lateral guide rollers, or by adjusting the optical system, when such adjustment is provided, correct film travel path may be assumed. When one or both notes are *intermittently* heard, this indicates film weave. If the weaving be due to warping of the film, its effect may in some cases be reduced by adjusting the sound gate tension springs.

Incorrect relative alignment of the projector head and the sound head also may cause weaving.

(2) *6000-Cycle and 9000-Cycle Constant Frequency Tracks.*—When the maximum volume of sound is obtained for each of these frequencies, it may be assumed that the optical system is correctly positioned for obtaining the best results; that is, that the scanning light is sharply focused *and* perpendicular to the direction of travel of the

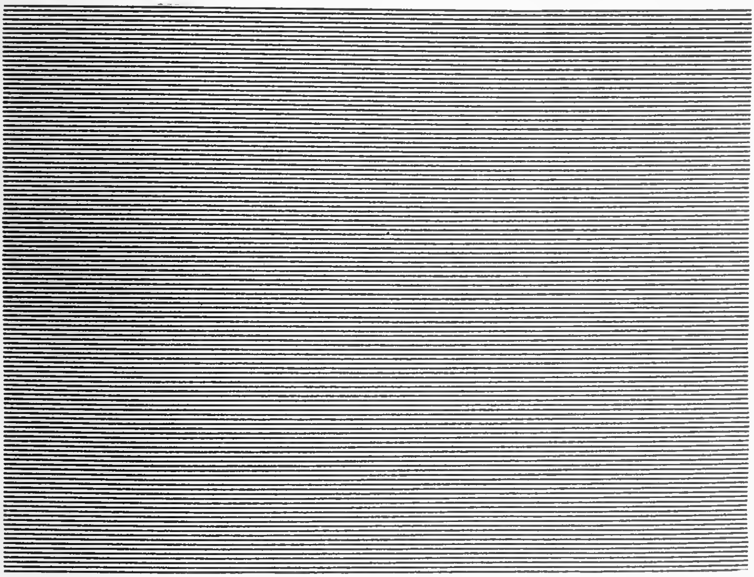

FIG. 4. Horizontal line target for testing aberration of projection lens.

film. The 6000-cycle note is used for making an approximate adjustment, and the 9000-cycle note, if audible, for still finer adjustment. This positioning should not be undertaken unless the optical system has been specifically designed to be adjusted and suitable adjusting tools are available.

(3) *Selected Frequencies.*—This track is so recorded that no voltage calibration (on a volume indicator) is required. Assuming a perfect scanning slit and a "flat" amplifier, the resulting over-all characteristics, as determined by a volume indicator, would be flat. The ear will naturally be more responsive to the 1000-cycle note, whereas the higher and lower frequency notes will sound less loud. Of course, a

volume indicator would admit of making precise measurements of the sound level; this applies equally well to sections 2 and 3 above.

On the other edge of the sound test film are recordings of voice, piano, and orchestral music. The vocal portion is to be used for testing intelligibility of speech and theater reverberation; the piano recording for detecting flutter ("wows"); and the orchestral recording for noting the naturalness of reproduction, which is determined by the range of frequencies reproduced by the equipment. This recording contains notes ranging from the lowest notes of the tuba and double bass to the very high overtones of the string and brass instruments. The metallic quality of special instruments, such as the wire brushes, should be particularly noticeable.

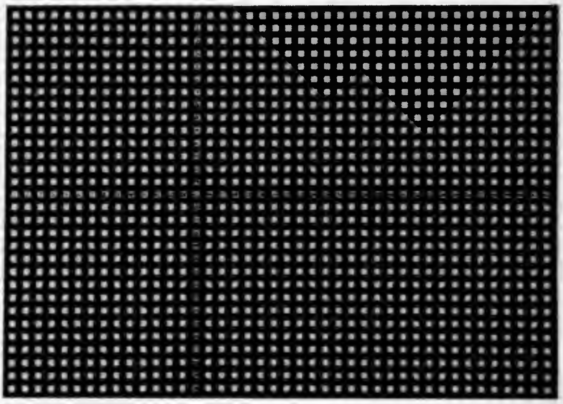

FIG. 5. Small square target for checking focus.

OPTICAL ALIGNMENT TOOL

In conjunction with the test reel, the Committee recommends a tool to be used in aligning the arc, condenser, projector aperture, and projection lens on the optical axis. The model, designed by the Committee, and referred to in the following description, conforms to the standard 13.6-mm. carbons used in high-intensity lamps. To obtain the maximum illumination and most uniform distribution of light on the screen, it is of prime importance that the arc and all components of the optical system be accurately centered. Fig. 6 shows the several parts of this tool:

A is a disk having a hole through the center, which is placed in the condenser mount instead of the condenser. *B* is a cylinder having an axial hole through the center, which is clamped into the projection lens holder. *S* is a short pointed bar, which is inserted through cylinder *B* and extended through to the aperture of the projector. The bar should be in the center of the aperture. An aperture plug having a centered circular hole with clearance for the bar can be provided as an additional convenience.

L is a pointed bar, 36 inches long and approximately $^1/_2$ inch in

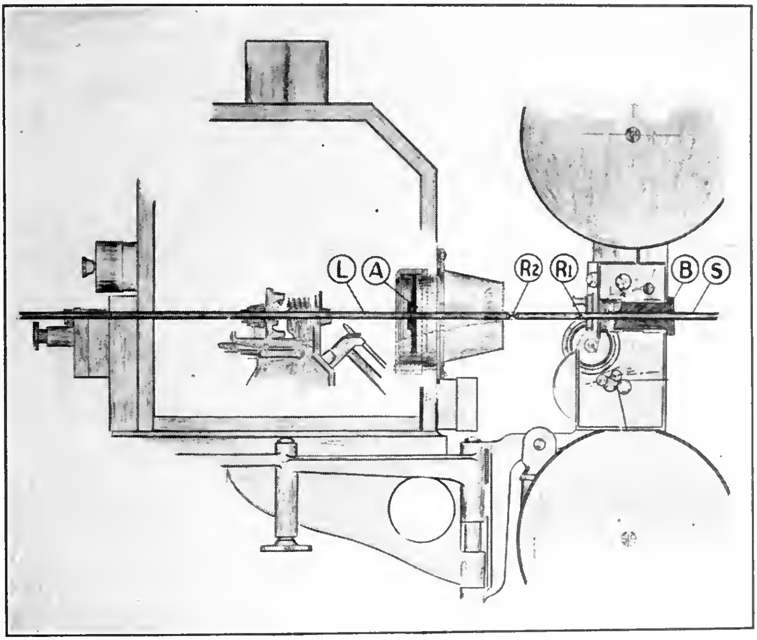

FIG. 6. An optical alignment tool in use.

diameter (the approximate diameter of the 13.6-mm. positive carbon), which is inserted through the back of the lamp house, through the positive carbon clamp and through the disk *A*, which occupies the position of the condensers. This bar, which replaces the positive carbon, should be aligned along its entire length with the center of the condenser mount. The bar is then extended to the aperture where, by manipulating the arc housing on the base of the projector, the points of the two bars, *L* and *S*, may be aligned, as at R_1.

Subsequently to this alignment, a confirmatory test is made by drawing the long bar back toward the disk A and extending the short bar through the aperture so as to touch the point of the long bar as indicated at R_2. Further manipulation of the arc housing may be required before the bars are exactly aligned. After this operation, it should be possible to withdraw bar S, the smaller one, and extend bar L through cylinder B without difficulty. (This device is a modification of a similar piece of equipment used on a limited scale some years ago. The Committee strongly recommends a much wider use of this tool.)

POSITIVE PRINT DENSITY AND STUDIO PROJECTION SCREEN ILLUMINATION

It has been definitely established that the intensity of illumination of the screens used in most studio projection rooms is greatly in excess of the intensity that can be obtained in the theaters. The great disparity that was found to exist was pointed out in a report of the Theater Lighting Committee, published in the February, 1931, issue of the JOURNAL. Complaints regarding dense prints still persist, however, indicating the need of additional emphasis in the matter.

The Projection Practice Committee has conducted a partial survey of typical theaters for the purpose of determining the values of screen illumination obtaining in practice, and it is significant that its findings, in a widely separated territory and after a lapse of two years, check closely with the findings of the Theater Lighting Committee referred to above.

The results of these two independent surveys indicate that the average intensity of the projected light at the surface of theater screens lies between 8 and 12 foot-candles, and that the average coefficient of reflection is about forty per cent, corresponding to intensities between 3.2 and 4.8 foot-candles, these figures being based on the use of diffusive screens.

In the tests made by this Committee, each projector was equipped with a two-blade, 90-degree shutter which caused a reduction of approximately 50 per cent of the screen illumination as compared with measurements made when the projector was at rest. In each test, the auditorium illumination approximated that obtaining during the presentation of pictures.

Invariably much smaller pictures are projected in the studio projection rooms than in the average theater, resulting in excessive screen illumination. In addition, reflective screens are sometimes used in studio rooms, adding further to the brightness of the projected picture. In the great majority of theaters, however, not only are much larger pictures projected than are shown in the studio rooms, but, in addition, diffusive screens are used. It is obvious that under such circumstances it is extremely difficult to reconcile studio "screen values" with theater "screen values," unless some compensating adjustment is made in the studio room. It seems highly desirable that no reflective screens be used in studio rooms in which print density is to be judged.

On the basis of these facts, therefore, and in view of the easy and inexpensive manner in which the requisite change can be made, the Committee suggests that in each studio projection room where the screen illumination is excessive, each projector be provided with a diaphragm or iris in front of the lens to reduce the flux of projected light while measurements of screen illumination are made. The iris can be so adjusted that the screen reading approximates the average value obtaining in the theaters, after which a diaphragm mask having a fixed aperture of the proper size can be substituted at will for the iris.

CHANGE-OVER MARKS AND THEIR LOCATION

It is obviously not good practice to attract the attention of the audience to the marks used for start-motor and change-over cues. Attention will, however, be drawn to the marks if important action occurs near them.

Neglect of a corresponding precaution has resulted in giving undue prominence to change-over marks in certain recent feature films. Greater care in arranging the location of the indicating marks would prevent such occurrences. The placing of indicating marks should be in accord with desirable practice, as follows:

(1) No motion of objects directly toward or away from the mark is desirable, and

(2) The marks should not be placed over moving objects or near significant action.

The first requisite is that the indicating marks shall be properly positioned; and next, that they shall be visible to the projectionist. Unless both these requisites are emphasized, the crude punching and marking of film by individual projectionists will undoubtedly continue, if not actually increase, and cause a pronounced loss of entertainment value and waste of film stock.

The Committee proposes that the studios experiment with marks of different shape, in order to distinguish between start-motor and change-over cues; *e. g.*, a diamond for a motor-starting mark and a circle for a change-over mark. This is an additional safeguard against faulty change-overs.

In view of the fact that prints having marks that are not sufficiently visible from the projection room are still being released, the Committee feels justified in referring again to the suggestion made in its preceding report; namely, to surround each black indicating mark with a thin white circle that will be visible against a dark background. Two of the major film producers have acknowledged the value of this suggestion and have adopted it in practice.

HARRY RUBIN, *Chairman*

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T. C. BARROWS	J. J. HOPKINS
G. C. EDWARDS	W. C. KUNZMANN
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C. FLANNAGAN	P. A. MCGUIRE
S. GLAUBER	R. MIEHLING
C. GREEN	F. H. RICHARDSON

V. A. WELMAN

DISCUSSION

DR. GOLDSMITH: The company that has made the negative of the test reel, the RCA Victor Company, has stated to the Society its willingness to make prints and to furnish them to the Society or others upon the request of the Society. That is, the Society can buy the prints and ship them, or the Society can act to instruct the maker of the prints to ship them.

The Board of Governors has had data on that subject laid before it, but has not yet fixed on a definite price for the prints, because there are shipping costs and handling costs which the Society must consider. It is likely that as soon as, and if, this reel is accepted and suitable prints become available, the Society will undertake to announce to the theaters that this reel is available; and that theaters, exchanges, laboratories, or others who wish such a reel for test purposes, can address the headquarters of the Society. By sending a suitable remittance, for the reel and for the shipping and handling charges, such a reel will be then sent to that theater exchange, laboratory, or other organization. In other words, the Society would become the clearing house through which the test reels will reach the theaters, and the Society will instruct the shipper to whom to send them.

That procedure may not be the one that may be adopted. It is too early to make a definite statement and it must be understood that I am speaking unofficially. The Board of Governors has not as yet ruled on the matter.

MR. RICHARDSON: It seems to me that the Society itself might perhaps offer to furnish these reels at a fair rental and to recommend that all exchanges carry at least one copy of the film for rental to their customers.

DR. GOLDSMITH: The superior facilities of an exchange for arranging the rental and for collecting the rental fees, would make the exchange a more logical agency for distribution. We would have some hesitancy in saddling the office of the Society with the task of arranging for the rental of these films, perhaps to hundreds of theaters per month, and then arranging for the collection of rentals, the shipping of the film, and the like. Our natural inclination would be to let an exchange, that was interested and that believed that the Society's recommendation of this test reel was valid, buy such a film from the Society and rent it until the reel no longer was usable, and then buy another one. In other words, the exchange would handle these films in much the same way that it would handle any other theater film.

MR. RICHARDSON: In the legend accompanying the travel-ghost target, the projectionist should be warned that he can not detect a faint travel-ghost from the projection room, especially when the projection distance is long; not even with an opera glass. It is necessary to approach within 25 feet of the screen, at least, in order to be sure that faint travel-ghost is not present.

MR. TUTTLE: I do not believe that the definition test object is sufficiently critical. Some sort of pie chart, or a series of pie charts, might be more critical. When making the steadiness test, one notices not only the steadiness of projection, but the steadiness of the print as well. We assume that the print will be accurately made, but I wonder whether an accurately punched film, the perforation of which would show on the screen, would not be a better kind of test object to use. Also, I believe that the aberration test object would be somewhat better if the horizontal and vertical lines were closer together.

MR. KURLANDER: Like Mr. Tuttle, I feel that some of the test objects used in this film are too elementary to do what they are designed to do. Certainly any method, to be an improvement over the means already at the disposal of the projectionists, must be more precise than those described.

With respect to the first test object, as Mr. Richardson pointed out, he recently had to go within 25 feet of the screen in order to detect travel-ghost. That wasn't the projectionist's fault; the travel-ghost was present, but he couldn't see it. It seems to me that an adjustment when once made, should be permanent, and should be made carefully and very critically. If we give the projectionist the proper kind of target, he will be able to make those critical adjustments precisely. Instead of the travel-ghost target used in this report, I recommend that the travel-ghost figure be made up of alternate white and black horizontal bars of equal width. A slight amount of travel-ghost would cause the white bars to increase in width at the expense of the black bars. This would result in an alteration of the entire pattern that would be easily detected.

As travel-ghost increased, the white bars would become broader and the black bars narrower, until finally the black bars would disappear entirely and the pattern would consist of alternate white and gray bars.

It is extremely difficult to detect an increase in the width of a white line; but it is comparatively easy, with a regular pattern, to detect a change over the whole pattern and I would suggest that horizontal bars of equal width be used. The best width would have to be determined experimentally.

A test for lens definition was described some time ago in the *Transactions* which consisted of a fine engraving of various characters in the form of an over-all pattern. Such an engraving would seem to be necessary in order to determine whether or not the lens is a good one. The proposed bar pattern seems too crude for the purpose.

As for the optical alignment tool, it is not new. It was used in the days of Mazda lamp projection, and the greatest drawback to its extended use was its cumbersomeness. In the first place, it is a little awkward to make. The average projectionist probably would not go to the trouble of making such a tool, as it is a machine job. I would suggest some optical method instead of the alignment tool.

As regards the use of an iris diaphragm for framing, I would suggest that the statement be made in the report that the iris diaphragm should be placed over the mouth of the projection lens. It can be used also to diaphragm the condenser; or, in a similar manner, to diaphragm the mirror of the reflector arc. The most logical way, however, is to diaphragm the projection lens.

With respect to screen intensity, I am not so sure that high intensities should not be used in the screening rooms of studios. Screening is an inspection process, and the observers ought to be very critical; certainly they should inspect films under a much higher intensity than that to be used in the theaters. It seems to me that the point to be stressed is the standardization of print density.

Now, with respect to the change-over marks, we have all the elements in a modern projector for changing over automatically. There are present a photoelectric cell, ample light, and electricity. Perhaps some photoelectric cell method for automatic change-over can be devised that will eliminate the change-over marks; or, at least, incorporate them in the film in some way, so that the projectionists won't have to watch for them.

The density of the film should be such as to suit the requirements of the average theater, according to the illumination provided. We now receive many prints that are satisfactory in the big theaters where the intensity of the light source is sufficient; but they are far from being satisfactory in the smaller houses of the country. In order to determine the proper density to which the films should be printed, they should be viewed in the screening room at about the same brightness they will have in the theaters.

MR. FINN: The pattern of the travel-ghost target was designed with the definite idea in mind that it must be seen from the projection room. It would be very difficult to see from the projection room a pattern like the one Mr. Kurlander suggested. If travel-ghost is eliminated to the extent possible with this target, there will be an enormous improvement in projection.

As for utilizing the photoelectric cell to actuate an automatic change-over, it is true that we have available every necessary component. But it occurs to me that whatever will actuate the photoelectric cell will have to be on the film itself. Although an automatic change-over device is very desirable, I do not believe that one rational idea has been proposed so far that would utilize a photoelectric cell for a change-over.

As for the optical alignment tool, the Committee emphasized the fact that it is not a new device; but that like so many other things that are proposed, it finds its way into the library, and that is the end of it. Although this tool was used in the days of the tungsten lamp, it is not being used now. True, the tool is a machine job; if it is to be used in the projection room, it will have to be bought.

MR. EDWARDS: Anybody who has operated a projector for any length of time has found out very early that it was impossible to eliminate travel-ghost while looking at a picture. The old way of doing it was the way it is done today—to wait for the title—because the title contains horizontal lines, vertical lines, and points, by means of which one can detect the travel-ghost. Unfortunately, in sound pictures there is not very much in the way of titles.

Alternate bars of black and white will, it is true, show the travel-ghost fringe; but that fringing will be three times as hard to detect on a bar pattern as on a point pattern, because on the point pattern one sees the stream of light coming right up to the points.

As for the change-over marks, I think every projectionist has had this experience when starting a projector, that just at the time when his eyes should be glued to the screen, something happens that diverts his attention for an instant, with the result that the mark slips past. The other mark comes along a little later, and he starts his machine at the change-over mark. I think the idea of having the start-machine mark in the shape of a diamond, and a change-over mark in the shape of a circle, will prevent many cases of that kind. The projectionist would know at once what the mark was for when he saw it.

As for the automatic change-over, such schemes would be workable if every theater always ran first-run film. The number of theaters that run first-run film are a small minority. But what will happen in the theater that receives 30- or 60- or 90-day films, and sometimes 200-day films, in which case one is particularly lucky if he has the last scene in at all. How will the actuating device for the photoelectric cell work then?

So many different kinds of marks appear on film that it would be almost impossible to place a mark that would not be duplicated several times throughout the run of the film by accidental marks made by faulty equipment.

MR. KURLANDER: The value of the travel-ghost pattern rests on the fact that when no travel-ghost is present, a pattern is seen; and if travel-ghost is present the pattern is thereby changed. It is true that the projection distance will determine what the width of those lines should be. That is a point the Committee should investigate. The pattern, however, was advanced with the idea of detecting a very small change or increase in travel-ghost.

With respect to photoelectric cells, Mr. O. H. Caldwell, in a paper presented on the first day of this convention, certainly gave enough illustrations of the work that can be done by small photoelectric cells.

MR. FINN: I am very familiar with Mr. Caldwell's paper. I still maintain, however, that the fact that a photoelectric cell, or a light-sensitive cell, will operate a relay and cause a garage door to open doesn't mean that it is suitable for change-over purposes. A photoelectric cell must have some actuating means; and I insist that the film travel controls the change-over process. A mark is required on the film itself. What else is going to control the cell's operation?

MR. SCHLANGER: Some of the same films as, or films similar to, those used for testing projection equipment, could be advantageously used by the exhibitor to test the particular view of the screen that each seat in the theater may afford.

A simple device could be used in conjunction with the test films. It would consist of a piece of glass or other transparent material, small enough to hold in the hand before the eyes. On it would be printed a pattern, similar to the pattern used in the test films, consisting of a series of horizontal lines in one case, and vertical lines in another. By looking through this glass frame at the test film projected on the screen, the amount of distortion of the screen image from any seat in a theater could be measured.

Such a testing method is intended chiefly for use in existing theaters having seating arrangements in need of correction to obtain a proper view of the screen. If such a device accompanied the test films distributed to exhibitors, and should the exhibitors themselves witness the distortion of the screen image as seen from the poor seats, they might show more interest in improving the sight lines of their theaters.

MEMBER: The accuracy or value of the optical alignment tool depends entirely upon the straightness of the rods. I wonder whether they might not become bent during use without being noticed; and whether a certain degree of springing might not occur—so that, when the test is made, it might be thought that the system is faulty, when it isn't.

I would suggest the use of tubes instead of rods, with the idea that one might sight through the tubes and correct the alignment that way. If the tubes were bent, it would be noticeable. And I believe also that by that method it should be possible to make the alignment with only one setting instead of two, as are necessary in the case of a rod. A light would be placed at the end of the tube in the projection head and one would sight through the tube in the lamp house.

MR. RICHARDSON: Suppose the tube is placed in the front end of the projection lens, and the lens itself is a bit out of alignment. Then the whole system would have to be out of alignment to get the result sought.

MEMBER: Wouldn't that objection apply in the case of the rod?

MR. RICHARDSON: No, because the rod would extend clear through.

MEMBER: It would be necessary to place some object at the end of the front tube.

MR. RICHARDSON: It seems to me that the rod is the logical thing, but I think your objection is well put as to the possibility of bending.

MR. RUBIN: This tool is made of steel that can't be bent without great difficulty.

MR. KROESEN: Many tests should be made before the rod is finally adopted, because there are too many variances throughout the projector mechanism to warrant our saying it is accurate without testing it sufficiently. Many manufacturing tolerances should be taken into consideration.

MR. JONES: The manufacturers of projector lenses certainly have during the past years given the subject of testing those lenses a great deal of careful study. I am quite sure that they have worked out tests that have proved satisfactory for detecting the various kinds of aberration; and I am wondering whether they have been consulted with regard to the various test objects that are adapted to show with the maximum of magnification these various defects that we wish to locate. If not, I certainly think that before we decide to adopt any particular test film, the matter should be discussed with them.

MR. RUBIN: The purpose of the Committee has been to design or suggest, a set of tools for the projectionist that would be simple and easy to use, without requiring the assistance of specially trained engineers. Up to the present time, the projectionist has not been provided with any tools with which to test his equipment. He has not been encouraged by any society, to provide himself with such tools. The Projection Practice Committee has attempted to do so.

The tools—the test film and the alignment tool—have been so designed as to require no special training on the part of those who use them, to require a minimum of time in which to conduct the tests, and to require no additional equipment whatever. Perhaps these tools can be improved; I am sure that the optical companies have better testing equipment, but it is probably more elaborate.

For many years projectionists used titles for testing for travel-ghost. Since the inception of sound and the absence of titles, he has had to substitute something for the title, and has found that any vertical sharp point against a black background, or a white spot against a black background, is the best test for travel-ghost.

In the present design the sharp points against the black background are easily visible, and provide the best means for accurately correcting the travel-ghost. Both fine lines and heavy lines are provided, and you will notice that the sharp lines show the travel-ghost much better than the other lines; and furthermore, until such time as means are developed that will make it unnecessary for the projectionist to use spy glasses or to go within 20 feet of the screen, we shall have to do the best we can with the system that we have.

MR. KURLANDER: The reason, I think, why titles were so effective in showing up travel-ghost was simply that the titles approximate horizontal lines the height of which was small in comparison with the extent of the travel-ghost. Not much travel-ghost is needed to show in a title. But in the proposed test target, the figure is large, and one can not see much travel-ghost in a figure of that size.

With respect to the alignment tool, it is very difficult to induce projectionists to use tools of any kind in aligning their equipment. A similar tool was tried years ago and a few conscientious projectionists used it. But the larger number of projectionists didn't care and they did not use it; that is why the tool went out of use. I doubt whether such a tool will find extensive use.

MEMBER: Has any one looked into the possibility of designing some device for adjusting the optical system?

MR. RUBIN: This Committee has been endeavoring to obtain the coöperation of the manufacturers in designing such tools, but up to the present we have had no such coöperation. The Committee would be very happy to have the coöperation of every manufacturer. With the help of the RCA Victor Co. we were able to prepare the test reel that you saw today. We have in mind a number of other tools and have invited many manufacturers to coöperate in the work. I am sure from this discussion here today that something will be done.

MEMBER: Why should the device for testing equipment exist separately from the equipment itself? There is a possibility that the operator will pay no attention to a separate piece of equipment, whereas, if the equipment is made part of the main apparatus, he may be induced to look at it occasionally.

MR. RUBIN: The lens manufacturer may have a little gadget for his lens, but what about the mechanism, and the sound head, and the condensers, and the lamp, and other elements that go with it?

MEMBER: Are there no graduations on those things to show when they are correctly aligned? Couldn't they be extended?

MR. RUBIN: Probably they could. But this Committee is working with material already in the theaters; we must obtain the best results with the equipment that is in the field.

DR. GOLDSMITH: The point that has just been brought out is well taken. There are two ways of determining the momentary condition of a piece of equipment. One is by means of some indicator, which is an integral part of the device itself, as, for example, a voltmeter or an ammeter or some mechanical indicator which shows the instantaneous condition. The second method is by means of a separate adjunct that can be brought by a service man to the location of the device.

The difficulty is that we face a condition where something over 10,000 theaters in the United States have actual projection equipment in their projection rooms and, economic conditions being what they are, it will be some time before most of these projectors are replaced. When they are replaced, certainly the projector manufacturers would be well advised to consider the inclusion of self-contained indicators wherever practicable.

Certainly the rod-type centering mechanism that has been described could hardly be included in the projector, because it would occupy space to the exclusion of the carbons, the film, and the lens. It is, therefore, a device that apparently could not be permanently in place. But certain other things might well be included in the projector, such as mechanical gauges or sighting devices. Even if nothing else is accomplished by these suggestions except that we direct the attention of the projector manufacturers to these points, the discussion will have been of value.

Facing the conditions that it did, the best that the Projection Practice Committee could do was to devise external and separate indicators and devices that could be carried into the projection room and used for tests, leaving until some later date recommendations for the production of new projectors that would enable these tests to be carried out without any further test equipment.

MR. GOLDEN: With regard to the alignment tool, I believe that it should be known that the entire Loew's circuit is now using such tools, which have been found to be very effective and helpful in aligning equipment.

As to the possible chances of getting the projectionist to use the tool, after all, the projectionist of today can not be compared with the projectionist of the early days. With the advent of sound, he was forced to use tools that he had never dreamed of. So, therefore, since he has been able to master and handle sound, why can't he, if shown that this tool is practicable, be able to help put on a better show. The projectionist, once shown that the tool will help him in his work, will use it.

MR. BLIVEN: The entire procedure seems to me to represent good practice in projection work; but the only objection that I have to make is the possibility of fatiguing the eye in checking the definitions. Why not use a very light straw color instead of the pure whites?

DR. GOLDSMITH: It was suggested that a gray glass be slipped before the lens but the difficulty is that as soon as the sharp edge contrast is lost, the sensitiveness of the test goes down again.

MR. BLIVEN: May I suggest that the field of test film be limited, to cover specific points at a time. Probably a thousand-foot film would not be long enough for that, or perhaps the cost of the films would be prohibitive.

DR. GOLDSMITH: The Committee had in mind using a vignette with one of the test subjects so that only a portion of the field would be shown, the rest of the field being dark; and letting the person watching the vignette travel around. But difficult production problems would be involved, and more elaborate research than was thought justified.

MEMBER: In the early days when the machine had to be taken apart and oiled and cleaned, the obvious way for the operator to adjust the shutters was to place a small flash-lamp in front of the projection lamp and project the beam on the film; and then to set the shutters so that it covered the lens as the pull-down started. In all the years that I used that scheme I never had to use a test object on the screen to see whether I had travel-ghost. Travel-ghost is caused by the shutters being out of time, and the lens must be closed while the film is being pulled down. It is not difficult at all to set the shutter in the projection booth without using any test object whatever on the screen. I think it is going to be impracticable to use a long reel. If the tests were made on four-foot loops, each one stored in a can by itself, the required test could be selected whenever desired. There would be a number of such loops, one for definition, one for aberration, and another for travel-ghost, or whatever the defects happen to be; and one would select the particular four-foot loop needed, and run it for whatever time necessary to adjust the projector.

AN EXPERIMENTAL APPARATUS FOR THE PROJECTION OF MOTION PICTURES IN RELIEF*

HERBERT E. IVES**

Summary.—*An experimental demonstration apparatus is described for projecting motion pictures in relief by application of the principle of the parallax panoramagram. A series of thirty-two posed, still pictures is made by the use of a large diameter concave mirror forming an image on a transparent concave ridged screen, which in turn is imaged on lantern-slide plates. Positives from these negatives are mounted on a slowly rotating disk in the slide plane of a projection lantern. A flashing mercury lamp illuminates each picture as it comes into position. The projected image is received upon the back of a translucent convex ridged screen. When viewed from the front, the moving picture changes its appearance with the observing position, and exhibits stereoscopic relief.*

While methods of projecting motion pictures in relief, depending upon the use of apparatus at the eyes for separating the appropriate views, have been successfully demonstrated, methods and means by which motion pictures might be seen in relief without individual viewing devices have not heretofore been developed, even in an experimental form. Popular interest in the possibility has indeed brought forth many attempts, but these have quite generally proved to be scientifically unsound, and, in the vain hope of making the apparatus simple and practicable, have failed to face squarely the essential conditions.

Ideal requirements for a scientific solution of the problem (not necessarily to be identified with commercial practicability) may be listed as follows:

(1) No individual viewing apparatus for spectators.

(2) A single photographic exposure for each of the successive pictures out of which the motion picture is built up.

(3) A single projection device.

Certain other goals, while undoubtedly desirable, may be dismissed as being incompatible with the nature of the problem, such as the use

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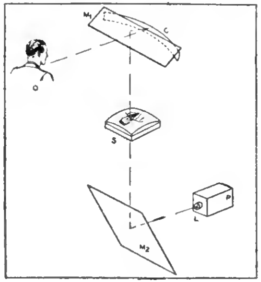

FIG. 1. Diagrammatic sketch of the camera for making relief projection negatives.

FIG. 7. Relief image on the rod screen, as viewed from three directions.

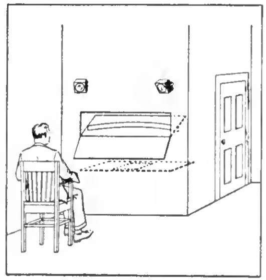

FIG. 3. The "camera" room.

of an "ordinary" motion picture camera and the use of an "ordinary" projection screen.

These requirements may be met by applying the scheme of the parallax panoramagram. As described in earlier papers,[1] multiple strip pictures, produced by a single exposure with a large diameter

FIG. 2. Photograph of the taking apparatus from the rear.

concave mirror, in conjunction with a concave ridged screen, can be projected upon a translucent convex ridged screen, and yield a relief image. For this image to exhibit motion, it is necessary to project a series of such pictures of a moving object taken in rapid succession. It is this last step that has been achieved in the apparatus here described.

The key problems to be faced in the transition from a single projected relief image to a rapidly moving sequence are those of accuracy of registration. Each multiple strip picture must be projected in turn upon the ridged screen with no relative distortion or lateral shift with respect to the preceding and following ones, since any varying distortion of position, even if exceedingly small, will result in wavering or jumping of the image. In order to meet this

FIG. 4. One of the thirty-two parallax panoramagram pictures used to build up the motion picture in relief.

requirement, since it was considered doubtful that pictures on celluloid film would be likely to be sufficiently rigid or could easily be guided with the requisite accuracy, the use of glass plates was resorted to, and the series of pictures was mounted on a rotating disk. This is, in effect, a return to the earliest form of motion pictures, the magic disk of Plateau, one form of which, the *zoötrope*, was a common laboratory toy before the motion picture emerged in its present form.

With this statement of the over-all form of the projection apparatus, we may proceed to a description of the details of the actual system.

The Camera.—Fig. 1 shows diagrammatically the single exposure camera used for making the individual "frames." At O is the object; at C the 4-foot diameter (spherical) concave mirror, of which a horizontal strip one inch wide is used. For simplicity of fabrication, this mirror actually consists of sections of three mirrors, carefully adjusted with their surfaces on the same arc. At M_1 is a half-silvered mirror set at 45° to the path of the light; at S a glass plate on which are cut 180 concave grooves of semicircular cross-

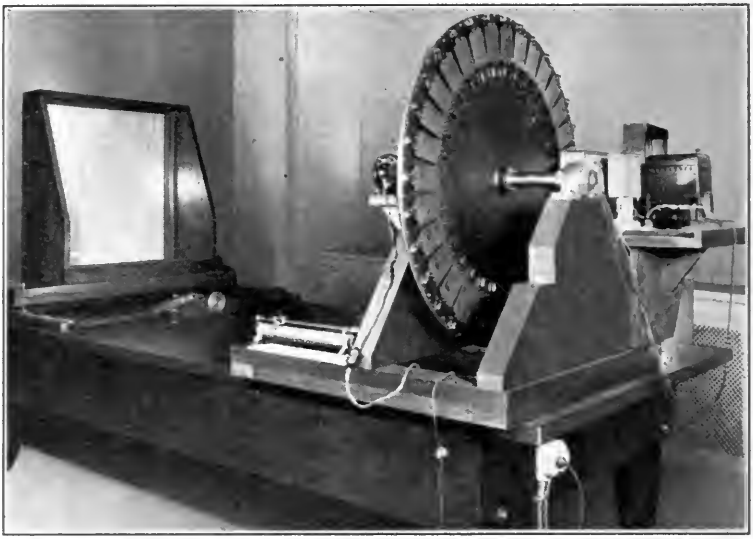

FIG. 5. View of the projection apparatus from the rear, showing the method of carrying the thirty-two parallax panoramagrams on a rotating disk.

section; at M_2 is a front surface silvered mirror at 45°, at L is a high quality lens, and at P the sensitive plate. The distances and dimensions are so chosen that the image at P falls conveniently inside the dimensions of a plate the size of a lantern-slide.

In Fig. 2 is shown a photograph of the apparatus, and in Fig. 3 a sketch of the room built around it, constituting the "camera."

The essential features of this set-up have been previously described, so that little need be added here. It will be recalled that the choice of *concave* grooves on the screen S is occasioned by the decision to use a *convex* rod transmission screen for projection; an opaque line grating or convex grooves could be substituted at S if projection screens of other types were chosen. The single exposures made by this apparatus can be instantaneous if sufficient light, such as provided by several flash-lamps, is available. In the actual experiment, a group of incandescent lamps was used for illumination, calling for exposures of several minutes with commercially available plates. Because of the length of exposure required, the object O was a dummy head, mounted so as to be movable between exposures into a series of positions, by two circular racks and pinions. Thirty-two pictures were made, showing a complete cycle of motion of the head from right to left and up and down. A print of one of the negatives is shown in Fig. 4.

The Disk.—Fig. 5 shows the projection apparatus from the rear with details of the 30-inch diameter disk on which the 32 pictures are mounted. Each picture is carried in a frame provided with adjusting screws, permitting it to be accurately centered by observing the position of fixed points on the slide and on the projected image. The whole disk is mounted on an accurate ball bearing, true to $^1/_{20,000}$ inch. It may be emphasized that the *success of the experiment hinges on the accuracy that has been achieved in the modern ball bearing.* Since the panoramic strips are approximately $^1/_{60}$ inch wide, the positioning of the successive pictures is thus correct to about 1 part in 300. The disk is driven at a speed of $^1/_2$ revolution per second.

Any intermittent feed such as the Geneva movement used with films is, of course, out of the question with such a large mass; so the apparatus has been devised for continuous rotation, with intermittent illumination. This is provided for by a vacuum mercury arc, which is flashed by discharges from a condenser system, following the general scheme described by Edgerton.[2] The housing of the flashing lamp is shown at the right of Fig. 5. The flashes are timed by a contact that slides over a ring attached to the disk, breaking the current at narrow slots cut in the ring.

The Lens.—A highly corrected Tessar lens of $8^1/_2$-inch focus, made by the Bausch & Lomb Optical Company for airplane mapping work, is used to project the image of the slides, with a minimum of distortion, to the screen.

The Screen.—The screen, which is 3 feet by 3 feet in size, is built up of 180 glass rods, 12 inches and 9 inches in length, arranged in a stagger pattern so as to avoid prominent horizontal junction lines. The curvatures of front (clear) and back (frosted) surfaces are such as to project a narrow parallel sheet of light into the observing space from each linear image element on the rear surface. The disk, lens, and screen are mounted on a rigid frame, with screw adjustments for distance, tilt, and lateral displacement of the screen, as shown in Fig. 6.

Performance.—The apparatus when operated in the manner permitted by its construction exhibits on the screen a moving picture

FIG. 6. View of the projection apparatus from the front, showing the projecting lens and the rod screen.

that presents a different aspect for each direction of observation (Fig. 7), constituting a true motion picture in relief, visible to a small group of spectators by direct observation. It therefore constitutes a scientific solution of the problem, to be ranked with the exhibition of successive, posed photographs of many objects by a disk in a projection lantern, which was the earliest form of projected moving picture. Just as the modern motion picture has reached its present perfection by the contribution of practical details, preëminent among which is the celluloid film, so this experimental achievement may conceivably be followed by detailed refinements that will put it into the realm of practical motion picture art.

Much, however, remains to be done to lift it to that state, and the difficulties to be overcome are very great. Beginning with the process of making the panoramic negatives, it is obvious that the exposures required, although made singly and with a stationary camera, are impracticably long. This difficulty may be overcome in time by the development of far more sensitive photographic materials. An alternative taking device would be a battery of motion picture cameras closely juxtaposed—a complicated and costly outfit, but required only in the studio. By projecting the negatives so produced by a battery of projectors upon a convex rod screen and rephotographing the back of the screen, prints similar to those here described and suitable to be projected in the same way could be made, thus circumventing the difficulty of over-long exposures.

Taking up next the disk, it is obvious that it would have to be replaced by some device not limited in respect to the number of pictures that it could carry. Roll film naturally suggests itself, but such film would of necessity have to possess exceedingly fine photographic grain, or be made much larger than regular film, if it is to carry an adequate number of panoramic strips. Also, it would have to be quite free from any tendency to warp out of shape, and be so guided that the lateral hunting would be much less than the ordinary perforations permit.

A characteristic limitation of the parallax panoramagram is the falling off of definition in those parts of the scene that lie much in front of or behind the plane of the picture, due to the finite size of the elementary linear image elements, and their consequent overlapping. This defect is prominent in the projected relief pictures, and can be overcome theoretically by attaining exquisite definition of the panoramic images both in the negative making and in projection. This calls for optical work of excessive accuracy, both in the camera and projection lenses, and in the screen elements, and threatens to prove the most serious bar to any practical outcome of this scientifically sound method of projecting motion pictures in relief.

Acknowledgments.—The author wishes to acknowledge the very great assistance given by Mr. Howard Hall in the design and construction of the mechanical features of the apparatus, and of Mr. W. Knoop in the problems connected with the flashing mercury

lamp. The author also wishes to express appreciation of the co-operation of Mr. W. B. Rayton and the Scientific Bureau of the Bausch & Lomb Optical Co. in the fabrication of the glass rods used in the projection screen.

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DISCUSSION

MR. P. A. MCGUIRE: Why is it that when we photograph an approaching object, the result conveys an illusion of depth?

DR. IVES: In motion picture photography there are a number of well-known factors that contribute to the perception of depth. First, there is *linear perspective*—the fact that lines converge to a distant point. If we see two men, one occupying an angle of five degrees and another an angle of one degree, we know they are both men and that their sizes are not in the ratio of those angles at all. We immediately interpret the difference of angle subtended as meaning that one man is farther away than the other.

Then we have *aerial perspective*—the general desaturation, the blurring of colors, due to intervening atmosphere. Distant objects exhibit less contrast than nearer ones. Another and very important factor that assists in the perception of relief is the *relative motion* of objects in different planes. As one moves his head from side to side, for instance, distant objects do not appear to change much as to their angular position, but nearer ones seem to move a great deal. That is a signal, to our minds, that the objects are located in different planes.

But if the camera, or the object, or the observer, can not move in any way, then we have to rely on other things for the perception of depth, of which the most important is the *binocular* or *stereoscopic* relief dependent upon the use of two eyes.

MR. J. I. CRABTREE: I don't quite understand the precise structure of the parallax panoramagram. Of course, it consists of a series of strip images, the number of images corresponding to the number of openings in the grating through which one views it. But consider the left-hand strip: Is it a panorama of the entire object; or, does it consist of a large number of narrow strips of the left-hand portion of the object as viewed from different positions?

DR. IVES: The panorama developed in each strip is the panorama one obtains on moving the eye laterally across the large lens or mirror, keeping it directed always to the point on the scene that is focused on the grating strip. It is a panorama in the sense of "looking around" the object from a series of points of view, and thus differs from the pictures made in the usual panoramic camera, when the lens "looks around" from a fixed point.

MR. CRABTREE: As one views the panoramagram through the grating he sees a narrow strip of the first panorama, a narrow strip of the second panorama, and so on, and these are integrated by the eye to constitute the picture. Is that correct?

DR. IVES: Yes, that is correct.

MR. P. H. EVANS: If each successive strip in the photographs that were shown on the screen is a panoramagram of the entire picture, why is there not a greater similarity between strips as one's view progresses across the screen? In the picture of the man's face, the center was white; there was no shadow in it at all. And yet the strips to the right had shadows in them, and the strips to the left had shadows.

DR. IVES: The answer to your question lies in the fact pointed out to Mr. Crabtree; namely, that the panorama in each strip is obtained by pivoting around the point in the scene that is focused on the grating plane. A flat object at the pivoting point will look the same no matter from what direction it is viewed, and will result in a panoramic strip that is uniform across its width. That is approximately the condition in portions of the man's face. In addition, it is to be remembered that the angle embraced by the panorama is only the angle subtended by the large mirror used for taking, namely, about 60 degrees. If the entire 180-degree angle could be used there would be a greater variation in the appearance of each strip.

MR. CRABTREE: How many lines are there to the inch on the viewing screen?

DR. IVES: The rods are about a quarter of an inch wide.

DR. H. ROSENBERGER: What is the significance of the horizontal lines on the screen?

DR. IVES: The machines of the Bausch & Lomb Optical Company available for grinding these cylindrical rods will accommodate only a twelve-inch length; these rods were made, some nine and some twelve inches long, so as to stagger them and avoid a bodily shift of one part of the picture in respect to another.

MR. CRABTREE: I believe you mentioned in your Swampscott paper that before we could apply these principles to motion picture theaters we would need emulsions that have a much finer grain and a tremendously higher speed than what we now have.

DR. IVES: I grouped together all these questions of structure in my remarks about our getting down to the wavelength of light. That applies also to the grains of the photographic emulsion. They would have to be too small. And the matter of speed I brought out indirectly by mentioning the exposure used in taking these pictures, namely, about a minute. The photographic emulsion speed required for making twenty exposures a second can be worked out arithmetically on that basis.

A NEW ALTERNATING-CURRENT PROJECTION ARC*

D. B. JOY AND A. C. DOWNES**

Summary.—*A new type of arc operated on alternating current is a desirable substitute for the low-intensity, direct-current arc used in the majority of motion picture theaters. This arc is a modification of the well-known white-flame arc, in which the light sources are concentrated at the electrodes by using heavy currents and low arc voltages on specially designed carbons.*

It is operated at current densities higher than those employed in direct-current arcs, and produces a screen light of a blue-white color similar to that obtained with the direct-current, high-intensity arc. The bluish white screen light is remarkably steady and uniform. The power required to produce a given screen illumination is considerably less than that required with the low-intensity, direct-current arc.

In projecting motion pictures, several grades or types of carbon and several makes or designs of lamp are used. But all the grades of carbons produce arcs of only three fundamental types; and all the lamps can be placed in one of three classes if the very few installations still using lamps of the condenser type, burning either direct-current, neutral-cored carbons or the white-flame, alternating-current special carbons, be omitted.

The three carbon arc types are the high-intensity, rare-earth, cored-carbon, direct-current arc, the plain neutral-cored, direct-current arc, and the so-called special white-flame, alternating-current projector arc.

The three lamp classes and the carbons burned in them are shown in Table I.

Both Classes I and II use the direct-current, high-intensity arc, which produces the brilliant light of blue-white sunlight quality universally considered desirable in the theater. In the range of current used in these two classes, there is no gap of any magnitude, so that the theaters using these high-intensity arcs can easily arrive at the level of screen illumination best suited to their particular conditions.

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* Presented at the Spring, 1933, Meeting at New York, N. Y.

** National Carbon Co., Cleveland, Ohio.

TABLE I

Classes of Projector Lamps and Carbons

Class	Kind of Carbon	Type of Lamp	Current Used (Amps.)	Per Cent of Carbons Used
I	11-mm. high-intensity positive carbon 13.6-mm. " " " " 16-mm. " " " " $^{11}/_{32}''$ to $^{1}/_{2}''$ Orotip negative carbon	Condenser lenses, rotating positive carbon	85–150 d-c.	15
II	9-mm. high-intensity positive carbon $^{5}/_{16}''$ Orotip negative carbon	Reflecting mirror, rotating positive carbon	65–85 d-c.	18
III	7–10-mm. reflecting arc negative carbon 10–14-mm. " " positive "	Reflecting mirror, non-rotating positive carbon	16–42	60
Miscellaneous:	White-Flame A-c. Special Low-Intensity D-c. Arcs with Condenser Lenses			7

There is a large drop in current value, however, between the high-intensity arcs of Class II and the low-intensity arcs of Class III; and the color of the light from the low-intensity installations, while appearing a brilliant white viewed by itself, is yellowish white when compared with the high-intensity sources of Classes I and II.

A large number of the theaters using the low-intensity light sources desire the same blue-white light of the high-intensity sources, but to obtain this desirable light color would require a change to more expensive lamp equipment and higher power cost.

To bridge the gap between the high-intensity and low-intensity

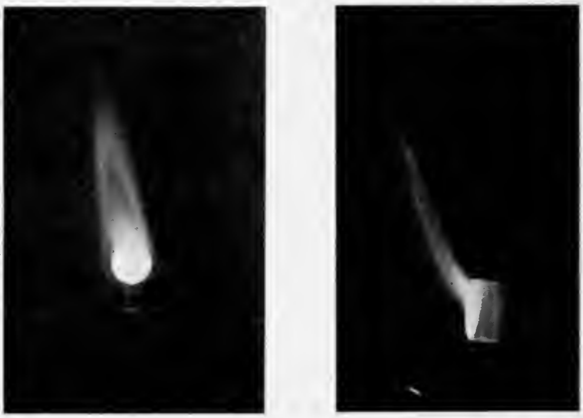

FIG. 1. Direct-current, high-intensity arc.

arcs, and at the same time to give the small theater the advantage of the blue-white light enjoyed by the larger theaters, has been the object of researches in the laboratories of the National Carbon Company for several years. The results of this long research show that it is possible to fill the gap between the high-intensity and low-intensity sources with an arc giving a light color very similar to that of the high-intensity arcs, which will also provide a number of other advantages to theater owners of Class III, who outnumber the high-intensity classes by two to one.

The desired result has been accomplished by means of an alternating-current arc burned on the secondary of a specially designed transformer, without the ballast resistance, always necessary with direct current, and also without the motor-generator set or rectifier now required in the vast majority of theaters of all classes. This alternating-current arc is a modified white-flame arc with specially designed carbons containing compounds of the cerium rare earth group of elements. The accompanying Figs. 1 to 4 show the differences in the light sources of various carbon arcs and why this new alternating-current arc should be of great value in projection.

Fig. 1 is a front and side view of a high-intensity arc, showing very clearly the very brilliant, concentrated light source at the positive crater and why this arc is easily adaptable to an optical system employing either a mirror or condenser lens. This type is used in light source Classes I and II.

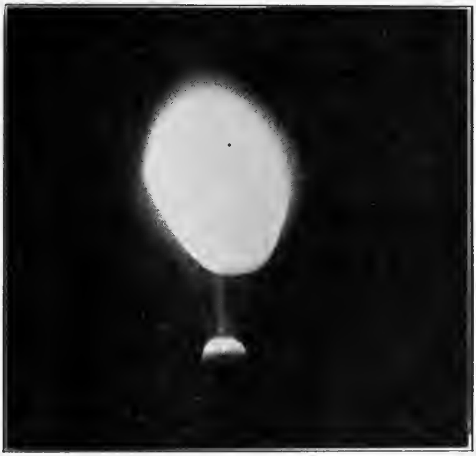

FIG. 2. Direct-current, low-intensity arc.

Fig. 2 is a direct-current, neutral-cored carbon arc (used in Class III light sources), in which the light source is the brilliant crater on the positive carbon. This figure shows the much less brilliant negative tip and the very faint arc stream between the carbons. This shows, as in the high-intensity arc in Fig. 1, that by far the largest part of the light comes from the positive crater.

Fig. 3 is an alternating-current, white-flame arc, burning carbons containing cerium group compounds. The light source is the brilliant flame between the electrodes; but the electrodes themselves are relatively dim, and emit only a very small fraction of the light. Such an arc, while producing a great deal more total light than a neutral-cored carbon arc using the same power on direct current, is obviously unsuitable for projection, as it is too large to be readily focused through an optical system and its intrinsic brilliancy is too low.

The light emitted by the white-flame arc at currents up to 30 or 35 amperes increases directly as the voltage, but as the square of the current. The rate of increase in light, with increasing current, decreases above 30 or 35 amperes until at very large currents the rate of light increase becomes equal to the rate of current increase.

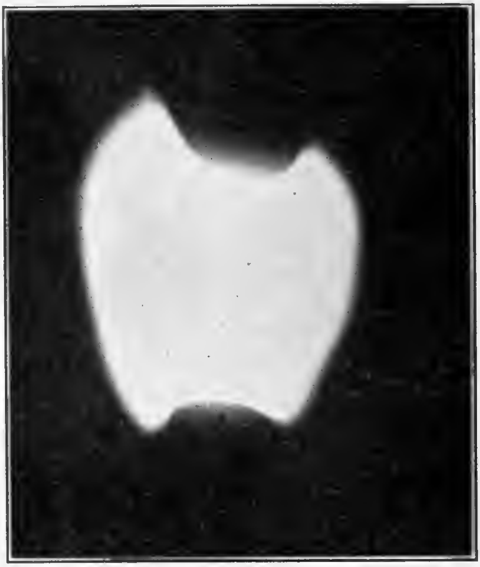

FIG. 3. Alternating-current, white-flame arc.

Increasing the current, which, if no other adjustments are made, will also cause a small increase in arc voltage, will therefore very materially increase the light produced. If, instead of permitting the arc voltage to increase with increasing current, the arc voltage and also the arc length be decreased, the arc becomes steadier and the sources of light are concentrated into smaller volumes near the electrode tips, as shown in Fig. 4. This arc is quite different in character from any other arc of which we know today. Either of these small, brilliant light sources can be focused by means of a mirror, and therefore can be used for projection.

In spite of the fact that practically all the useful projection light comes from only one of these sources, early experiments showed that with this alternating-current arc at least 15 per cent more light could be projected to a screen with a given optical system and aperture plate than with a low-intensity, direct-current arc using the same line power. The color of the screen light from the alternating-current arc was blue-white, resembling that produced by the direct-current, high-intensity arc.

In addition to these advantages is the fact that ballast resistances, expensive switchboards, and motor-generators are unnecessary. The motor-generator and ballast resistance are replaced by a relatively

FIG. 4. Alternating-current projection arc.

low-priced transformer, and the switchboard can be very simple and cheap.

A number of years ago Mott found that if two alternating-current arcs, one with resistance and the other with reactance ballast, were operated with the same line power, the arc with reactance ballast produced 33 per cent more light.

There is no reason why the new alternating-current arc can not be controlled with a ballast resistance; but Table II, following, shows that since the transformer will cost little or no more than a good resistance unit, there should be no incentive to use the resistance.

The carbons for this alternating-current arc service have been made in 6-mm., 7-mm., and 8-mm. sizes for use at 40–45, 60–65, and 75–80 amperes, respectively. A large number of laboratory tests have been made on these sizes. Since the current densities are about 800 to 1000 amperes per square inch of cross-section, it is necessary to use metal-coated carbons.

The carbon consumption is approximately 4 to 4.5 inches per hour for the 6-mm. carbons at 45 amperes, and 4.5 to 5.5 inches per hour for the 7-mm. carbons at 65 amperes and the 8-mm. carbons at 80 amperes.

The uniformity of screen illumination is as good as that obtained with direct-current arcs, as shown by Table III. The same optical system, consisting of a reflector, aperture plate, and objective lens, was used in these tests. There was no rotating shutter in the system. It should be noted that these data were obtained on a laboratory set-up, and while they are perfectly comparable among themselves, they are not indicative of what might be obtained with any other set-up of optical system and screen.

TABLE II

Power Required for Equal Screen Light Using Resistance and Transformer Control

Control	Line Voltage	Arc Voltage	Arc Current	Power Consumption in Watts
Resistance	115	30	80	9200
Transformer	115	30	80	2500*

TABLE III

Comparative Screen Light from Alternating-Current and Direct-Current, Neutral-Cored Carbon Arcs with the Regular Mirror Arc Optical System

Carbons	Line Cur.	Line Volt.	Line Watts	Arc Cur.	Arc Volt.	Foot-Candles on Screen** Middle	Left	Right	Top	Bottom
7-mm. Pos. 5-mm. Neg. Neutral Core	9 d-c.	110	990	9 d-c.	50	21	20	19	20	21
32832–2	8 d-c.	110	680	34 a-c.	19	27	25	25	26	27

Table III shows that there is no question that the uniformity of screen illumination with the new alternating-current arc is equal to that of the low-intensity, direct-current arc, with the very distinct

* Assuming transformer efficiency of 95 per cent.

** Weston photronic cell.

advantage that the blue-white color of the light resembles very closely that obtained from the direct-current, high-intensity arc.

There are not yet available detailed comparisons of the arcs of higher amperages, but a sufficient number of measurements have been made to be certain that the following Table IV provides a general idea of what may be expected from these alternating-current arcs in terms of well-known direct-current projection systems.

TABLE IV

Performance of Alternating-Current Arcs with Large Currents

Carbons	Current	Volts	Average Line Watts*	Optical System	Screen Light Compared with SRA Carbons at 35 Amp., 55 Volt.	Line Watts
6-mm. a-c.	40–45	22–25	945	Regular Mirror Arc	60–70%	3500
7-mm. a-c.	60–65	23–26	1580	"	85–95%	3500
8-mm. a-c.	75–80	24–29	2130	"	115–150%	3500

In arriving at the values for line watts an efficiency of 80 per cent has been assumed for the motor-generator sets in the case of the direct-current arcs and 95 per cent for the transformers for the alternating-current arcs.

One practical test has been in progress since September, 1932, in a theater with a 12 × $16^1/_2$-foot screen and a throw of about 100 feet. There have been no complaints concerning the quality of the screen light or the quantity, and no unusual operating troubles have been encountered.

In order to furnish a general idea of the probable fields of use for this arc there is given in Table V a general summary of carbons, currents, voltages, wattages, and screen light in arbitrary units on a screen of a given size. The optical systems were the conventional ones employed with the different kinds of carbons and lamps in actual use in the theaters.

* Transformer efficiency, 90 per cent.

TABLE V

Summary Table of Data

Lamp Type	Carbons: Positive	Carbons: Negative	Current Amperes	Arc Voltage	Line Watts	Screen Light Arbitrary Units Same Screen Size
High Intensity	16-mm. H. I.	$^7/_{16}$″–$^1/_2$″ Orotip	145–150	75–80	16700–17300[1]	
High Intensity	13.6-mm. H. I.	$^3/_8$″–$^7/_{16}$″ "	115–120	60–70	13200–13800[2]	110–190
High Intensity	11-mm. H. I.	$^5/_{16}$″–$^3/_8$″ "	85–95	50–60	9800–10900[2]	
High Intensity (HiLo)	9 mm.	$^5/_{16}$″ "	60–85	45–55	6900–9800[2]	80–140
Low-Intensity Reflecting Arc	12–13-mm. SRA	8-mm. SRA	28–42	55	3000–4600[3]	60
					2000–2900[5]	
Low-Intensity Reflecting Arc	10–13-mm. Reg. MA	7–10-mm. Reg. MA	16–30	55	1600–3450[3]	40–60
					1100–2200[5]	
High-Intensity Alternating Current	7–8 mm.		60–80	23–28	1450–2350[4]	40–85

[1] 115-volt line, with resistance between line and lamp.

[2] Either 115-volt line with resistance between line and lamp; or motor-generator set, 80 per cent efficient, delivering direct current at 90 volts to resistance and lamp.

[3] Either 115-volt line with resistance between line and lamp; or motor-generator set, 80 per cent efficient, delivering direct current at 85 volts to resistance and lamp.

[4] A-c. line with transformer, 95 per cent efficient.

[4] A-c. line with rectifier, 75 per cent efficient.

DISCUSSION

MEMBER: Since the arc is supplied directly from the a-c. supply lines through a transformer, every voltage variation of the outside lines will be transmitted to the arc. In view of the fact that all power companies allow themselves a variation of at least 5 per cent above and below the normal voltage (a total of 10 per cent between minimum and maximum), what would be the effect of such variation on screen illumination and flickering?

MR. DOWNES: We have not found a 5 per cent variation in voltage in our laboratories and factories except at two very definite times each day: in the morning when the factory starts and in the evening when the greater part of the power load is taken off the line. Such a condition may be found in an industrial district where the loads are heavy, but we have thought the voltage changes in our laboratories to be largely confined to our own lines on the low-voltage side of the power transformers serving both factory and laboratory. If difficulty is encountered with variable voltage, the trouble may be very easily corrected by a small rheostat in the lamp circuit or by variable taps on the transformers.

MEMBER: How do the a-c. carbons compare in price with the present d-c., low-intensity carbons?

MR. E. R. GEIB: The operating cost of the new a-c. projector trim will be a little over 50 per cent higher than it is with the present low-intensity, d-c. trim, but this cost is just about one-half that of Hi-Low operating cost. The improvement in intensity and color of light with the new a-c. arc far more than offsets the slight increase in operating expense.

MR. F. H. RICHARDSON: It was extremely difficult for projectionists to maintain steady screen illumination with the old style a-c. arc; the craters were small and difficult to handle. Will this trouble occur in any degree with the new a-c. carbons?

MR. DOWNES: I do not want to say that there will be no trouble with this new arc system; but such difficulties as are encountered will be only those more or less minor annoyances commonly found in all projection systems. You certainly will not have the difficulties encountered with the old a-c. arc, as the new arc is entirely different.

MR. RICHARDSON: Another important consideration is the possible effect upon light tone. The old-style a-c. arc furnished a rather harsh light tone; and the light appeared to be very penetrating, much more so than light from a d-c. arc.

MR. DOWNES: We have had many requests from the smaller theaters such as: "Can't you give us the same blue-white light the larger theaters have?" There seems to be a general consensus of opinion among the projectionists that the blue-white color is far more desirable than the other.

MR. RICHARDSON: Are those carbons ready for the market now?

MR. GEIB: Yes.

MR. RICHARDSON: What is the amperage of the two lamps?

MR. DOWNES: The power consumption at the arc is the same; the one we are demonstrating consumes between 40 and 45 amperes at 18 volts.

PROFESSIONAL MOTION PICTURE PHOTOGRAPHY WITH HIGH-INTENSITY SHORT-LIFE INCANDESCENT LAMPS*

M. W. PALMER AND E. W. BEGGS†**

Summary—*To increase the light output per watt, to improve the actinicity of the light, to increase the proportion of blue light badly needed for color photography, and to reduce the size and number and increase the output of the lighting units, tungsten lamp filaments are heated to temperatures as near the melting point as is practicable. Reference data are presented on lumen output, efficiency, color (energy) distribution, and lamp life. Practicable safe operating limits are indicated. A new "super photoflood" lamp is described and data on overvoltage lamp operation for location lighting are presented for reference.*

I. LAMP CHARACTERISTICS

Recent trends in the use of incandescent tungsten lamps for photography indicate an increasing desirability of obtaining adequate levels of illumination by operating lamps at higher efficiencies rather than by increasing the wattage. A successful application of this idea is the high-efficiency, short-life photoflood lamp, which has proved to be a most convenient and satisfactory light source for indoor amateur motion picture and still photography. In professional motion picture photography, the operation of tungsten filaments at high temperatures is especially appropriate where the available power is limited and where undue heat on the set may result from overcrowding the lighting units.

The advantages to be derived from operating tungsten filaments at temperatures higher than those found in present practice are pointed out in the illustrations, which show various relations between filament temperature, visible light output, photographic effect, and lamp life.

Fig. 1 shows diagrammatically the tremendous increase of visible light emitted from a coil of tungsten wire at various temperatures up to 3500°K. The area beneath each curve represents the energy

* Presented at the Spring, 1933, Meeting at New York, N. Y.

** Motion Picture Lighting Co., Long Island City, N. Y.

† Westinghouse Lamp Co., Bloomfield, N. J.

resident in the visible light radiated at the temperature indicated. These curves also bring out the fact that as the temperature of the filament is increased, the increase of energy radiated at the shorter wavelengths of light, *i. e.*, violet, blue, and green, is much greater than the increase at the longer wavelengths, *i. e.*, yellow, orange, and red. This is a fact that is of especial value in color photography.

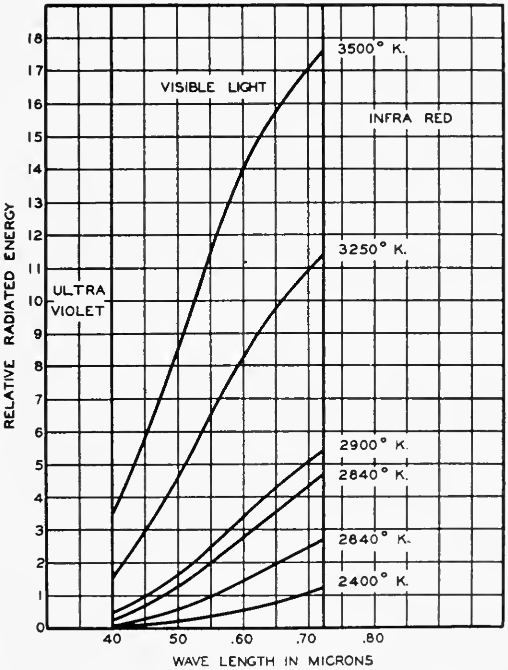

FIG. 1. Distribution of visible energy radiated from tungsten filament.

The change of photographic effectiveness due to this change of spectral quality of the light emitted by a tungsten filament lamp at various temperatures is illustrated in Fig. 2 for both panchromatic and orthochromatic emulsions. The curves show distinctly that, for a given intensity of illumination, measured visually, the higher the filament temperature the greater the photographic effectiveness. This, of course, is much more noticeable with orthochromatic than with panchromatic film.

Increasing the temperature from 3000°K. to 3500°K. multiplies the lumens of visible light emitted from a certain tungsten filament about five times. Actually, the power consumed is also increased; but, due to the greater proportion of the energy radiated in the visible range when the filament is heated to higher temperatures, the increase of light far exceeds the increase of power required. These relations between the power and the light output, for various filament temperatures, are indicated in Fig. 3. The curve correlates the lumens per watt, or efficiency of the tungsten filament, with the temperature of the filament, and shows clearly how much more rapidly the light output increases than does the power. For example, increasing the

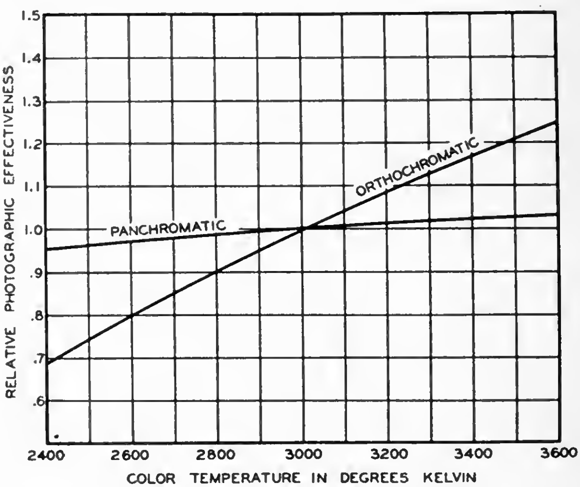

FIG. 2. Relation of photographic effectiveness to color temperature of incandescent tungsten.

filament temperature from 3000°K. to 3500°K. in a 1500-watt lamp results in an increase of 20 to 35 lumens per watt, or a gain in light output of 75 per cent.

Fig. 4 shows the relation between the temperature of the filament and the life of the lamp. The molecules of tungsten that are loosened from the incandescent filament vibrate more violently and in greater numbers as the temperature increases, resulting in a gradual loss of metal from the wire. Finally, by this process, called "sublimation," the filament wastes away until at some point in its length it becomes too thin to carry the current; the filament melts at that point, and the lamp burns out. The curve shows the life *vs.* temperature characteristic of a tungsten filament lamp.

The data given in the curves of Figs. 2, 3, and 4 are the basic data from which the best filament temperature for a given set of conditions can be calculated. These data apply more to the studio than to "location." They show that if the lamp manufacturers were to make lamps especially for motion picture studio service they might well allow the filaments to operate at higher temperatures than they do now. Suppose, for instance, that the performance of a 1500-watt, 115-volt, *PS-52* bulb, 1000-hour general lighting lamp

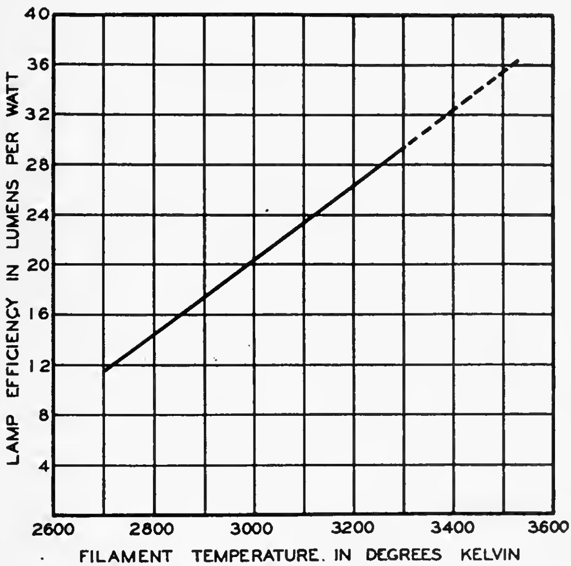

FIG. 3. Efficiency *vs.* filament temperature; 115-volt, gas-filled Mazda lamps.

were to be compared with that of a 1500-watt lamp similar to it but designed to have a life of 10 hours. Such a comparison would show some interesting facts.

The filament of a 1500-watt, 1000-hour lamp operates at a temperature of about 3000°K., and produces an initial output of 32,100 lumens. However, if a lamp were designed to operate at 3500°K. and yet consume only 1500 watts, such a lamp would produce about 55,900 lumens. This increase of 75 per cent is the increase of lumens per watt at the higher temperature (see Fig. 3). At the same time, the photographic effectiveness of the light is increased (see Fig. 2), with the result that one such 1500-watt lamp operating at a high temperature is photographically equivalent to almost two 1000-hour, 1500-watt lamps.

This remarkable increase of light output practically doubles the effectiveness of "broadside" lighting equipment and any other fixtures now using the 1000-hour type of lamp. It also increases, in the same proportion, the *lighting capacity* of the power generating plant and the wiring system.

Similarly, the heat radiated to the set by these lamps is almost

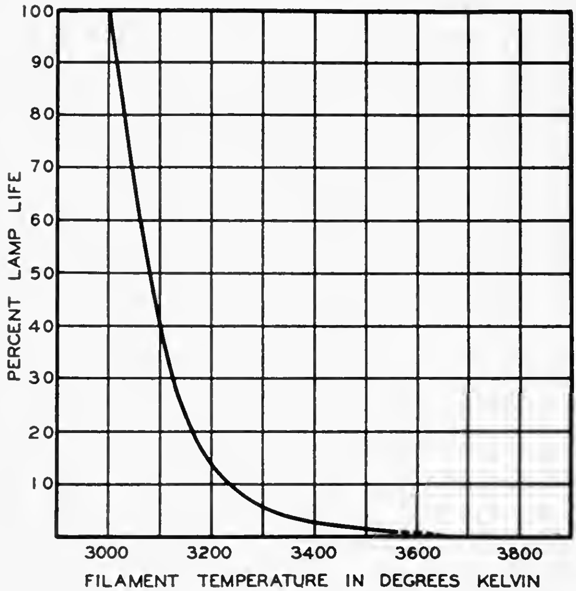

FIG. 4. Per cent lamp life *vs.* filament temperature; 115-volt, gas-filled Mazda lamps.

halved, because the heat produced by the lamps is determined directly by the amount of power consumed, and it is possible, owing to the higher filament temperature, almost to halve the power.

The changes resulting from an increase of temperature from 3000°K. to 3500°K. apply only to lamps of those types the filaments of which operate at the lower value. Such lamps in ordinary studio work are the *PS-52* bulb general lighting types, usually 1000-watt, and the 1500-watt *PS-52* bulb lamps.

The illumination in a motion picture set, according to present practice, is obtained partly with general lighting *PS-52* bulb lamps, usually rated at 1500 watts, operating in broadside or overhead units developing a diffused general illumination of high intensity throughout the area of the set. The total required varies widely, but in ordinary cases represents about half the total power used. It is here that the greatest increases in photographic effectiveness of the light can be achieved.

However, it is also possible to increase the filament temperature

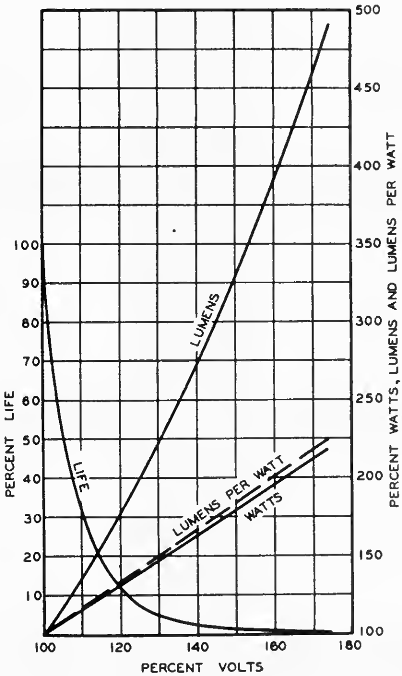

FIG. 5. Characteristic curves of Mazda lamps.

of the higher powered lamps in a similar manner. The 2000-watt *G-48* bulb spotlight and the 5000-watt *G-64* bulb lamp, both of which are of the types generally used to create highlights, shadows, and modeling effects, have filaments that operate at higher temperatures than the 1500-watt, 1000-hour type discussed above. The filaments of these lamps operate at approximately 3200°K., so that in such lamps, also, an increase of temperature is possible. This would produce an appreciable improvement in their efficiency for

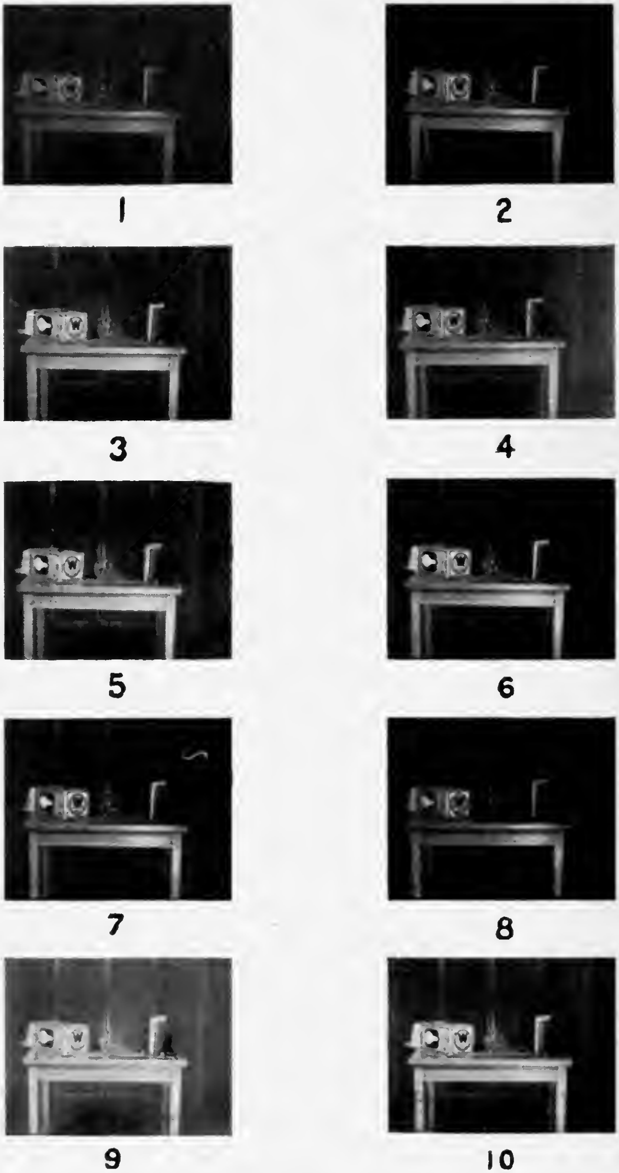

FIG. 6. Prints of frames photographed under different lighting conditions, with the percentage of normal voltage of the lamps and the camera aperture as follows: (1) 100%; (2) 115%; (3) 130%; (4) 145%; (5) 160%. For higher voltages the lens was stopped down, as follows: (6) 160%, *f*/5.6; (7) 160%, *f*/8.0; (8) 160%, *f*/11; (9) 170%, *f*/3.6; (10) 170%, *f*/5.6.

black-and-white pictures, a very great increase for color photography, and would reduce the total amount of heat radiated to the set for a given lighting intensity.

As a result of these calculations and of the practical application of the lamps in motion picture photography, lamp manufacturers have designed *PS-52* bulb short-life lamps (approximately 10 to 20 hours) of 1500 and 2000 watts with their filaments operating at approximately 3450°K., which are now available for commercial use. The standard higher-powered lamps for the present are being used in actual studio practice with the impressed voltage set at about 110 to 120 per cent of the labeled voltage of the lamps. If the need for special lamps in these sizes becomes apparent, they will be developed and supplied.

All the data presented in the foregoing discussion are concerned with lamps especially designed for high filament temperatures. At the outset, experiments were made with lamps having filaments designed to operate at 3000°K., approximately, but operated at an overvoltage in order to increase the temperature to higher values on the scale. In Fig. 5 are four curves that show the result of overvoltage operation on the performance of any given lamp. It will be seen that an increase of voltage from 100 to about 175 per cent of normal results in an increase of lumen output from 100 to 500 per cent. At the same time, the photographic effectiveness of the light is increased not only five times, but with orthochromatic film 6.25 times, and with panchromatic film 5.16 times. Of course, such an enormous overload on the lamp may cause some part of its structure to fail, even though the filament may actually be operating below its melting point. This may result in early or immediate burnouts. However, 1000-hour lamps have been operated at overvoltages sufficiently high to reduce the operating life to less than 10 hours with surprisingly good results. Such operation of the lamp is, of course, at the operator's risk. The lamp manufacturers can not guarantee the operation of their product at such voltages, since all the design work and practically all the tests are conducted at the normal voltage, or at no more than 115 per cent of the normal voltage.

II. PRACTICAL APPLICATION

In this section of the paper will be considered some practical applications of lamps burning at voltages greater than the normal in professional motion picture photography. It becomes occasionally desirable on location to photograph by means of artificial light. Very often in such cases the current that is available is insufficient to provide the amount of light required. By using lamps having a voltage rating less than that of the line voltage available, a considerable increase of photographic light may be effected with an increase of power.

The illustrations in Fig. 6 show the photographic results obtained by raising the voltage in increments from 110 volts normal to 170 per cent of normal voltage. The lamps used were three 1000-watt, 110-volt *PS-52* lamps mounted in porcelain enameled reflectors. The position of the lighting units was not changed during the exposures. The illustrations are prints of frames taken from a series of exposures made with a standard motion picture camera operating at a speed of 60 feet per minute and with the lens aperture set as indicated in the caption. At *1* in Fig. 6 is shown an exposure made with the lamps operating at the normal voltage, with which the other exposures, made at voltages greater than normal, may be compared. Examples *2* to *8*, inclusive, are exposures made with lamp voltages up to 160 per cent of the normal value. When 160 per cent of the normal voltage was attained, the lens was stopped down.

Examples *9* and *10* show the results obtained with a still higher voltage, 170 per cent of normal, with an aperture of $f/3.5$.

As shown in the first section of this paper, there is a practical limit to which the voltage may be increased, since with each increase in voltage there is a corresponding decrease of the life of the lamps. It is, however, possible to increase the photographic light by almost 100 per cent without increasing the wattage, a matter of great importance in making it possible to conserve power to a considerable extent in producing motion pictures.

DISCUSSION

MR. J. I. CRABTREE: Suppose the photoflood lamp is designed for a normal line voltage of 110; at what voltage will the filament melt?

MR. BEGGS: There is naturally a limit, but the photoflood lamp, as now designed, operates at normal voltage at a temperature that provides enough margin, before reaching the melting point of tungsten, to accommodate all the published voltages in the United States. These values also involve a secondary factor of safety. The voltage in New York City is nominally 120. The power companies arrange matters so that the average voltage at the lamp socket will be 120, which means that some socket voltages will be somewhat greater and some will be somewhat less than 120. These lamps have a factor in their design that accommodates all such conditions. A surge of voltage would probably have to exceed 130 volts for a period of over 5 seconds to "blow" the lamp.

MR. FARNHAM: The life of the photoflood lamp is usually given as two hours at 115 volts, thus emphasizing the point that the life of the lamp is quite critical as to voltage. A good general rule to remember is that a five per cent increase of voltage halves the life, so that if the voltage on a photoflood lamp were increased to 120, we should expect the lamp to last about one hour. However, if the voltage is increased much beyond 120, the melting point of tungsten is soon reached and the lamp fails immediately. Tests show that at 130 volts they fail almost immediately, and that they last a short time at 125 volts; hence the limiting voltage is undoubtedly between 125 and 130 volts.

In the course of a series of tests conducted by the General Electric Co., and the Eastman Kodak Co., in connection with motion picture photography in color, quite a large number of lamps of this type were employed. The process under development requires an illuminant having at least twice the blue-violet radiation as that obtained from the lamps generally used for black-and-white motion picture photography, for an equal amount of red radiation.

The widely used 1000- and 1500-watt *PS-52* bulb lamps operate at an efficiency of approximately 21 lumens per watt, but if the efficiency is increased to 33 or 34 lumens per watt the percentage of blue-violet radiation is about doubled. A 1500-watt lamp operating at that efficiency has the visual light output of a 2250-watt lamp and the approximate photographic effectiveness of a 4000-watt lamp. The life of these lamps is roughly 12 to 15 hours.

An analysis of costs in connection with these tests shows that $80 worth of lamps is sufficient to light a set of average size and permits the exposure of $2400 worth of film. This is considered a satisfactory ratio.

Because of the relatively short life of the lamps it is a good plan to operate them at a reduced voltage, probably about 90 volts, when preparing for the picture; then to increase the voltage to its full value just before photographing. This procedure will greatly prolong the life of the lamp. It has been found that the life of the lamp is greater when the voltage is increased to this intermediate value first and the lamp allowed to "warm up" before applying the full voltage. Where the work of photographing is interrupted by periods of preparation, the voltage should be reduced to the intermediate value and then increased to the full value again, rather than to turn off the lamps completely each time.

Lamps of this type blacken somewhat rapidly, hence a tungsten cleaning powder, similar to that now employed in the 5- and 10-kw. lamps, is incorporated in the bulb. Sliding this powder over the surface of the bulb from time to time restores the light output to its initial value. A periodic cleaning schedule, possibly once each day, is a good plan.

Because of the relatively great light output of these lamps as compared with the more generally used types, the wattages employed on sets for color photography are of the same order of magnitude as now employed for black-and-white photography, and hence the increase of temperature is negligible.

MR. RICHARDSON: If I increase the voltage of the lamp and thus increase its light-emitting power, will the same number of lumen hours result as would result had the lamp been operated at normal voltage?

MR. MILI: A much smaller number of lumen hours, with a shorter lived lamp. The life curve (Fig. 5) drops much more rapidly than the efficiency curve rises, wherefore the total output of the lamp decreases throughout its life, so to speak. But it is the intensity, possibly, that comes to be more important in certain applications rather than the total amount of light emitted by the lamp throughout its life.

MR. BEGGS: Regardless of the fact that the lumen hour output decreases throughout the life of the lamp, it may be convenient to operate the lamps at overvoltages in order to obtain the desired intensity, and to sacrifice the life to some extent; and in projectors, only by using short-life, high-intensity filaments can we obtain high intensities of screen illumination.

MR. CUTHBERTSON: What is being done to reduce the number of explosions?

MR. BEGGS: Every now and then a lamp does explode. We test thousands of them, and a small fraction of one per cent do explode, and a very small fraction of those explode violently. In most cases the glass simply cracks and gives way. An explosion may occur if the filament should melt at a certain spot in the coil of tungsten wire in such a way as to form an arc. If the arc is maintained for a long period of time, the gas in the bulb becomes hot, creates an internal pressure, and in some cases has been known to cause a bulb to explode.

However, explosions of Mazda lamps occur rarely, primarily because in lamp making the bulb has been so annealed that it has no strains in it, and a link is provided in the lead wire that fuses when an arc is formed. Two years ago we used to put our monogram on the end of the bulb; in making the mark we used silver metal and fired it in the glass, just as china is marked, thereby creating strains. But for the past year and a half or two years that strain has been eliminated, and every bulb is inspected by a polariscope for strains, so that arcs and explosions are now very rare.

MR. KURLANDER: When the total wattage employed in illuminating a set is very large, this method certainly will help to reduce lens focusing errors due to atmospheric refraction.

MR. ENGLEKEN: To what extent are photoflood lamps being used in the motion picture studios at present?

MR. FARNHAM: The small standard photoflood lamps are not used. The high wattage lamps of the photoflood type, of 1500 watts' rating, were employed in developing a color photographic process. Since they have proved to be satisfactory, they will very likely be used where such processes are employed.

MR. BEGGS: I might say that the small photoflood lamp, in professional studio work, is used occasionally in a lighting fixture—a home lighting fixture, for example—that will appear in the set. But it is not used for general lighting, because of the small size.

MR. ENGLEKEN: Is the photoflood lamp made at present in only the two sizes?

MR. BEGGS: Yes.

MR. ENGLEKEN: Are the filament dimensions of the 1500-watt lamp the same as those of the standard 1500-watt lamp?

MR. BEGGS: Slightly smaller. Physically, this lamp is interchangeable with a standard 1500-watt, *PS-52* lamp.

AN IMPROVED POTASSIUM ALUM FIXING BATH CONTAINING BORIC ACID*

H. D. RUSSELL AND J. I. CRABTREE**

Summary.—*Most hardening fixing baths containing potassium alum tend to lose their hardening properties and precipitate a sludge of aluminum sulfite long before the fixing power of the sodium thiosulfate becomes exhausted. It is customary in large-scale practice to offset this loss in hardening properties by adding acid to the bath several times during its useful life. The addition of boric acid (5 grams per liter) to a fixing bath containing potassium alum has been found to increase the hardening life about four times and to minimize the sludging tendency to such an extent that revival with acid is unnecessary during the useful life of the bath.*

A detailed study has been made of the properties of fixing baths containing potassium alum, acetic acid, sodium sulfite, and boric acid, and a suitable formula is recommended for motion picture work. Except for tropical use, it is considered that the formula containing boric acid is to be preferred to most chrome alum fixing baths which require frequent revival with acid during use in order to maintain uniform hardening properties.

Fixing baths for motion picture film consist essentially of an aqueous solution of sodium thiosulfate together with an acid hardening agent, which consists of a mixture of sodium sulfite, a suitable acid, and an alum. The alum may be either aluminum or chrome alum and, according to the particular alum used, the fixing baths are classified as (*a*) chrome alum baths, and (*b*) potassium alum baths.

Some of the properties of chrome alum baths have been described previously,[1,2] and although baths of this type are employed almost exclusively in some of the larger film processing laboratories, they require more precise control in order to maintain their hardening properties during use as compared with potassium alum baths, and for this reason the latter are to be preferred when facilities for such control are not available.

The factors which determine the properties of potassium alum fixing baths have also been investigated previously by Crabtree and Hartt,[3] who have shown that the desirable properties of such

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

baths exist only over a relatively narrow range of concentration of the various constituents. The chief objection to the usual potassium alum baths is that the hardening properties change with use and ultimately tend to disappear as the bath is neutralized by the alkali in the developer carried over by the films. Also, when the acidity of the bath falls below a certain critical value, the bath deposits a sludge of basic aluminum sulfite. This, in turn, tends to adhere to the film surface, and appears as dirt or a scum on the dried film. The quantity of developer which can be added before this sludge appears is termed "the sludge life."

Attempts have been made to prevent this sludge precipitation by

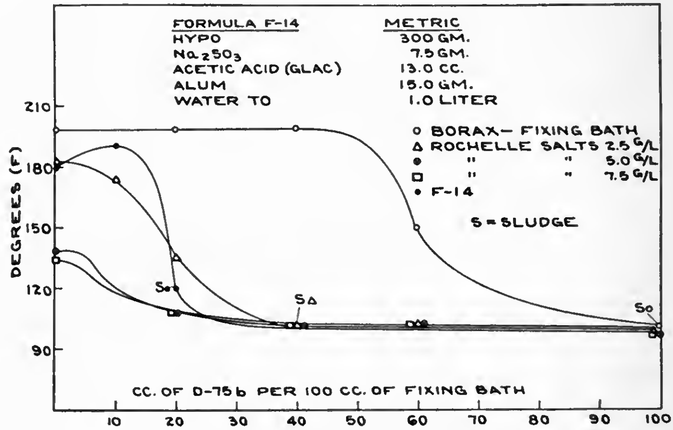


Fig. 1. Effect of Rochelle salts on the hardening properties of fixing baths.

the addition of relatively small quantities of organic acids, such as oxalic, lactic, citric, tartaric, malic, and maleic or their alkali salts. These acids have been shown by Sheppard, Elliott, and Sweet[4] to prevent the precipitation of an alumina sludge in the fixing bath, but they also lower the degree of hardening. These authors suggest that possibly this behavior is due to the formation of complex ions between the aluminum ions and those of the organic acid.

Mr. R. S. Becker, of the Eastman Kodak Company, has recently devised the following fixing bath containing borax* for the superhardening of paper prints, and in comparison with existing potassium

* Patent applied for.

alum baths, this bath has an exceedingly long hardening life and sludge life. It was considered that these properties were due largely to the presence of the boron ion, so that further experiments on the effect of the boron ion in fixing baths for film emulsions seemed worthy of investigation.

Borax Fixing Bath

Hypo	250.0 grams
Sodium sulfite (desiccated)	15.0 grams
Acetic acid (glacial)	12.5 cc.
Potassium alum	30.0 grams
Borax	7.5 grams
Water to make	1.0 liter

Tests have shown (Fig. 1) that the borax fixing bath has a hardening life approximately four times longer than that of the following *F-14* bath (which has been used for many years for deep tank work), while its sludge life is at least five times greater.

F-14 Fixing Bath

Hypo	300.0 grams
Sodium sulfite (desiccated)	7.5 grams
Acetic acid (glacial)	13.0 cc.
Potassium alum	15.0 grams
Water to make	1.0 liter

Tests have also indicated that the addition of 2.5 grams per liter of Rochelle salts to the *F-14* fixing bath does not appreciably affect the hardening properties and doubles the sludge life. The addition of as much as 5 grams of Rochelle salts per liter decreases the hardening properties and greatly increases the sludge life. Preliminary tests with the borax formula also indicated that the sludge life was greatly dependent upon the rate of addition of the developer to the bath. The bath did not sludge with the addition of 80 per cent of a strongly alkaline developer if it was added drop by drop with constant stirring, but if it was added in large quantities at one time, the bath sludged with the addition of 30 per cent of the developer. This sludge life was only slightly greater than that of the *F-14* fixing bath. The addition of developer drop by drop simulates practical conditions, because only a small quantity of the developer is carried into the fixing bath at any one time by the film.

The various factors tested in the determination of the properties of fixing baths containing boron compounds included the degree of hardening, the hardening life, the sludge life, the sulfurization life, and the *p*H value.

In the determination of the sludge life, a 100-cc. sample of a given bath was titrated with rapid stirring at a rate of $^1/_2$ cc. per minute with increasing quantities of a given developer. The quantity of developer which could be added to a given bath before the precipitation of an aluminum sludge occurred was considered as its sludge life. The samples containing developer were used to determine the effect of developer upon the degree of hardening, the hardening life, and the *p*H. The degree of hardening was determined in a manner similar to that described in previous publications.[2,3] The *p*H of the baths was determined colorimetrically with La Motte color standards.

Effect of Varying the Boric Acid Concentration.—Although the borax bath originally contained sodium borate, boric acid was used in most of the tests because it did not materially change the acidity of the baths. The effect of the addition of various quantities of boric acid on the *p*H, sludge life, and hardening life of the following *F-1* and *F-2* formulas was determined.

F-1 Fixing Bath

Water	1 liter
Hypo	240 grams
When dissolved add:	
Water	80 cc.
Sodium sulfite (desiccated)	15 grams
Acetic acid, 28%	48 cc.
Potassium alum	15 grams

F-2 Fixing Bath

Water	1 liter
Hypo	240 grams
When dissolved add:	
Water	50 cc.
Sodium sulfite (desiccated)	3 grams
Acetic acid, 28%	18 cc.
Potassium alum	6 grams

The results shown in Fig. 2 indicate that the addition of 0.1 per cent of boric acid to either formula does not appreciably change their sludging and hardening properties. The addition of 0.5 per cent increased the sludge life approximately four times, with a corresponding increase in the hardening life, but this did not affect the degree of hardening. The addition of 1.5 per cent also increased the hardening and sludge life, but decreased the degree of hardening.

The regular baths, *F-1* and *F-2*, sludged at a *p*H of approximately 4.8, when their usefulness as hardening solutions terminated, while the baths containing boric acid sludged at a much higher *p*H and maintained their hardening properties up to a *p*H of about 6.0. These tests indicated that about 5.0 grams per liter is the minimum concentration of boric acid which can be added to these baths if the most desirable properties are to be maintained.

Effect of Varying the Alum Concentration.—Since the composition

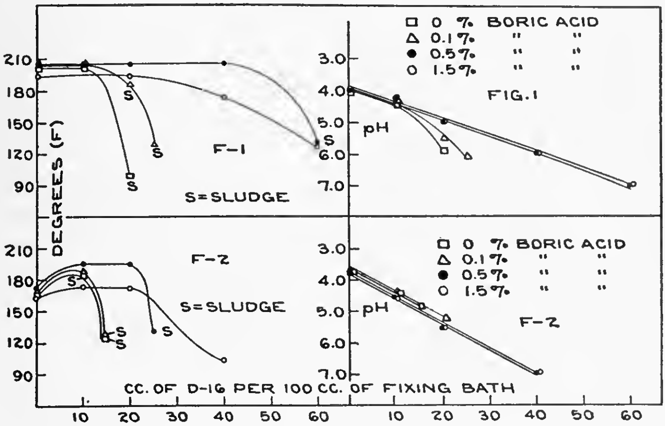


FIG. 2. Effect of the concentration of boric acid on the properties of the *F-1* and *F-2* fixing baths.

of the original borax formula was analogous to that of the *F-1*, with the exception of the alum concentration, and since the hardening life of the former was superior, the effect of varying the concentration of the alum on the properties of the borax fixing bath was investigated. The results shown in Fig. 3 indicate that equal degrees of hardening were obtained for equal *p*H values with concentrations of alum between 6.0 and 30.0 grams per liter. The *p*H value and the degree of hardening did not decrease as rapidly with the addition of developer to the baths containing a high concentration of alum as in the case of those with a low concentration, which indicates that the alum increases the total acidity of the baths.

The hydrolysis of aluminum salts into basic aluminum compounds possibly accounts for the increase in the total acidity of the baths with an increase in the alum concentration. Basic aluminum compounds have been reported in the literature and their formation may be represented by the following equation:

$$Al_2(SO_4)_3 + 2H_2O \rightleftharpoons 2AlOHSO_4 + H_2SO_4$$

$$\underset{\text{Sulfate}}{\text{Aluminum}} + \text{Water} \rightleftharpoons \underset{\text{Sulfate}}{\text{Basic Aluminum}} + \underset{\text{Acid}}{\text{Sulfuric}}$$

The most completely hydrolyzed salt which could be formed would

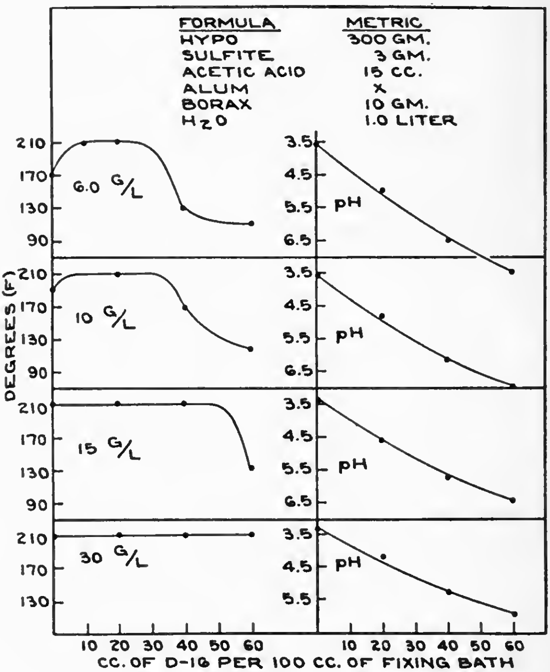


FIG. 3. Effect of the alum concentration on the properties of borax fixing baths.

approach aluminum hydroxide ($Al(OH)_3$) as a limit and intermediate compounds would have the general formula: $Al_x(OH)_ySO_4$.

Effect of the Concentration of the Acetate Ion.—Preliminary tests were made in an attempt to replace the acetic acid by other acids, and the results indicated that the acetate ion was as essential to the non-sludging properties of the baths as boric acid.

The effect on the hardening properties and sludge life of increasing the acetate ion concentration by the addition of increasing quantities of crystalline sodium acetate to the *F-1* fixing bath containing 5 grams per liter of boric acid was determined. The results given in Fig. 4 indicate that the addition of sodium acetate in quantities greater than 25 grams per liter decreases the degree of hardening.

In measuring the sludging tendency the usual method of slowly titrating the bath with developer was not employed, because under these conditions none of the baths sludged. In testing the sludging tendency, 100 cc. of the *D-16* developer were added all at one time to 100 cc. of the fixing bath. The results with this method indicated that the sludging tendency was not decreased until after 25 grams per liter of sodium acetate had been added. Since the acetate ions

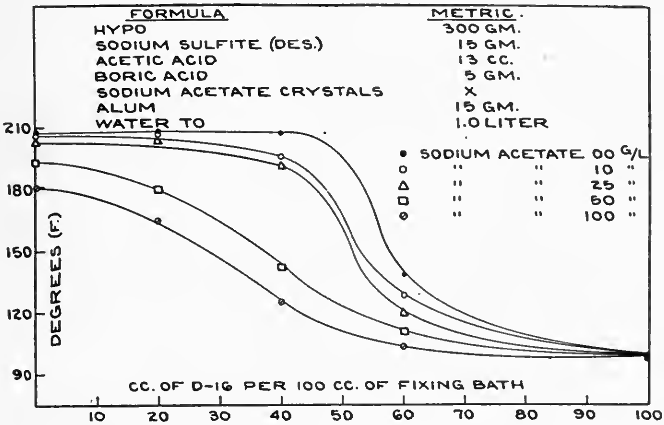


FIG. 4. Effect of sodium acetate on the hardening properties of a potassium alum fixing bath containing boric acid.

decreased the sludging tendency, it was considered that if a relatively high concentration of the acetate ion were used, a lower concentration of boric acid might be used. With the addition of 25 grams per liter of sodium acetate to the *F-1* bath, the boric acid could be decreased to 2.5 grams per liter. This was the minimum quantity which could be used with any concentration of the sodium acetate if the desired properties were to be maintained. If a quantity of sodium acetate less than 25 grams per liter was added, the minimum permissible quantity of boric acid was approximately 5 grams per liter.

Effect of the Sodium Sulfite Concentration.—An increase in the sulfite concentration has been shown to increase the sulfurization life of a given formula.[3] Most of the recommended formulas contain between 3.0 grams and 15.0 grams per liter of this material.

A variation in the sulfite concentration between these limits had no effect on the sludging properties of the *F-1* bath containing boric acid. Higher quantities of sulfite decreased the developer capacity of a given bath because it acts as a mild alkali and neutralizes some of the acid in the fixing bath. The addition of boric acid to a given bath did not appreciably change its sulfurization life.

Some fixing baths containing a relatively high concentration of sodium sulfite and acetic acid evolve considerable quantities of sulfur dioxide when fresh, especially when processing at high temperatures. In rooms that are not well ventilated, the concentration of this gas may become great enough to be very objectionable. Baths such as the *F-1* containing boric acid can be compounded, in which this tendency is greatly decreased by the substitution of sodium acetate for a portion of the acetic acid. This produces a bath with a higher initial *p*H and a shorter hardening life. However, if half the acetic acid in the *F-1* formula were replaced with an equivalent quantity of sodium acetate, the hardening life would be approximately equal to that of the *F-1* formula without boric acid, with the added advantage that less sulfur dioxide would be evolved.

Substitutes for Boric Acid.—Any boron compound which dissociates in an acid solution to give an oxygen acid of boron may be substituted satisfactorily for boric acid. In substituting boron compounds in a given formula with chemicals such as borax and the alkali salts of oxygen acids of boron, it is necessary to add an additional quantity of acid sufficient to form boric acid or the life of the bath will be impaired.

Compounds such as glycol borate, glycerol borate, phenyl borate, and other esters of boric acid may be added to the fixing bath without the addition of acid. Boron triacetate can be substituted in an equivalent quantity for both the acetic acid and the boric acid in the *F-1* formula.

Substitutes for Acetic Acid.—Equivalent quantities of the following acids were tested in comparison with acetic acid in the *F-1* formula containing boric acid: Phenyl acetic acid, chloro-acetic acid, amino acetic acid, propionic acid, lactic acid, furoic acid, tartaric acid, malic acid, maleic acid, glycollic acid, diglycollic acid, adipic acid, succinic acid, butyric acid, fumaric acid, glycero-phosphoric acid, sulfuric acid, and hydrochloric acid. The only acids which produced baths similar to those containing acetic acid were propionic acid and butyric acid. The other acids either did not affect the properties or decreased the hardening properties in a manner similar to tartaric acid.

A Satisfactory Fixing Bath Formula.—The requirements for a satisfactory alum fixing bath have been stated by Crabtree and Hartt,[3] and these apply also to the compounding of an alum bath containing boric acid. In general, 5 grams per liter of boric acid added to a fixing bath containing hypo, alum, sulfite, and acetic acid will increase its sludge and hardening life at least 3 to 4 times. In case a bath with a longer life than this is desired, more acid should be added. The total acidity of the bath can be increased by the addition of further quantities of either acetic acid or potassium alum. Although some alum is required to maintain satisfactory hardening properties, it is more economical to increase the acidity by the addition of acetic acid rather than by the addition of alum.

The alum concentration has very little effect on the degree of hardening, but in order to produce satisfactory hardening throughout the useful life of the fixing bath, the concentration should be at least 10 grams per liter. The exact concentration of the alum is not critical because even in high concentrations potassium alum does not harden the gelatin to such an extent that there is danger of excessive brittleness of the film.

Since the non-sludging properties are due to the presence of the borate and acetate ions, it was considered that the minimum concentration of boric acid should be 5 grams per liter and that of the glacial acetic acid, 10 cc. per liter. A lower concentration of either of these decreases the hardening life and increases the sludging tendency. A higher concentration of boric acid decreases the sludging tendency but also decreases the degree of hardening.

The acetate ion concentration may also be increased by the addition of sodium acetate, which decreases the sludging tendency and does not affect the hardening life or the degree of hardening unless an excess is added, such as a quantity greater than 25 grams per liter of sodium acetate crystals.

The sulfite concentration should be sufficient to prevent sulfurization of the bath over a period of at least one month at 70°F. A quantity which usually prevents this is equal to one-half the acetic acid concentration. Baths containing equal weights of acetic acid and sodium sulfite have a much longer sulfurization life and are desirable when they are to be kept for long periods. An excess of sulfite (a quantity greater than 20 grams per liter of desiccated sodium sulfite) has no particular advantage, and may decrease the hardening life because it acts as a mild alkali and neutralizes some of the acid.

Baths for the processing of motion picture positive film should produce a uniform degree of hardening without acid revival throughout the period of processing 400 feet of film per gallon. With negative films, a life of only 200 feet per gallon is necessary because the fixing power of the hypo is usually inadequate at this stage of the exhaustion.

Baths which meet these requirements should not precipitate a sludge when a 100-cc. quantity is titrated, drop by drop, with 50 cc. of the developer with which it is to be used. Developers such as *D-16* are moderately alkaline, and do not require a very acid fixing bath. Baths which are to be used with very alkaline developers may require as much as 20 cc. of acetic acid with an equal weight of sodium acetate crystals in order to prevent sludging.

From the above discussion, it is evident that a safe rule to follow in compounding a satisfactory bath is to add approximately equal weights of potassium alum, acetic acid (glacial), and sodium sulfite (desiccated) to a hypo solution with 5 grams per liter of boric acid. The concentration of the alum, sulfite, and acid should be at least 10 grams per liter and not over 30. Less sodium sulfite may be used if the bath is to be used within a short period after mixing, such as in motion picture work. If less sludging tendency is desired, sodium acetate may be added.

Fixing baths may also be compounded with boric acid which have a relatively high *p*H value. Such baths, when fresh, do not evolve as much sulfur dioxide as the regular baths without boric acid.

Baths such as the *F-1* and *F-2* may be improved in this respect by substituting one-half the quantity of acetic acid with an equivalent quantity of sodium acetate. For each cubic centimeter of glacial acetic acid, 2.5 grams of crystalline sodium acetate should be substituted. The hardening life and sludge life will be approximately one-half that of the regular baths containing boric acid but will be as long as that of the regular *F-1* and *F-2* baths without boric acid.

The constituents other than the hypo can not be compounded in a concentrated hardener such as the *F-2a* formula because of the relatively low solubility of the boric acid, but more dilute hardeners may be prepared with a limiting concentration of 25 grams per liter of boric acid. In this case, it would be necessary to add one part of hardener to four parts of hypo solution in order to have 5 grams per liter of boric acid in the final bath.

TABLE I

Effect of Boric Acid on the Properties of Chrome Alum Fixing Baths

Exp. No.	Concentration per Liter in 30% Hypo					Per cent MQ-25	Melting Point	Sludge Life	
	Chrome Alum (Grams)	Sodium Sulfite (Des.) (Grams)	Sulfuric Acid (Cc.)	Acetic Acid (Cc.)	Boric Acid (Grams)			Per cent MQ-25	Time to Sludge at 70°F.
1	15	15		15	5	0	110		
2						80	100	80	1 Day
3	30	15		5	5	0	140		
4						50	100	50	1 Day
5	80	40				0	200		
6						20	110	20	Immediately
7	80	40			5	0	200		
8						20	110	20	1 Day
9	80	40			15	0	200		
10						20	110	20	2 Days
11	80	40		2.5		0	200		
12						20	110	20	7 Days
13	80	40		2.5	5	0	200		
14						20	110	20	10 Days
15	80	40		10		0	200		
16						20	140	>60	
17	80	40		10	5	0	200		
18						20	140	>60	
19	32	17.5 (*F-23*)	2.0			0	200		
20						10	200	20	7 Days
21						20	110	60	Immediately
22	32	17.5	2.0		5	0	200		
23						10	190	20	10 Days
24						20	110	60	1 Day
25	32	17.5	2.0		15	0	200		
26						10	180		
27						20	110	60	4 Days
			Propionic Acid (Cc.)						
28	40	20	10		5.0	0	190		
29						20	110	60	5 Days

The Effect of Boric Acid on the Properties of Chrome Alum Fixing Baths.—It was considered that the addition of boric acid to a chrome alum fixing bath might also have a beneficial effect on its hardening and sludging properties. The effect of the addition of boric acid to the *F-23* formula and various experimental formulas is given in Table I.

The results indicate that (1) the boric acid did not diminish the degree of hardening (Expts. Nos. *5, 7, 9, 19, 22,* and *25*); (2) the hardening life was not extended (Expts. Nos. *20, 21, 23, 24, 26, 27*);

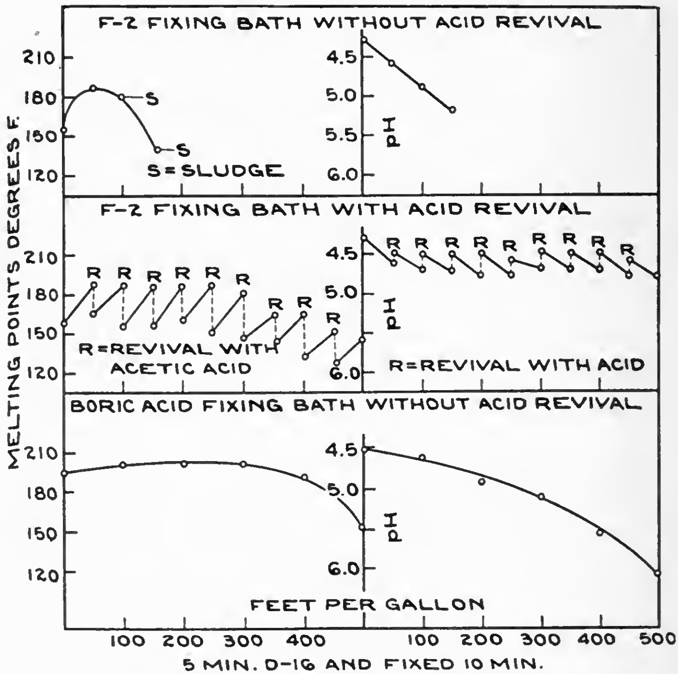


FIG. 5. Effect of exhaustion on the hardening properties and *p*H values of various fixing baths. (*D-16* developer.)

and (3) the addition did not increase the sludge life but prolonged the time before sludging occurred (Expts. Nos. *6, 8, 10*).

Since the addition of boric acid improves only those potassium alum baths which contain acetic, propionic, or butyric acids, tests were made to determine whether satisfactory chrome alum baths could be compounded containing boric acid and one of these acids. Previous tests[2] have indicated that acetic acid decreases the hardening properties of chrome alum solutions and decreases the sludging tendency.

Experiments Nos. *7* to *18*, inclusive, indicate that the addition of boric acid did not improve the properties of baths containing acetic acid. However, acids may ultimately be found which will produce a chrome alum bath having the desirable properties of a potassium alum bath containing boric acid, and further work in this connection is in progress.

Theoretical Considerations.—A regular potassium alum fixing bath such as the *F-1* will precipitate a sludge on the addition of a developer at a *p*H of approximately 4.8. The sludge consists of a mixture of aluminum hydroxide and aluminum sulfite, the exact proportion of each depending upon the conditions of precipitation.

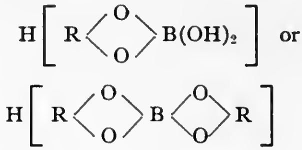
Certain organic acids can be added to the bath and thereby increase the *p*H value at which sludging occurs. Acids such as citric and tartaric behave in this manner, but they also decrease the degree of hardening. Citric acid, undoubtedly, prevents the precipitation of the sludge by forming complex ions with the aluminum ions, which, in turn, are not hardening agents for gelatin.

The addition of boric acid to an alum fixing bath containing acetic acid, also increases the sludge life, and may extend the hardening life up to the sludging point. The addition of boric acid does not produce an absolutely non-sludging bath; it only extends the *p*H range over which sludging does not take place.

The hardening action of ordinary fixing baths usually decreases rapidly at *p*H values greater than 5.0, but it is possible to compound boric acid baths which have satisfactory hardening properties at a *p*H value as high as 6.5 and which do not sludge at *p*H values less than 8.0.

Any theory which explains this action must account for the fact that boric acid produces the above properties only in a bath containing potassium alum, sodium sulfite, acetic acid, and hypo, or their equivalents. In this case, the aluminum sludging is probably prevented by the formation of complex ions between the alum, the acetic acid, and the boric acid.

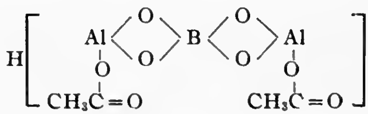
Complex ion formation between hydroxy organic compounds and boric acid has been investigated by Boeseken and Vermaas,[5] who state that "when a diol or (α-oxy acid) is added to a solution of boric acid in water, the compound $R\left\langle \begin{matrix} O \\ O \end{matrix} \right\rangle BOH$ is primarily formed, which, on account of the tendency of boric acid to assume the pentavalent condition, can pass into the following mono-basic acids:



R = any favorable diol or (α-oxy acid).

These acids are strong and are analogous to the acid $HB(OH)_4$ which has been shown to account for the acidity of a boric acid solution.[6]

Aluminum hydroxide, in this case, may be considered as a favorable diol and forms the following compound with acetic acid and boric acid: $2Al(OH)_3 + 2CH_3COOH + H_3BO_3 \rightleftarrows$



$+ 5H_2O$

The formation of this compound possibly does not take place until aluminum hydroxide begins to form, which accounts for the fact that a sludge can be obtained in the boric acid baths when relatively large quantities of developer are added immediately.

In applying the mass law to the above equation, it is seen that an increase in the concentration of borate ion or acetate ion would increase the concentration of the compound and, therefore, produce a bath with less tendency to sludge. This is in accord with experimental facts.

SUMMARY

(1) The effect of varying the concentration of the various constituents of a potassium alum fixing bath containing boric acid has been investigated.

(2) The addition of boric acid to a fixing bath such as the *F-1* increased the hardening life approximately four times by extending the *p*H range over which hardening occurred and also by preventing sludging.

(3) The sludging tendency of a given bath containing boric acid can be decreased by increasing the concentration of the acetate ion or borate ion. Five grams per liter of boric acid and 10 cc. per liter of acetic acid was considered the minimum concentration of these two constituents.

The sludge life of a given formula is determined largely by the manner in which the developer is added. If a relatively large quantity of developer is added rapidly, the bath will sludge immediately; but if the developer is added drop by drop, the total quantity which can be added before sludging occurs will be very much greater. This latter condition simulates that existing in practice.

In formulas such as the *F-1* containing boric acid, the addition of 25 grams per liter of sodium acetate decreases the sludging tendency to such an extent that large quantities of *D-16* may be added rapidly without sludging. Concentrations of sodium acetate crystals greater than 25 grams per liter decreased the hardening properties.

(4) An increase in the alum concentration increased the total acidity of a given bath and, therefore, increased the hardening life and sludge life.

(5) Any compound which dissociates in an acid solution to produce an oxygen acid of boron can be substituted for boric acid. Such compounds include borax, sodium metaborate, boron triacetate, and esters of boric acid.

(6) Substitutes for acetic acid include boron triacetate, propionic acid, and butyric acid.

(7) Satisfactory fixing baths containing hypo and 5 grams per liter of boric acid can be compounded by the addition of equal parts of potassium alum, acetic acid (glacial), and sodium sulfite (desiccated). For general use, the concentration of each of the latter ingredients should be at least 10 grams per liter and usually not more than 30. If a bath with a less sludging tendency is desired, sodium acetate may be added. Also, if the bath is to be exhausted within a short period after mixing, the quantity of sulfite can be decreased one-half.

(8) The non-sludging properties of a potassium alum bath containing boric acid have been ascribed to the formation of complex ions between the alum, acetic acid, and boric acid.

(9) The addition of boric acid to chrome alum baths containing either sulfuric or acetic acid or a mixture of the two does not affect the hardening properties and does not increase the sludging life, but merely retards the time required for sludging to occur.

PRACTICAL RECOMMENDATIONS

The following fixing bath formula is recommended for use with motion picture positive and negative films.

	Metric	Avoirdupois
Hypo	300.0 grams	300 lbs.
Sodium sulfite (desiccated)*	5.0 grams	5 lbs.
Acetic acid (glacial)	10.0 cc.	1 gal. 26 oz.
Boric acid	5.0 grams	5 lbs.
Potassium alum	10.0 grams	10 lbs.
Water to make	1.0 liter	120 gals.

Dissolve the hypo in one-half the required volume of water and then add the remaining chemicals in the order given after dissolving in a small quantity of water. Dilute with water to the required volume.

* This bath contains a minimum quantity of sulfite, which is such that the bath will not sulfurize within a period of 3 to 4 weeks at 70°F. If the temperature is apt to rise above 70°F., twice the quantity of sulfite should be used.

A comparison of the hardening properties and *p*H values obtained during the exhaustion of the *F-2* formula (with acid revival) and the boric acid bath (without revival) is shown in Fig. 5. The baths were exhausted with motion picture positive film which was developed in *D-16* but not rinsed before placing in the fixing bath. The *F-2* formula was revived at intervals corresponding to 50 feet of film per gallon with 7.5 cc. of glacial acetic acid.

During the exhaustion of the *F-2* formula, a considerable change in hardening properties and *p*H value occurred when the bath was revived with acid. The hardening life with acid revival was approximately 500 feet of film per gallon. Without acid revival, the life was less than 100 feet per gallon. The degree of hardening of the boric acid bath did not change during the processing of 400 feet of film per gallon, but it decreased rapidly after 500 feet of film had been processed.

A similar test was made by exhausting the boric acid bath with motion picture panchromatic negative film developed in *D-76*. The life of the bath in this case without rinsing the film was 400 feet per gallon.

The degree of alkalinity of the fixing bath can be determined readily by the addition of 1.0 cc. of a 0.04 per cent aqueous solution of bromo-cresol-purple to a 10.0-cc. sample of the fixing bath. When the bath is fresh, the color of the solution will be faintly yellow, which will deepen during exhaustion, and finally have a distinct reddish tint when the bath is exhausted. This occurs at an approximate *p*H value of 5.6. Although most of the boric acid baths will harden the gelatin up to a *p*H value of 6.5, it is desirable to discard the bath at this point because most of the acid has been neutralized, and further exhaustion may produce developer stains.

The addition of boric acid to a potassium alum bath does not interfere with the efficient recovery of silver from an exhausted bath by the electrolytic process, and tests have indicated that the wear and tear properties of film fixed in the above bath are not inferior to those of film fixed in the *F-2* formula.

Except for use under tropical conditions, it is considered that the recommended boric acid formula which does not require revival with acid during exhaustion, is to be preferred to most chrome alum fixing baths. In order to maintain their hardening properties, chrome alum baths require revival with sulfuric acid at intervals during exhaustion, and for best results the precise quantity of acid to be added must be determined by chemical analysis.

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A PRACTICAL METHOD AND PHOTOMETER FOR CONTROLLING EXPOSURES IN PHOTOGRAPHY*

M. LASKY AND B. RUBIN**

Summary.—*The need of determining accurately the brightness of subjects to be photographed so as to enable the cinematographer to determine the optimum exposure of the film in motion picture cameras by instrumental means rather than by visual estimate, is discussed at some length; and the errors inherent in the visual methods are shown to be very considerable.*

An exposure meter known as the Graphometer has been designed for the purpose of enabling the cinematographer to determine the proper exposure of the film; it operates on the photoelectric cell principle and may be used with a standard camera. A brief discussion of the method of using the Graphometer is included.

Much progress has been made in the technical phases of the motion picture industry, largely as a result of the introduction of more precise methods of measurement and control in various operations relating to the handling of film. Camera exposures, however, are still determined mainly by individual judgment because meters for measuring exposure have not been adopted to any extent by the majority of cameramen.

Motion picture technicians, however, are convinced of the necessity of controlling exposure quite accurately. The rigid requirements imposed by sound-on-film processing, together with the demand for the utmost in pictorial quality and economy of operation, have created a situation in which indefinite methods of determining photographic values and the attendant complications and waste can no longer be tolerated.

In the laboratory, the inertia of technicians toward changes of method was overcome by the advent of sound, which necessitated a precise determination of the various factors involved: exposure of the negative, development, timing of the print, development of the print, *etc.*, resulting in a fuller appreciation of the value of sensitometric methods and their general adoption by laboratory technicians. In the case of exposure of the original picture negative, however, the tendency has been, oddly enough, away from standardization.

* Presented at the Spring, 1932, Meeting at Washington, D. C.

** New York, N. Y.

Research has been in the reverse direction. Film emulsions are produced with more latitude; negative developing formulas and developing speeds are varied; printing machines are designed with a greater number of light changes in order to compensate for errors occurring in negative exposure because of human variability. Moreover, it is obvious that errors of judgment must occur. Instead of assisting sensitometry in its general purpose, such measures, due to their interdependence, conduce to a sacrifice of quality and complicate laboratory operations, with resultant economic disadvantages.

In so far as the cinematographer is concerned, the predetermination of light intensity is of great importance. A method by which the camera operator could determine the intensity of the actinic light on an object or scene would be extremely desirable, and would enable him to confine the exposure of the film to the straight-line portion of the characteristic curve of the emulsion, so as to maintain a constant negative density, reproducible with fidelity from the highest light to deepest shadow; it would also enable him to predetermine light effects accurately, and have them reproduced with the light proportioned as desired. In short, it would provide a definite relation between subject brightness and negative density.

Up to the present time the use of photometers has in general been regarded apathetically, due mainly to a lack of appreciation of sensitometric principles. In addition, the various kinds of photometers or exposure meters available have been either impracticable or inaccurate. Let us consider briefly some of these exposure meters and the method employed to indicate the correct exposure.

The photoelectric type of instrument consists of a light-sensitive cell, such as selenium, cuprous oxide, *etc.*, and a meter calibrated in *f* values, corresponding to lens diaphragm markings. In use, the instrument with the photoactive surface is directed toward the scene to be photographed, the light falling upon this surface causing a physical change in the light-sensitive element which, in turn, actuates the indicator of the meter. In order to appreciate the faults inherent in such methods, the following illustration may be taken:

Two cards, *A* and *B*, Fig. 1, are equally illuminated. These cards may represent light and dark sections of the scenes to be photographed.

As can be observed, the photographic brightness values of *cc* and *dd* are equal. In other words, the photographic contrast in the two cards is the same. Using the kind of exposure meter just mentioned, a reading is made of card *A*. Since the white area of this card is large, most of the light falling on it is reflected to the sensitive surface of the photometer, and a reading is obtained indicating a lens diaphragm setting of $f/16$ as the proper exposure. Since the small white area of card B reflects proportionately less light than A, a measurement would indicate a lens diaphragm setting of $f/2$. Accordingly, one value of exposure would be indicated as 64 times that of the other, yet both cards are equally illuminated and their photographic brightness contrasts are identical. Obviously, this method of determining illumination for photographic purposes will not suffice if precise measurements are required. Further, the possible

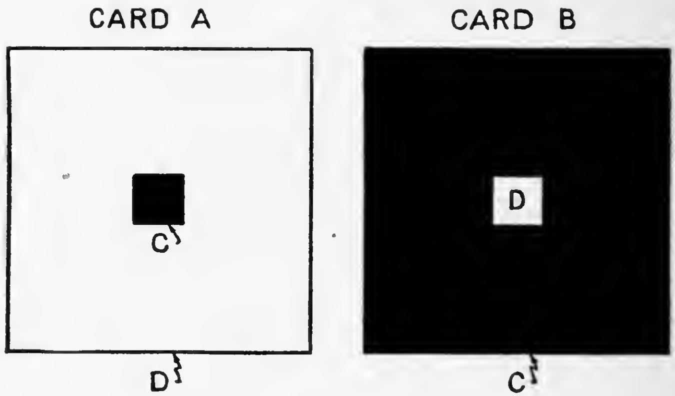

FIG. 1. The total brightness measurement of these two subjects illuminated with the same intensity would indicate exposures in the ratio of 64 to 1.

differences in light transmission of lenses having the same f rating, and the decrease in relative aperture as the lens is focused at closer ranges than infinity, precludes the possibility of obtaining accurate results by any method which does not take into account these factors.

It can therefore be seen that any instrument designed to indicate photographic exposure accurately demands consideration of the following:

(1) *Brightness of the Subject.*—For fidelity of tone, exposure depends upon the brightness of the subject, not upon the quantity of light impressed on the scene. Suppose it is planned to photograph a black card; and then, using the same illumination and lens aperture, to photograph a white card. In order to achieve a faithful reproduction of both cards, retaining the brightnesses in the same pro-

portions as in the original, both cards will require the same exposure. The use of a highly reflective setting for these cards will simply reduce the exposure needed for both. However, a knowledge of the total amount of light coming from the same is of no use, as it does not indicate the brightness of any one part; it is necessary to know the brightness of definite parts of the subject.

(2) *Control of Exposure through Lens to Be Used for Photographing to Insure against Unknown Transmission Values.*—The light-passing power of a lens may vary greatly from long shot to close-up because of the change of relative aperture. Very frequently variations also occur in the speed of lenses that are similarly marked, due to the peculiarities in manufacture.

(3) *Facility and Speed of Operation.*—In modern swift picture production, it is desirable that measurements take but a few seconds and that the instrument be easy to operate. This is of utmost importance inasmuch as time is all-important from the economic standpoint.

(4) *Constancy and Dependability of the Instrument Used.*—Any instrument to be used by cinematographers should be extremely portable. In addition, frequent changes in picture making locale necessitate that the instrument be unaffected by atmospheric conditions or ambient temperatures. It must also retain its accuracy for a reasonable period of time with normal usage.

The above requirements have been embodied in an instrument known as the *Graphometer*. Its principles and dependability have been proved under actual working conditions for more than a year, during which time many suggestions for improvement in design and operation of the instrument were offered by cinematographers and technicians.

In its present form, the Graphometer is used in connection with the Mitchell camera. It is possible, however, to make this unit an integral part of the camera. Fig. 2 shows the design and placement of the parts.

The meter may be calibrated for various types of emulsion in terms of per cent of normal exposure or in light intensities, degrees, *etc.* The power is obtained from a small $22^1/_2$-volt battery. Compensation for depreciation of the battery is provided by means of an adjustable rheostat.

In operation, the cinematographer proceeds in the usual manner to set up, focus, and arrange the lights in their approximate positions for the particular kind of lighting desired. Having focused the lens to be used, the camera head is moved to the right to its farthest position, and the Graphometer is placed directly behind the lens. Guide rails on the instrument assure alignment of the focusing screen in the same position behind the lens as the photographing aperture. With the lens covered to exclude light from the photocell, the battery is switched on and the meter indicator is set to read zero by adjusting

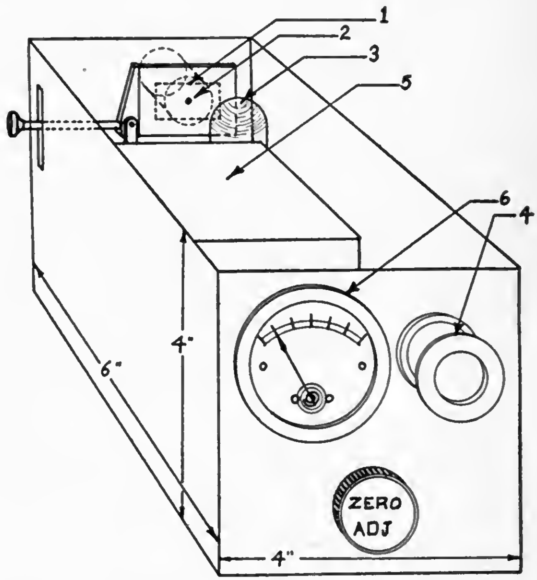

FIG. 2. Diagram of Graphometer; *1*, focusing screen; *2*, adjustable mask with an aperture; *3*, photocell; *4*, sighting tube; *5*, photocell amplifier; *6*, meter.

the rhoeostat. The light values are then measured as follows: a white card (which is used as the standard of radiation or reflection), 20 inches square, is held by an assistant at any point in the scene at which the light value is to be ascertained. Looking through the sighting tube, the operator adjusts the moving mask so as to receive only the image of the card in the 1-millimeter opening. The photocell is then brought into position, to receive the light admitted from this opening, and a direct meter reading is obtained. Any deviation from the normal may be compensated for by an increase or decrease of illumination or adjustment of the lens diaphragm. Additional readings can be taken at any other points in the scene and corrections similarly made.

When photographing with a large and uniform light source, such as daylight, only one reading is necessary to adjust the lens diaphragm properly. The occasion frequently arises, however, when it is necessary to determine light values of sunlight and shade where both are included in the scene. In such cases, the operator can favor with accuracy either side, or choose an intermediate balance for the best reproduction of both sides.

It has been found for all practical purposes that by using neutral density filters, the same meter calibrations can be used for color filters and different emulsions. For example, if the meter is calibrated for normal, using a supersensitive emulsion, and it is desired to use a film with only half the speed, a neutral density filter having a transmission value of 50 per cent may be slipped over the lens when taking the reading, and the same normal point on the meter would indicate the correct amount of light for that emulsion. Before photographing, the filter must be removed from the lens. The light can also be equalized when using color filters by the same procedure. If it is desired to use a color filter having a factor of 10, a neutral density filter transmitting only 10 per cent of the light is employed; the lens diaphragm is adjusted so that normal is indicated on the meter; then the neutral density filter is replaced by the color filter before photographing. Corrections for differences in actinic values of incandescent and sunlight can also be made by this method.

Since all measurements are made through the lens at the relative aperture at which photographing is to take place, all the conditions actually existing in the scene are considered.

Normal exposure as here referred to is meant to indicate the exposure at which faithful reproduction is obtained for all the shades and gradations, ranging from black to white, which were present in the original scene. Variations of development factors in different laboratories make necessary an initial test to determine the proper normal dial setting for the laboratory that is to process the negative. Practical determination of this point is best accomplished by making a series of exposures of a light wedge or gradation chart, and noting the meter readings for each exposure. After normal development, the meter reading corresponding to the perfect exposure is set as the normal. It will then be found possible to photograph the gradation chart under different light conditions on the same film strip and at varying camera distances, and maintain the negative density constant throughout.

In some tests recently conducted over a period of months and under light conditions that required lens diaphragm settings ranging from $f/2$ to $f/22$, a negative was obtained of such consistency that all takes were printed on one light intensity. These tests were made repeatedly with both incandescent lighting and sunlight with the same results.

Unquestionably the application of sensitometric principles in studio practice will effect much needed economies such as elimination of light tests and the time consumed in making them; the maintenance of illumination in accordance with actual requirements with consequent savings of current and equipment; elimination of retakes because of under- or over-exposure; standardization of developer compositions and speeds; elimination of waste and complications in print processing; elimination of tests and retakes in trick and process photography, *etc.* It is also practicable to combine picture and sound track on the same negative without loss in quality of either.

Although these economies are vitally necessary, of equal importance is the fact that only by sensitometric methods can full advantage be taken of the photographic art; only by the definite knowledge which these methods provide can the utmost in pictorial beauty be attained.

SOUND RECORDING AND REPRODUCING USING 16-MM. FILM*

C. N. BATSEL AND J. O. BAKER**

Summary.—*This paper deals with the various problems involved in applying sound to 16-mm. film and points out the advantages of the particular type of film that was chosen. There are two general methods of producing 16-mm. positives, the direct and the indirect. The direct method involves the recording of sound directly on a 16-mm. negative, from which is printed a 16-mm. positive either by contact or by the reversal process. The indirect method concerns various ways of obtaining 16-mm. positives from 35-mm. film. The problems involved in printing and reproducing 16-mm. sound films are discussed.*

The use of sub-standard film in the motion picture industry dates back to 1897, but it did not gain much popularity until 1923. It was at that time that the Eastman Kodak Company perfected the reversal processing of their 16-mm. film, and announced it to the trade together with the first hand-powered Ciné-Kodaks and motor driven Kodascopes. The Ciné-Kodaks used the 16-mm. safety film, and the daylight loading feature proved to be very popular with the amateur.

Other attempts have been made to popularize motion pictures in the home; but none of them gained very much momentum, lacking the desirable simplicity of operation of the Eastman camera and the assurance of a good percentage of acceptable pictures with the reversal process. There were no film libraries and, as a result, the attempts to interest the amateur without the means of making the films were soon forgotten. Some rapid changes took place during the five years following 1923. In 1926, the Eastman Kodak Company announced a spring-driven Ciné-Kodak, and about the same time the Bell & Howell Co. announced their 16-mm. line. In 1927, film libraries began to spring up. Educational and industrial pictures began to make their appearance along with 16-mm.

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versions of news items. In 1928 the Eastman Kodak Company announced the Kodacolor process for 16-mm. film.

With these new developments, the public and the professions quickly adopted the 16-mm. film, and its use became general in the medical, educational, amusement, and business promotional fields. Its popularity has continued to the present time, with only little slackening due to the depression.

In 1928, it became apparent that the addition of sound to 16-mm. movies would be the next great step; consequently, work was begun by the Radio Corporation of America for the purpose of accomplishing this. The efforts were restricted to sound-on-film apparatus. At the same time a number of companies were announcing synchronized sound-on-disk for 16-mm. film. These equipments consisted of $33^1/_3$ rpm. turntables geared to the 16-mm. projector, and employed the $33^1/_3$ rpm. theater disks. The film was reduced from the 35-mm. film. Some of the more elaborate ones were mounted in cabinets. The equipment never became popular, as both the films and records were expensive and hard to obtain.

It is appropriate to mention here some of the problems that had to be overcome to produce successful 16-mm. sound-on-film equipment, inasmuch as after the adaptation of sound to 35-mm. film it would seem that, by applying the same principles to 16-mm. film, good results could likewise be achieved. Such is far from the case. In the first place, the linear speed of the narrow film had to be less than that of the 35-mm. film if the usual 24 pictures per second were to be projected. This was desirable in order not to use more film than necessary and at the same time to maintain the same proportions in the 16-mm. pictures as in the original 35-mm. pictures. At this greatly reduced speed the fact that 16-mm. film has only forty sprocket holes per foot, instead of 64, presented the very difficult problem of providing a mechanical filter that would successfully eliminate "wows," and at the same time eliminate the 24-cycle sprocket tooth flutter. This problem was finally solved, and 16-mm. sound reproduction that is practically free from "wows" and flutter is now attainable.

Not only did the low speed offer new filter problems, but it placed a serious handicap on the frequency response. When one considers that with a ratio of $2^1/_2$ to 1 in speed the 4000-cycle wavelength on the 16-mm. film is equal to the 10,000-cycle wavelength on the 35-mm. film, it can readily be seen with what the engineers had to contend. The film companies coöperated by improving the acetate base and the emulsion, and in the latter part of 1932 perfected a 16-mm. sound negative that gave very good results. By suitably equalizing the electrical circuits, it was possible to attain with this film, on standard studio recorders and re-recorders, 16-mm. sound track, the response of which is reasonably flat up to and even beyond 4000 cycles.

A third problem that had to be overcome before 16-mm. equipment could be offered commercially was that of standardizing the film. The RCA Victor Company in conjunction with several others and one leading film company took the stand that the size of the 16-mm. picture frame should not be reduced, as had been done in the case of 35-mm. film when the sound track was added. By eliminating one row of sprocket holes it was possible to place a 60-mil sound track on the film and retain the same picture size as on the old 16-mm. silent film. Such a procedure presented certain difficulties in printing, which will be mentioned later, but by retaining the old picture dimensions, the projectors could project either the old silent films, many of which are valuable, or the new sound films without having to change apertures in the projectors. By thus using the sprocket hole space it was possible to record a sound track of sufficient width to achieve a satisfactory ratio between the recorded sound and the noises inherent in the film and amplifiers.

After producing satisfactory recordings and sound projectors the next problem was to devise ways of making the 16-mm. prints available to the purchasers of the projectors. There were two alternatives: one of making all 16-mm. sound film directly, the other of making 16-mm. prints from the existing 35-mm. film. Both plans have been followed.

We shall now consider various methods of producing 16-mm. sound film from the 35-mm. sound film. The first is to reduce both sound and picture optically, by means of a continuous printer. This is not easy to do with existing printers, due to a slight slipping between the two films which causes the high frequencies in the sound track to be lost. Also, no corrective compensation can be applied between the 35-mm. and 16-mm. films. The difference between the sizes of the pictures also prevents the simultaneous reduction of sound and picture. If the proper kind of 35-mm. recording is available we can now optically reduce the sound track satisfactorily.

Another way that was considered was to use a combination step reduction printer and re-recorder. While such a method would have been satisfactory, the machines proved to be expensive and were not adapted to the general layout of modern printing and processing laboratories.

The most practicable plan that has been developed up to the present is to re-record the sound from a 35-mm. sound print on a 16-mm. sound negative. The picture is reduced from the 35-mm. negative to the 16-mm. print in a step printer, and the sound is printed by contact on this print either before or after the picture is reduced. The printing and processing then present no greater problems to the laboratory than the printing and processing of any other sound film. By restricting the re-recording to the recording studios, the experience of the sound recordists in the 35-mm. sound field can be applied to the production of 16-mm. sound-film. When properly compensated by an experienced recordist, good 16-mm. sound is obtained from 35-mm. film which if optically reduced would be a failure. After obtaining the 16-mm. negative, it may be printed in any laboratory equipped to print and process 16-mm. sound film.

For making the 16-mm. recordings directly, the 35-mm. recording channels have been duplicated, properly compensated for the difference in the frequency response of the 16-mm. and 35-mm. films. These recorders can be synchronized with a 16-mm. camera, if desired, or can be used to score existing 16-mm. films or add sound to 16-mm. versions of the silent 35-mm. films. This method of making 16-mm. film is now used extensively in making advertising, educational, and other commercial film. It is fairly expensive, however, and does not solve the amateur problems. In order to popularize 16-mm. sound film among the vast army of amateurs and others who might want to make 16-mm. sound film pictures, a combination 16-mm. camera recorder has been developed.

Such a camera must be small and light in weight. The addition of sound must not complicate the operation of the camera, and the entire mechanism must be practically fool-proof. It must record sound acceptably, and adhere to the accepted 16-mm. dimensions, so that its product can be reproduced by standard reproducers. In other words, the problem was to make a sound recording camera very little larger than the existing silent cameras, and to design it so that any one familiar with a silent camera could, with a little instruction, make good sound motion pictures.

As a result of a large amount of developmental work the RCA Victor Company has produced a complete sound recording camera, the over-all dimensions of which are $7^1/_2$ inches high, $8^3/_{16}$ inches long, and $5^{11}/_{16}$ inches wide. Its weight is approximately nine pounds. It is equipped with a spring motor, capable of running twenty-five feet of film, which can be increased to 50 feet if desired, at one winding. It is equipped with a revolving turret head, telescope finder, and a variable footage indicator. It has a one-piece removable door. The film is threaded in the camera as simply and easily as in the ordinary silent camera, over only one sprocket and through the picture gate, and the only loops to be formed are those on either side of the picture gate. It accommodates either 100- or 50-ft. rolls of daylight loading reversal film. The entire recording optical system has been reduced almost to the size of an average ink bottle, and will record frequencies of a range sufficient for good reproduction of speech.

There are to be two types of the camera: namely, the autophone and the microphone. The autophone type is extremely portable and simple to operate, and is designed to be used in difficult places, and for making pictures to be described by the operator of the camera. No amplifier is used, the recording mirror being actuated by the sound waves from the speaker's voice. The current for the recording light is supplied by three small flashlight batteries contained within the camera.

The electrical type is identical in so far as the mechanical construction is concerned, but contains an electrically driven galvanometer and includes an amplifier and microphone as part of the equipment. It is, of course, not as portable or as easy to operate as the autophone type, but is much more flexible, in that in addition to being able to do everything that the autophone can do, it can be used for recording amateur plays, news items, and all events where sounds emitted by the subjects are important to the picture.

Work has been done by the film companies, for the purpose of producing a suitable film for use in this equipment. The earlier reversal films were very poor for recording sound, so that a great deal of experimentation was required of the film manufacturers in order to produce emulsions that would provide good results with sound and at the same time not impair the photographic qualities now claimed for the reversal films. Sound films are now available, perforated on one side, that meet these requirements.

THE USE OF MAZDA LAMPS FOR COLOR PHOTOGRAPHY*

R. E. FARNHAM**

Summary.—*By operating the filaments of high-efficiency tungsten lamps at higher voltages than normal, not only are the operating characteristics of the lamps improved, but a more desirable spectral energy distribution for color photography is attained, the increase of the blue-violet radiation amounting to about 140 per cent of the increase of the red-orange radiation. In view of the fixed voltages used on sets, the lamps are, in effect, designed for lower voltage and wattage. Data on the candle-power distribution with suitable reflectors are presented.*

The recent commercial availability of at least two satisfactory systems of three-color motion picture photography will undoubtedly result in a more extensive production of colored motion pictures than has taken place in the past.

Since all the motion picture studios are equipped with incandescent lighting equipment, and the advantages of high-efficiency tungsten lamps, such as reduced labor costs, inherent quietness, accuracy of light control, *etc.*, are well recognized, the studios are naturally interested in the application of this light source to the color photographic processes.

In the case of black-and-white photography using panchromatic film we employ an emulsion that is highly sensitive at the blue-violet end of the spectrum and somewhat less sensitive toward the red-orange region. The Mazda lamps have their greatest radiation in that part of the spectrum where most light is required and less output where the film is most sensitive. This combination results in utilizing the panchromatic film to its full advantage, and gives excellent rendering of the faces and properties in the sets.

The color photographic processes require a light source having more nearly equal proportions of all colors as well as approximately fifty per cent greater illumination intensity than is necessary for black-and-white photography. The simplest method of obtaining light of the required quality is to employ a suitable filter, either at the lens

* Presented at a meeting of the Pacific Coast Section, June 15, 1933.

** Engineering Dept., General Electric Co., Cleveland, Ohio.

or in front of the lighting equipment to absorb the excess red-orange-yellow light and thus more nearly approximate a white light.

However, the amount of blue-violet radiation required is such as to necessitate an excessively high wattage when lamps of the usual studio type are employed, and the process becomes an extremely wasteful one. Hence the desirability of having lamps which produce not only a greater proportion of blue-violet light as compared to red-orange, but a greater volume of light for a given wattage, since the amount of heat on a set is largely determined by the wattage employed.

It is generally known by those familiar with the behavior of incandescent lamps that if the voltage applied to a lamp is increased, the light output increases at a much faster rate than either the voltage;

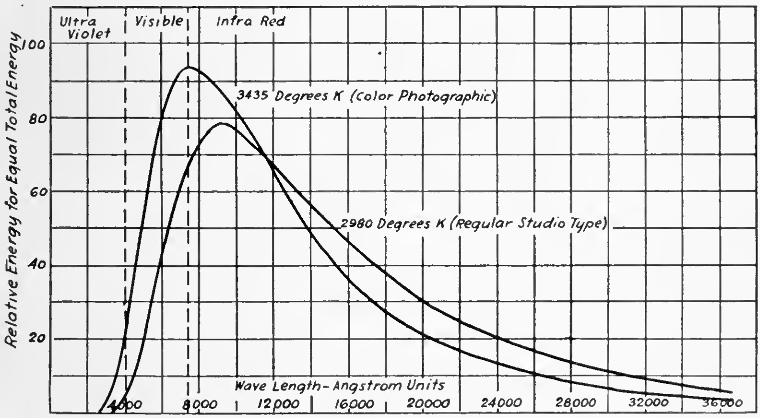

FIG. 1. Total spectral energy distribution of Mazda lamps.

or wattage; in other words, the amount of light per watt is increased, also the amount of blue-violet radiation increases at a greater rate than does the red-orange light. For a more complete presentation of the relationship of lamp voltage-life-light output and temperature, the reader is referred to the paper on this subject by M. W. Palmer and E. W. Beggs.[1]

Referring to Fig. 1, showing the total radiation, and Fig. 2, showing the visible output from two incandescent lamps, one operating at 2920°K. (21 lumens per watt), typical of the lamps now used for general lighting service in the studios, and the other at 3435°K. (33 lumens per watt), the photoflood type, it is evident that the increase in radiation in the violet region (4000–4500 Å) is 270 per cent while the increase in the red (6300–7400 Å) is 55 per cent. Based on an equal quantity of red radiation for the two lamps, the increase in the violet is 140 per cent.

Thus by the simple process of operating the lamps on overvoltage, we receive not only a greatly increased volume of light but light of an improved color quality, applicable to color photography with minimum

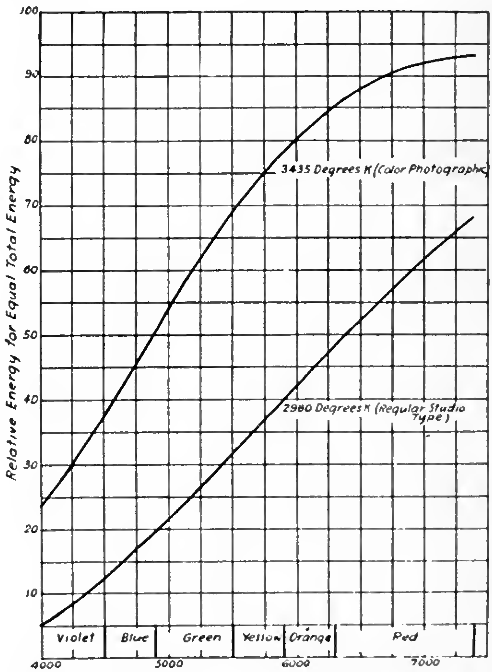

FIG. 2. Visible spectral energy distribution of Mazda lamps.

wattage. To be sure there is still some excess red-orange, which must be filtered out, but the losses are very much reduced. Such filtering can be accomplished by adjustment of the apertures in front of the red-green-blue filter, by a color filter in front of the lens, by color screens incorporated in the lighting equipment, or even the use of a colored glass bulb for the lamp. The first two schemes mentioned permit the more accurate control of the quality of light entering the camera. The third and fourth methods remove the excess red and infra-red radiation from the actors and sets. The use of colored glass for the lamp bulbs means that in effect the filter is thrown away with each lamp renewal and, of course, lamp cost is increased.

Operating the lamp on overvoltage is not practicable from an operating standpoint since the voltages at the sets are fixed, but the lamp can be designed for a high efficiency and accomplish the same result. This permits operation on the standard 115-, 120-volt circuits. In effect, the lamp is designed for lower voltage and wattage. This is what has been done in the case of the small photoflood lamp and

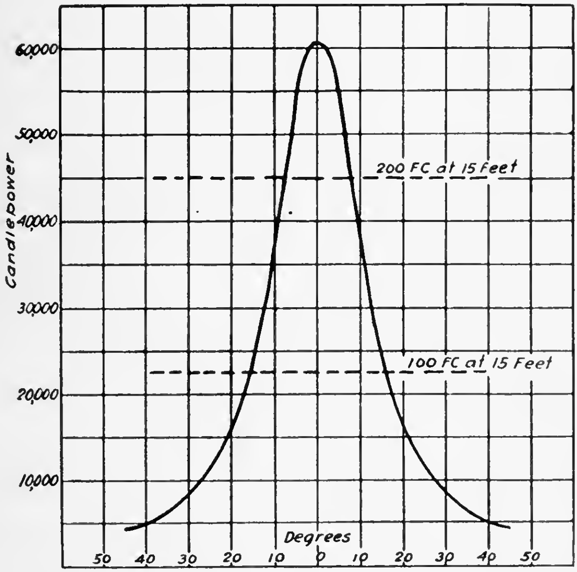

FIG. 3. 1500-watt, 115-volt *PS-52* bulb Mazda lamp in *M.R.* rifle unit (21 L/W design).

what is being done in the case of the big 2000-watt photoflood or color photographic lamps.

Another factor which aids very materially in placing sufficient intensity of illumination on the sets with minimum wattage, is the use of lamp equipment which directs a high percentage of light within the angle where it can be used most effectively. The Mole-Richardson "rifle" unit is a particularly good example of a unit of this type. It is capable of directing 50 to 60 per cent of the light output of the lamp within angles where it can be used. This is several times more than is obtained with those equipments either not having good reflectors, or in which accurate control of the light has not been attempted.

Fig. 3 illustrates the candle-power distribution obtained from a standard 1500-watt *PS-52* bulb lamp now employed for general lighting, in an *M. R.* rifle unit, and Fig. 4 the distribution from a 2000-watt *PS-52* bulb lamp of the color photographic type in the same reflector. Analyzing these data we find that the 1500-watt

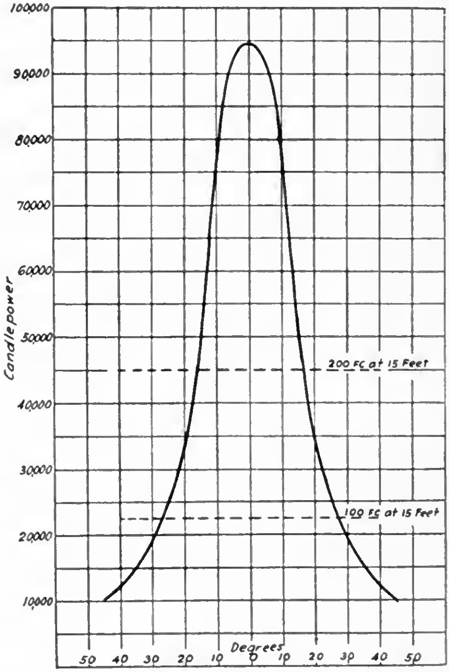

FIG. 4. 2000-watt 120-volt *PS*52 bulb Mazda lamp in *M.R.* rifle unit (33 L/W design).

lamp directed 17,200 lumens in the 60-degree useful angle. The 2000-watt lamp gave 34,400 lumens in this same 60-degree angle, an increase of 100 per cent over the standard studio type.

Photographically, the increase is greater than that, since the photometer employed has its greatest sensitivity in the orange-yellow, where the increase is less pronounced. The use of the 2000-watt, high-efficiency lamp, in place of the 1500-watt standard type, thus doubles the illumination intensity on the set; and the general requirement of 50 per cent more illumination for color photography, together with the filter absorption, means that satisfactory color pictures can be made with approximately double the average wattage now employed for black-and-white photography.

The 2000-*PS-52* bulb color photographic lamps as designed for studio service have a life of 15 to 18 hours, and it is therefore advisable to "save" them as much as possible. A very good practice is to operate the lamps at approximately 90 volts, obtained by either field control at the generator, or by the use of grids outside the set, when preparing, and bring them to full voltage only when actually photographing.

With all the lamps operating at the same reduced voltage, lighting balances, contrasts, and shadows are not altered when the lamps are brought up to full voltage.

Lamps of this type darken sooner than the longer lived types, and therefore contain a cleaning powder which allows the light output to be restored to its initial value. A cleaning after each 5 to 6 hours of full-voltage operation is sufficient.

The 2000-watt *PS-52* bulb lamp adequately takes care of the general lighting requirements. For modeling or spot-lighting service, 5- and 10-kw. lamps, similar in every respect to the present standard lamps but of 105-volt rating, should be used.

These lamps normally operate at 29 to 30 lumens per watt, and the overvoltage to which they are submitted when operated on 120-volt circuits not only increases the quantity of light emitted but makes the color quality of the light the same as that of the color photographic lamps.

REFERENCE

[1] PALMER, M. W., AND BEGGS, E. W.: "Professional Motion Picture Photography with High-Intensity Short-Life Incandescent Lamps," *J. Soc. Mot. Pict. Eng.*, **XXII** (Aug., 1933), No. 2, p. 126.

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SOCIETY ANNOUNCEMENTS

BOARD OF GOVERNORS

A meeting of the Board of Governors was held at the Hotel Pennsylvania on July 14, at which time the various administrative and fiscal affairs of the Society were reviewed with a view of making possible alterations conforming to the changing conditions of the times. The problems incident to revising the rates charged for dues and non-member subscriptions for the JOURNAL were also considered, and initial plans were made for the Fall convention.

FALL, 1933, CONVENTION

The next convention of the Society will be held in Chicago, early in October, with headquarters at the Edgewater Beach Hotel. The exact dates will be announced later. An attractive program is being arranged by Mr. W. C. Kunzmann, chairman of the Convention Arrangements Committee, and Mr. O. M. Glunt, chairman of the Papers Committee.

The Chicago Section will collaborate with the Committees in order to make the visit to Chicago a most interesting and profitable one. The members of the Society are urged to make every effort to attend; an additional inducement is afforded by the coincidence of the convention with the Century of Progress Fair, which terminates at the end of October.

The Society regrets to announce the deaths of

Dr. Walter Akemann

April, 1933

and

William C. Hubbard

July 20, 1933

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HONOR ROLL

OF THE

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By action of the Board of Governors, October 4, 1931, this Honor Roll was established for the purpose of perpetuating the names of distinguished pioneers who are now deceased:

LOUIS AIMÉ AUGUSTIN LE PRINCE
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(*Complete information on page 256 of this issue of the Journal*)

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXI SEPTEMBER, 1933 Number 3

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JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

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

RADIO CITY SOUND EQUIPMENT*

BARTON KREUZER**

Summary.—*The paper describes the equipment used in the Radio City Music Hall, explains the mode of operating it, and the use of the component systems; it refers to the engineering design of the various portions of the system, their performance, and some of the installation problems involved.*

The term Radio City has been somewhat loosely applied in the past. Radio City is that part of Rockefeller Center occupied by the Radio Corporation of America and its associated companies. Rockefeller Center lies between Forty-eighth and Fifty-first Streets and Fifth and Sixth Avenues in New York City. The theatrical part of this enterprise consists of two theaters, the "RKO Roxy Theater," seating 3700 persons, and the "Radio City Music Hall," seating 6200. The remarks in this paper will be restricted to the latter theater, since, from an equipment and engineering standpoint, the smaller theater is a proportionately smaller copy.

A considerable number of systems were involved in equipping the Radio City Music Hall. They may be summarized as follows:

I. Sound on film reproducing equipment.
   A. Double channel equipment main projection booth.
   B. Rear projection equipment.
   C. Portable film phonograph.
   D. Two complete preview rooms.
II. Public address and sound reinforcing equipment.
III. Rehearsal system.
IV. Sound effect system.
V. Stage manager's call system.
VI. Radio frequency distribution system.
VII. Custom built radio, phonograph, and monitoring system.

The sound-on-film reproducing equipment is of the latest "high fidelity" type, employing the newly developed sound-heads shown in Fig. 1. The main projection booth is equipped with four projectors

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* Presented at the Spring, 1933, Meeting at New York, N. Y.

** RCA Victor Co., Inc., Camden, N. J.

and a double-channel 80-watt amplifying system, which is completely a-c. operated. This assures a complete "standby" equipment for emergency use, which can be placed in immediate operation by turning a single knob. A further guarantee against interruption is the fact that the 80-watt output is obtained from two 40-watt amplifiers coupled together so that all stage speakers will be supplied

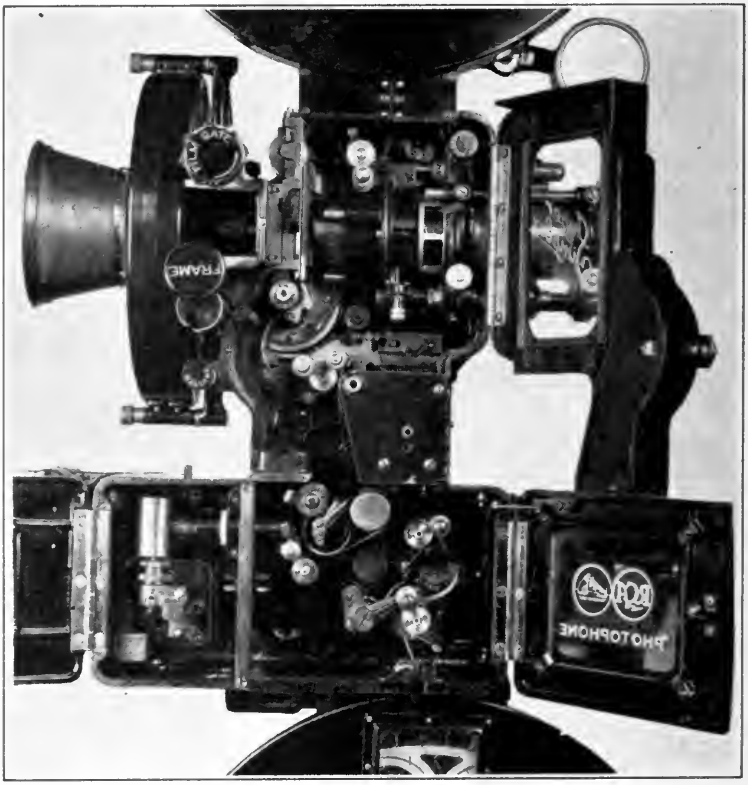


FIG. 1. New sound-head.

with energy even if one of the two power amplifiers should become inoperative.

Amplifier volume and fading from one projector to another are controlled remotely by push buttons located adjacent to the projectors. Key-operated remote volume control stations have also been placed throughout the theater.

The stage loud speakers consist of three 10-foot directional baffles and three 5-foot directional baffles. The larger speakers are placed in a horizontal line so as to cover almost the entire house with the exception of the front part of the orchestra, which is covered by the three smaller speakers hung directly beneath the others. These

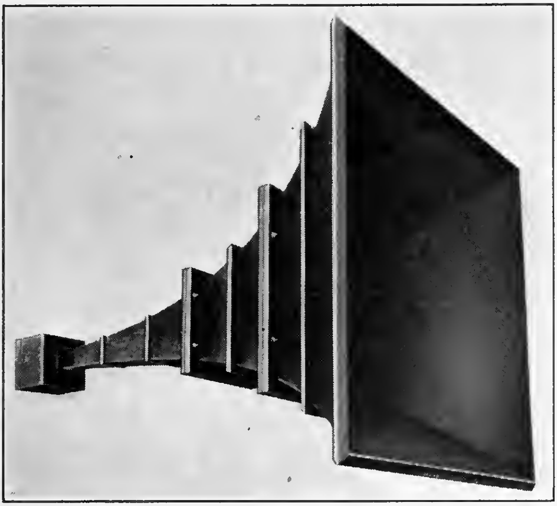


FIG. 2. Stage loud speaker.

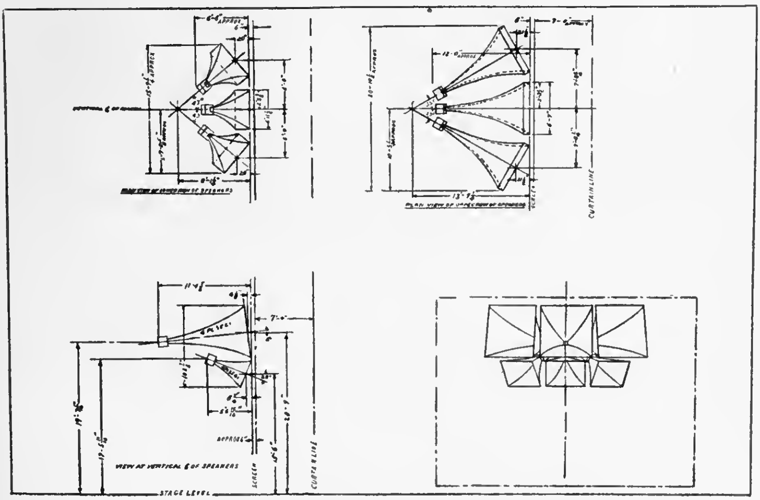


FIG. 3. Layout of stage loud speakers.

speakers are of the large throated, electrodynamic cone type. They have been previously described in the JOURNAL.[1] Fig. 2 is a photograph of one of the large directional baffles and Fig. 3 shows the speaker positions.

These speakers are mounted in metal "cages" and are provided with an electric motor system that folds the three large baffles, removes all the speakers to the "wings" (four to the Opposite Prompt side and two to the Prompt side) and "flies" all speakers in fifty-five seconds. This achievement is due to Peter Clark, Inc.

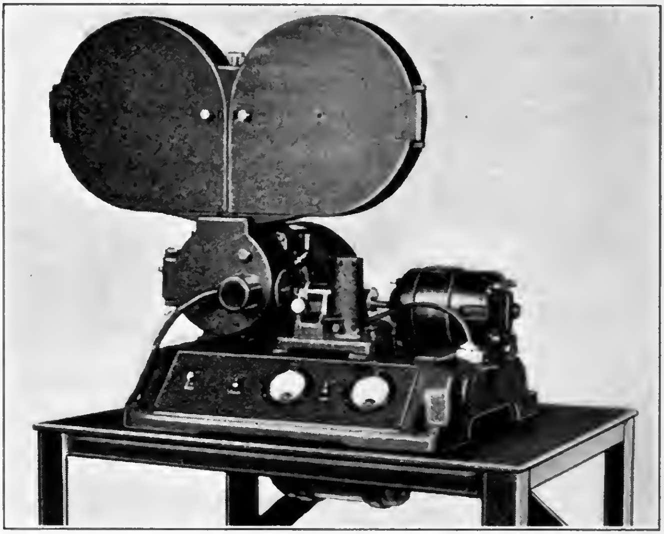


FIG. 4. Film phonograph.

The rear projection equipment, which may be used to create "panoramic" backgrounds or to project regular pictures, is similar to that employed in Translux theaters. For the sound equipment newly developed sound-heads are used and an a-c. operated booster amplifier is provided for transmitting the signal to the main projection room where it may be fed into one of the several systems mentioned.

The film phonograph is a portable table-mounted machine employing the magnetic drive which has been so successful on RCA Photophone film recorders. This assures the reproduction of sound of the highest quality from film, with absolute freedom from speed variations of any kind. This film phonograph is pictured in Fig. 4. Two positions are provided for it, *viz.*, in the rear projection room and the main projection room. Connections are quickly made to wall receptacles.

The preview rooms, together with a broadcasting studio, rehearsal halls, *etc.*, are located two stories above the projection room level. These rooms are equipped with "high fidelity" film reproducing equipment of the latest design, completely a-c. operated, with push-button remote control. One push-button location is in

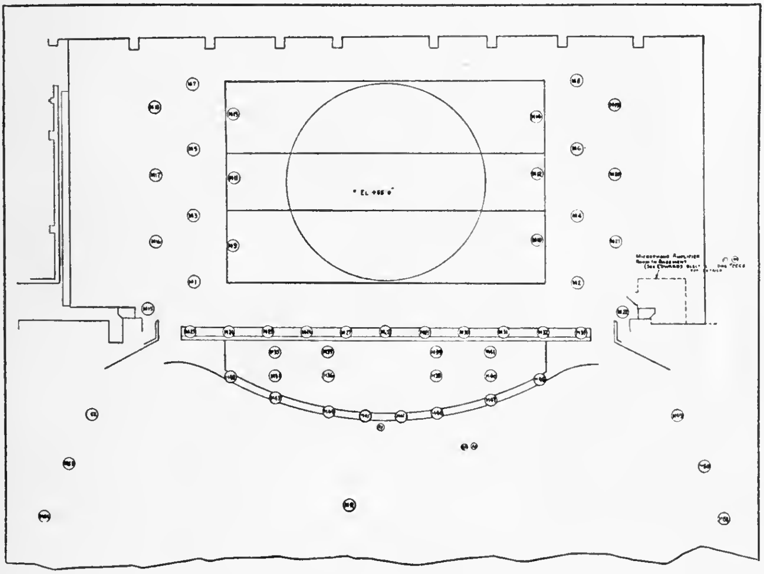


FIG. 5. Microphone positions.

the auditorium, so that the listeners may regulate the volume to their own satisfaction. This is particularly valuable in viewing "rushes" of various types. In engineering this project, these two preview rooms were treated as separate theaters and were so equipped.

The public address and sound reinforcing system utilizes ribbon microphones,[2] a-c. operated 80-watt amplifiers, and a mixer console and remote control panels, both of which are unusually flexible. The system is used, of course, to reinforce sound emanating from the stage or as a public address system that can be used, for instance, by an unseen person making announcements to the audience, and for other similar purposes. Six of the 3-foot directional baffles are used for loud speakers. These are concealed behind lighting grilles above and on either side of the proscenium arch.

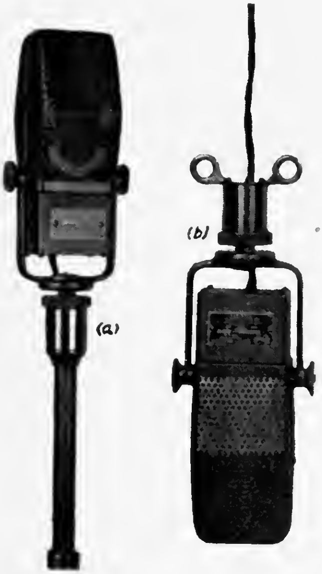


FIG. 6. Ribbon microphones (*a*) stand type; (*b*) hanging type.

There are 54 microphone positions on or above the stage, including those on the choral stairs. The most notable of these, perhaps, are eleven positions built into the disappearing footlights and eight positions in metal boxes whose tops are grilles made flush with the floor of the orchestra elevator. There are eight positions on the light bridges above the stage. Fig. 5 shows all the positions. Fig. 6 shows one of the ribbon microphones.

Fig. 7 is a skeleton diagram of the entire public address system. Many liberties have been taken in making this drawing for the sake of clarity and typical circuits rather than actual connections are shown. Audio circuits are shown as solid lines and power supply circuits as broken lines. Control circuits have been omitted, but some of the functions of the control racks have been marked adjacent to them. No interconnections to other systems are shown.

The output of the microphones is carried on intermediate im-

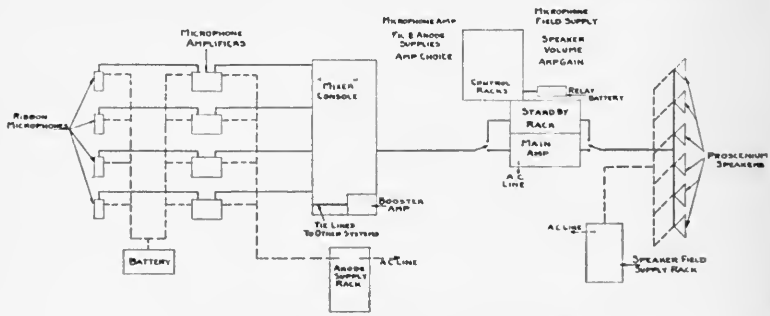


FIG. 7. Schematic diagram of the public address system.

pedance lines to the basement amplifier room where racks of microphone amplifiers with non-microphonic vacuum tubes are located. This type of amplifier is shown in Fig. 8. Filament current for these amplifiers and field current for the ribbon microphones are supplied by a 1000-ampere-hour glass cell storage battery located on the projection room level. This is a double-channel battery installation, one set being charged while the other is in use. Other than a smaller double-channel glass cell battery installation used for relay operation, no other battery power is used in any of the systems.

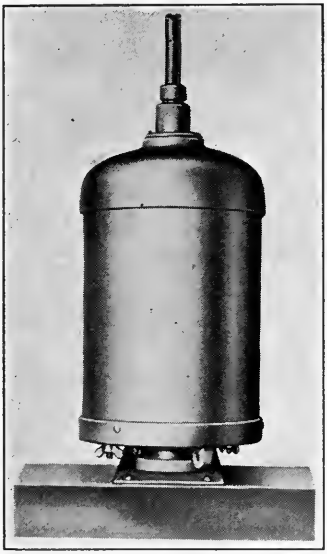


FIG. 8. Microphone amplifier.

The microphone amplifiers derive their plate supply from mercury vapor rectifier tubes in a power supply rack located on the projection room level. These rectifiers are also in a double-channel arrangement. The output of the microphone amplifiers is brought to the "mixer" console where the lines terminate in jacks. All mixer controls terminate in telephone plugs of the switchboard type with flexible drop-cords. In this manner, any microphone position may be connected to any mixer. There are four groups of these mixers, each group colored differently. The output of each group is brought to a correspondingly colored sub-master, which feeds into a single-stage booster amplifier located in the console itself. The amplifier employs a non-microphonic tube. At the output of the booster, the over-all master control is located. A volume indicator of the copper oxide rectifier type is built into the console and may be patched into any point in the circuit.

The console is shown in Fig. 9. It is constructed and placed so that the operator may have an unobstructed view of the stage and a portion of the auditorium proper. At the right may be seen the cords and jacks referred to above, and to the left may be seen a jack panel where tie lines to the other systems terminate.

FIG. 9. Microphone mixer console.

The output of the console is fed to the main amplifier or the standby amplifier, both of which are 80-watt amplifiers similar to those employed in the projection system. The output of this amplifier passes through a control panel, where an individual volume level may be established for each loud speaker, and thence to the loud speakers themselves. This control panel is part of two control racks located adjacent to the mixer console, shown in Fig. 10. Other functions of these control racks are to furnish control of all power-supply circuits by means of relays, selection of amplifier channels both for the main amplifier and for seatphones, selection of projection or public address program for seatphones, *etc.* In addition to this, a monitor loud speaker is provided on these racks fed by a separate amplifier, which may be connected to any of the systems at the operator's discretion. This provides a rapid check on the operation of all systems.

The rehearsal system, electrically, is a duplicate of the public address system but employs three ribbon microphones, located in the private box, the console box, and the twelfth row of the orchestra. The last is built into a portable desk which is used only during rehearsals. In addition to these, one carbon microphone station is built into the stage switchboard for the use of the chief electrician. These microphone outputs pass through a mixer panel located on the control racks mentioned above and thence to another 80-watt amplifier. The output of this amplifier supplies thirty-two 3-ft. directional baffles located at strategic points off-stage, below stage, in spotlight booths, projection room, *etc.* In addition, magnetic speakers of the wall type are used in a few locations, such as in the orchestra pit elevator shaft, choral stairways, *etc.*, where low volume is satisfactory. The level of the speakers is controlled in groups at the control racks.

FIG. 10. Control racks.

Three-foot portable speakers are used also to cover the front portion of the stage when addressing the cast, and are removed and stored together with the twelfth row microphone whenever there is an audience present. This system, which is most useful during rehearsals for talking to actors and stage hands, is almost invaluable for cueing during stage presentations when operated at a low level.

The sound effect system employs an 80-watt amplifier of the type described previously, which in emergencies is used as standby for the public address amplifier. Ordinarily, it is used to amplify sound effects created either by microphone pick-up from backstage, disk or film reproduction. Disk reproduction comes from a battery of four turntables capable of revolving at either $33^1/_3$ or 78 rpm., and allowing the pick-up to be pre-set at any desired point of the record. The pick-up is suspended above the record while the latter revolves. At the desired moment, a button is pressed, the oil-damped pick-up is lowered gently to the record, and the desired "effect" is reproduced without any delay in attaining the required speed or in locating the correct groove. This arrangement allows very precise timing. The

FIG. 11. Public address, effect, rehearsal, and miscellaneous amplifier racks.

outputs of the turntables are controlled at a small mixer table placed near the large mixer console.

The output of the "effect" amplifier supplies two gigantic directional baffles located in a separate room behind the cyclorama at the rear of the stage. Each of these baffles has a mouth opening of $19^1/_2$ by 12 feet, and is 20 feet long. The baffles terminate in four throats, each of which is supplied with sound energy by an electrodynamic cone unit. These loud speakers reproduce frequencies as low as 30 cycles per second.

Each of the four systems described so far is provided with remotely operated volume controls, which can be manipulated by means of push-buttons at the control racks adjacent to the mixer console.

Fig. 11 shows the rack assembly comprising the public address, effect, and rehearsal amplifier channels. In addition to these, a miscellaneous equipment rack is shown, which contains a sensitive

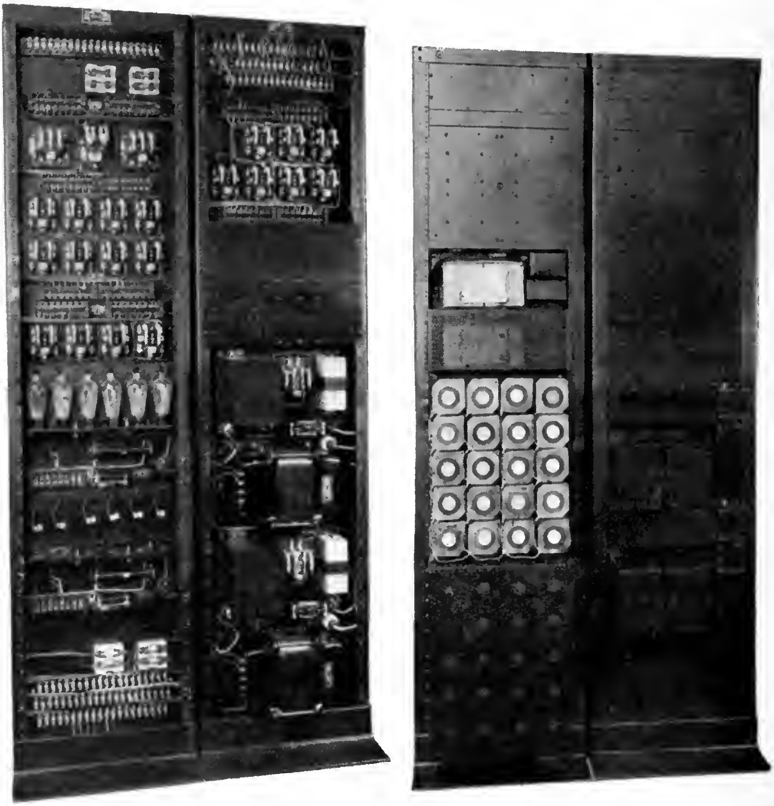
(*a*) (*b*)

FIG. 12. Eighty-watt amplifier and seatphone amplifier with cover plates removed (*a*) front; (*b*) rear.

radio receiver, a turntable, a tube tester, and patching panels. The radio and turntable may be patched into any channel for testing or for any special purpose. Fig. 12 is a front and rear view of one of the eighty-watt amplifier channels with the cover plates removed. Seatphone amplifiers may be seen at the bottom.

Fig. 13(*a*) shows the two power-supply racks with the front covers removed, exposing the mercury vapor rectifiers and the various relays. Fig. 13(*b*) shows the rear of these racks, including the main and standby channels for supplying field current to the loud speakers. These consist of copper oxide rectifiers.

Fig. 14 shows the circuits employed in the voltage amplifiers, Fig. 15 those used in the power amplifier and Fig. 16 shows the



(*a*) (*b*)

FIG. 13. (*a*) Power-supply racks with cover plates removed, front view; (*b*) two guards removed, rear view.

over-all frequency response of the public address system from uniform acoustic input to the microphone to acoustic output in the auditorium from the loud speakers. The characteristics of sound reproduced from film are equally excellent. The variations that do exist have been definitely proved to be room characteristics, and no corrections have been made because the "weighting" of these factors is so often open to question and the actual variations from uniformity are not great.

The stage manager's call system consists of a carbon microphone station, built into the stage switchboard, which feeds a 40-watt

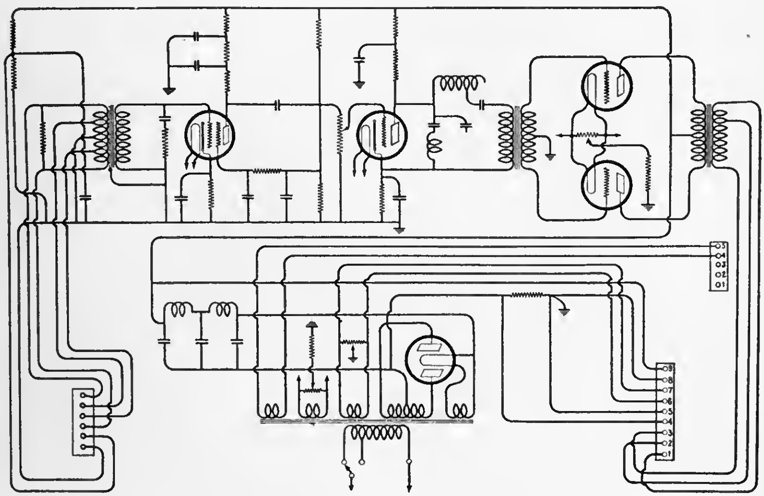


FIG. 14. Voltage amplifier circuit.

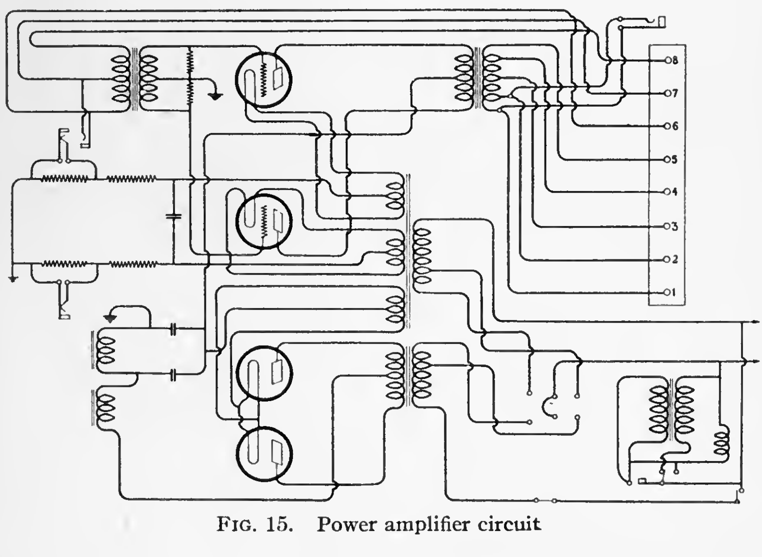


FIG. 15. Power amplifier circuit

amplifier located in the basement amplifier room. This amplifier supplies fifty-three magnetic loud speakers of the wall type located in the various dressing rooms, offices, rehearsal rooms, cafeteria, *etc.* By means of this system, announcements may be made and performers called. When the microphone is not being used, the call system "floats" on the public address system so that persons in any of these rooms are aware of what is happening on the stage.

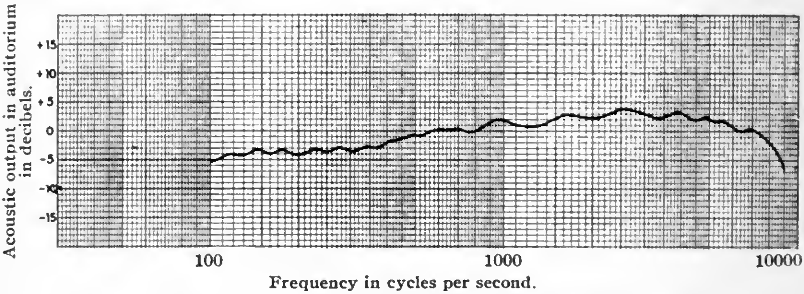


FIG. 16. Over-all frequency response; public address system.

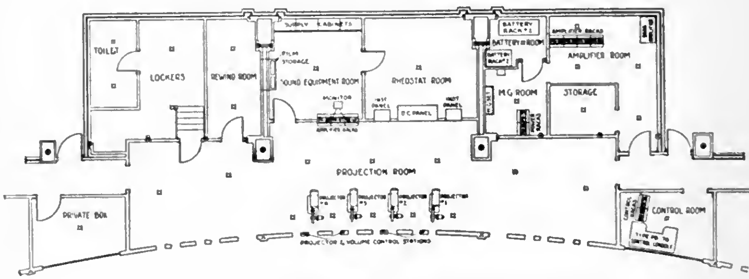


FIG. 17. Plan view; projection room level.

An emergency key is also supplied with the microphone, which enables the operator to connect the call system amplifier into the circuit of the auditorium public address loud speakers for making emergency announcements to the audience.

Lines are provided between all amplifier racks and between racks and the mixer console so that a very flexible and efficient system results. Any amplifier may be used as a standby for any other. Microphone output, "effects," film phonograph, or projector output, may be patched into any of the systems at will; any system may be coupled to the loud speakers normally operated by another system, *etc.* A plan view of the main projection room level, Fig. 17, shows the location of most of the equipment described so far.

The radio-frequency distribution system used to supply carefully shielded broadcast signals to radio receivers consists of a single, almost vertical, antenna wire feeding an a-c. operated radio-frequency amplifier located in a fan room near the roof. This amplifier increases the signal level and lowers the line impedance so that the signal may be fed down a specially constructed, low capacity, shielded cable to the various radio receiving channels in the building. At these points, coupling transformers increase the impedance to a value suitable for the input of a radio receiver. This system allows the use of a single antenna for several receivers and assures a signal free from "noise" pick-up within the building.

The custom built dial radio and monitoring system consists of a basic amplifier and control cabinet, located on the projection room level, controlled by telephone dials located at remote points, such as an executive office and an executive dining room. At these points, loud speakers are built into the walls behind ornamental grilles. At one location, an automatic record-playing mechanism is recessed into the wall. This machine will play a large number of records without requiring any attention after the initial loading of the magazine. If any selection is not liked, dialing a number instantly rejects that record and the machine passes to the next record.

Instant selection of twenty radio stations is assured, and the stage program or sound picture reproduction may also be heard. A high-quality radio receiver is the heart of the system. It is operated by the dial selectors of the same type as those used in automatic telephone exchanges.

One difficulty peculiar to this particular theater which was overcome is worth reviewing. As shown in Fig. 7, the stage consists chiefly of elevators, three of which are rectangular elevators having a rotatable section in the center made up of parts of the three elevators. In addition, there is an orchestra pit elevator.

To connect the microphones to these elevators for public address purposes was a relatively simple problem, which was solved by using "swing" cables beneath the elevators. However, the musicians comprising the orchestra sit in a motor-driven structure known as the "bandwagon." This can travel anywhere from its "garage" located under the first ten or twelve rows of seats to as far back as the rear stage elevator (see Fig. 18). It can be moved below stage out of sight if all the elevators are lowered (this necessitates raising a steel "curtain") or it can be raised and moved across the footlights, which sink into the floor, back to either the first or third elevators, where it can be lowered and returned to the garage out of sight. An alternative, sometimes made use of, is to stop the cycle and reverse it. Maintaining connections to seven microphones on this "bandwagon" was a difficult problem.

The problem was solved by using two cable receptacles on the "bandwagon" connected in multiple. Outlets were provided on the elevators and in the garage. Extension cables were used and whenever the "bandwagon" moves from one position to another,

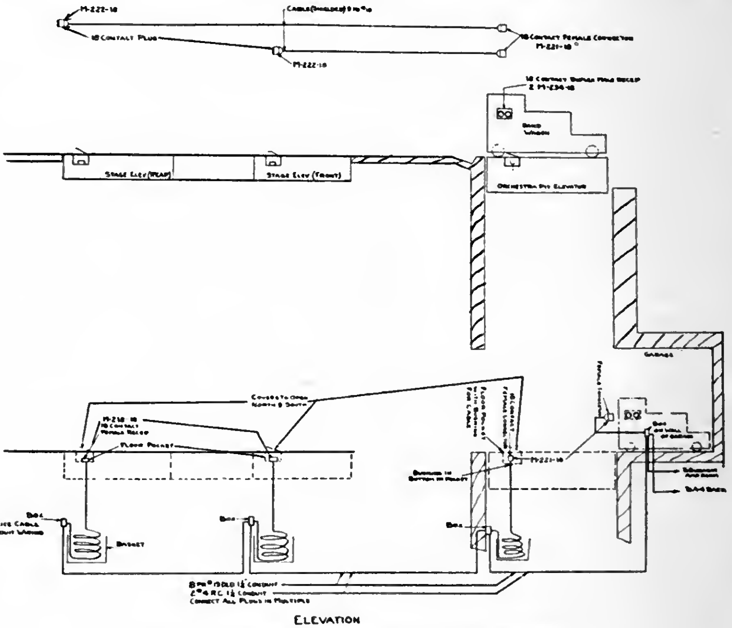


FIG. 18. Stage elevators and "bandwagon."

a second extension cable from the new position is plugged into place while the cable from the first location is still connected. Then the latter cable is removed. This is performed behind the "bandwagon" out of sight of the audience, while the "bandwagon" may be moving. In this way, continuous contact is maintained, and the orchestra may be picked up, amplified, and reproduced for the audience while it is below stage on the elevators moving to a new position.

The author wishes to acknowledge the great amount of help received in installing this equipment from Mr. G. A. Toepperwein of the RCA Victor Engineering Department who completely engineered and planned the project, from Messrs. Cochran and Lehman of the same department, who are responsible for a great deal of the apparatus design, and to Mr. Harry Braun who was responsible for the installation of equipment at the RKO Roxy Theater and who rendered valuable assistance in this installation.

REFERENCES

[1] OLSON, H. F.: "Recent Developments in Theater Loud Speakers of the Directional Baffle Type," *J. Soc. Mot. Pict. Eng.*, **XVIII** (May, 1932), No. 5, p. 571.

[2] OLSON, H. F.: "The Ribbon Microphone," *J. Soc. Mot. Pict. Eng.*, **XVI** (June, 1931), No. 6, p. 695.

DISCUSSION

MR. FRANK: The installation in the Radio City Music Hall cost something in the neighborhood of $75,000, including supervision of the installation, but not the electrical work connected with the installation.

MR. RICHARDSON: That, as I understand it, includes only the projection equipment?

MR. FRANK: Only the sound equipment, not the projectors or arc lamps.

MR. KREUZER: It does, however, include the public address equipment and the reinforcing.

MR. BLIVEN: Is there any correction from the center of the house?

MR. KREUZER: There has been no correction due to the fact that the house is usually dead beyond the center.

MR. BLIVEN: I noticed that if one listens at the center he can hear the voices from the stage as well as from the public address system. Is the microphone set-up responsible for that?

MR. KREUZER: It is possible that the set-up of the next scene behind the stage might have influenced the set acoustics at the time. I have occasionally observed that if the stage is entirely bare and the performance is going on directly in front of the large curtain, there is a rather large volume back stage, and it is possible to get a small amount of vibration from the white tiled walls. I think that could be prevented.

I can not verify your observation from my own experience, but I can say with the sound coming from the actors on the stage, it might well happen. We have made tests, and found that on most locations 100 per cent of the sound comes from the public address system.

DISTORTION IN THE PROJECTION AND VIEWING OF MOTION PICTURES*

CLIFTON TUTTLE**

Summary.—*At the instance of the Projection Screens Committee an investigation of the distortion in motion picture images was initiated. Although insufficient data have been collected to justify generalization, it appears that the distortion that may be tolerated by the average spectator is greater than one might at first suppose. The paper discusses the subject particularly from the viewing and projecting angles.*

The following discussion of distortion in the presentation of motion pictures has been prepared at the suggestion of the Projection Screens Committee. Although various phases of the subject have frequently been brought before the Society, with the result that some definite recommendations have been made, members of the Committee felt that the subject is not entirely closed. It was suggested in particular that an attempt be made to demonstrate the distortion resulting from projection at an angle.

The whole subject of warped perspective and distortion can conveniently be divided into three phases in accordance with three causes which adversely affect true rendition of form on the screen and in the eye of the observer. These are: (1) The discrepancy between camera point of view and audience point of view involving the relative values of camera and projector lens focal lengths. (2) The vertical elongation of figures and the keystone effect resulting from projection from a point above the screen. (3) The error in perspective caused by the off-center view seen by many members of the audience.

The three types of distortion are, of course, additive in their effects, but for the sake of simplicity in this discussion it seems best to treat them singly, leaving to the reader the task of evaluating the combined effect for the set of conditions in which he is particularly interested.

* Presented at the Spring, 1933, Meeting at New York, N. Y.

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

It was pointed out by Hardy and Conant[1] that ideal conditions of viewing appertain to only one point in the theater—namely, a point on the axis of projection, normal to the screen, and at a distance D from the screen such that

$$D = \frac{\text{focal length of camera lens}}{\text{focal length of projector lens}} \times \text{projection distance}$$

At other axial points, either closer to or farther from the screen, the observer sees an image distorted from its true perspective. If the focal length of the projection objective is chosen as recommended by Hardy and Conant to make the point D fall near the center of the audience, the average distortion is reduced to a minimum. This viewing distance defect in motion picture projection is obviously of a nature which can not be overcome, although, fortunately, in practice it does not seriously handicap the illusion for the average person.

Projection at an angle and viewing at an angle also are causes of distortion which can not be eliminated in practical presentation; but since both these are controllable to some extent in the design of theaters, it remains of practical interest to consider these matters and perhaps to specify limiting values for the guidance of architects and theater owners.

PROJECTION ANGLE DISTORTION

The question of projection angle has been frequently discussed before this Society, the most thorough treatment of the problem being that presented by the Projection Committee in 1929. The Committee recommended, first, that the angle be kept as near zero as possible, and then proceeded to analyze the amount of distortion as a function of the angle of divergence of the projected beam and of the angle which the axis of projection makes with the horizontal. They expressed the distortion as the percentage increase in height which results when the picture is projected at an angle to a vertical screen.

To quote from this report: "Now, the maximum permissible amount of distortion is a matter on which there seems to be considerable divergence of opinion. The Committee feels that in recommending 5 per cent as the maximum increase in picture height, it is erring on the side of laxity rather than on that of rigidity." For practical projection conditions a projection angle of 17 degrees results in an increase of image height of about 5 per cent. The Committee therefore fixed on this angle as the limiting value.

Through the kind offices of the chairman and members of the present Projection Screens Committee, the author has been supplied with data concerning the projection angles existing in one chain of theaters. These data show that about 60 per cent of the theaters in this group have projection angles equal to or greater than that recommended by the Committee, and about eighty per cent have an angle greater than the more rigorous specification of 12 degrees recommended in the standards adopted by the Society as the limiting value. Since the theaters of large seating capacity have the larger projection angles, it follows that the vast majority of theater patrons habitually see pictures which are projected at angles greater than 12 degrees. It would seem desirable either to bring the recommendation of the Society into line with practice or to exert pressure to bring future practice into line with our recommendation. Thus, it appears that a continued discussion of the problem is not out of order.

From some points of view it seems indeed that the 5 per cent increase in the ratio of height to width is a lax enough tolerance. Consider for a moment the effect on the human figure. While the pictures of some of our Hollywood actors and actresses might undergo with aesthetic advantage a 5 per cent increase in vertical to horizontal ratio, it hardly seems probable that the result would be highly satisfactory in the majority of cases. The 17-degree projection angle should in its effect be roughly equivalent to the once highly advertised 18-day grapefruit diet. Greta Garbo, Ruby Keeler, Joan Crawford, and others in the light-weight class apparently lose five or six pounds by the treatment.

There is a strong tendency on the part of the general public to accept what it sees on the motion picture screen as the last word in fashion and beauty. Large projection angles may, therefore, be largely responsible for the vogue for slender figures. It may thus be a grave responsibility upon the motion picture engineer in the interests of public health to prevent the motion picture screen from setting up an ideal of dangerous emaciation.

In addition to elongation of figures there is, of course, a second defect in an image projected at an angle which follows from the fact that the bottom of the screen image is magnified more than the top. What should be vertical lines in the image become convergent upward. A rectangular screen shape is maintained by shaping the mask, but nothing is done to rectify the convergence of lines within the picture. It is well known that the eye is extremely sensitive to the lack of parallelism between two lines. Mitchell[2] has recently thoroughly discussed this question for the edification of the cameraman, pointing out several matters which should be observed in scene composition. In some actual cases in theater projection the convergence amounts to five or six degrees, which is very apparent at the edge of the screen.

Fortunately, the attention of the audience is seldom concentrated on vertical lines in a picture. This is more true now than in the days of the silent picture with its numerous titles. It seems, therefore, that experimental demonstration of the practical effect of projection angle should be confined principally to such subjects as make up the greater bulk of motion picture presentation.

In preparing experiments to demonstrate and evaluate the limits of allowable distortion, one is confronted by two diametrically opposed points of view. Either one should seek to determine limits which would prevent the audience from ever seeing an image in which distortion could be recognized, or one should seek to find the limits which in the majority of cases would not allow distortion to destroy the illusion of naturalness.

In view of data which show that many successful theaters have projection angles in excess of the arbitrary limit recommended by the Society, it seems of interest to proceed on the latter basis; that is, to determine the degree of distortion at which the illusion of naturalness breaks down.

A number of still pictures of motion picture scenes were reproduced as lantern slides. These were projected on a screen at vertical angles which gave progressively 2.5, 5, 10, 15, and 20 per cent distortion. The screen picture was photographed at each position and lantern slides were made of the results.

All the groups of slides thus obtained were thoroughly shuffled together so that during projection no one of a series of slides would follow another of the same subject. The slides were then shown to a group of persons, each of whom was asked to select all pictures which looked unnatural and to state the reason for the objection.

Results of this test are summarized in Table I. In column one of this table, the subjects have been classified in a general way. The terms "close-up," "semi-close-ups," and "full-length figures" apply to human figures. Well-known inanimate subjects included pictures of houses, doorways, wagons (showing wheels), *etc.* The remaining columns headed by the value of distortion in per cent contain the record of the relative number of observers who objected.

TABLE I

Summary of Data Showing Susceptibility of an Average Audience to Different Degrees of Distortion

Subject	Relative number of observers who objected: in per cent of total number of observers					
	Per Cent Distortion					
	0	2.5	5	10	15	20
Close-ups	0	0	0	0	0	20%
Semi-close-ups	0	0	0	0	5%	25%
Full-length figures	0	0	0	0	15%	50%
Well-known inanimate subjects	0	0	0	10%	40%	50%

Individuals participating in the test were not informed of its object and they probably were neither less nor more critical than members of the usual motion picture audience.

The conclusion from these data is that for scenes in which actors or actresses form the principal interest, the image can be distorted 10 per cent before the illusion of naturalness is impaired. Stated in another way, this means that most persons unacquainted with what the real subject looks like are satisfied even though the picture is decidedly distorted. In the case of very familiar objects of definite shape as, for instance, a picture in which there was an axial view of a wagon wheel, the tolerance is somewhat narrower—some persons objecting when the image is distorted as much as 10 per cent.

DEFINITION AND AREA LOSSES

This discussion thus far has been limited to true image distortion. There are two other undesirable effects, however, which accompany projection at an angle. The first is the loss of image area which follows inevitably when the sides of the picture aperture are cut to make the frame rectangular. The second is the effect upon top and bottom image definition because of the path difference. Though neither of these can properly be classified as distortion, an evaluation of both has been included in Table II.* The third column shows

* Formulas sufficiently accurate for the calculation of these effects within a few per cent for projection angle, θ, are as follows:

Distortion (per cent) increase of picture height = Secant $\theta - 1.0$. Image size, approximately the area loss in per cent which results when a picture is projected with a 6-inch lens to a rectangular vertical screen, and the fourth column shows the diameter of the circle of confusion, or, more accurately, the major axis of the ellipse of confusion at the bottom and top of the field for a perfect lens working at an aperture of $f/2$.

TABLE II

Effect of Projection Angle upon Screen Definition and Loss of Area with Rectangular Masking

Projection Angle (degrees)	Per Cent Distortion	Area Loss, Per Cent	Image Size Bottom and Top of Screen, Mm.
0	0	0	–
12.5	2.5	2	0.9
17.5	5.0	3	1.3
21.5	7.5	4	1.7
24.5	10.0	5	2.0
27.0	12.5	5	2.2
29.5	15.0	6	2.6

The area loss, that is, the amount which must be masked from the lower corners of the picture, is not particularly serious at any commonly used combination of projection distance and focal length—provided that the elongated picture is not masked off to maintain the 3×4 picture.

The lack of definition as judged from a viewing distance of twenty feet becomes noticeable if the image size exceeds about 1.5 mm. Since the image size resulting from the projection angle is superposed upon the effect of the lens aberrations, it is probably reasonable to state that with practical projection lenses of $f/2$ aperture definition suffers noticeably at projection angles greater than 17 degrees.

SIDE VIEWING ANGLE DISTORTION

The second matter upon which some experimental data may prove of advantage concerns the viewing angle forced upon all the

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top and bottom of screen, for perfect focus at center $= \dfrac{H \tan \theta \sec \theta}{2\, f/\text{number of projection lens}}$

$$\text{Area loss (per cent)} = 100 - 100\,\frac{F - \tan\theta\, H/2}{F + \tan\theta\, H/2}$$

In these expressions H is the film frame height, and F is the focal length of the lens. Mitchell (*loc. cit.*) gives a method for determining the value of the area loss which is accurate over a greater range of projection conditions.

members of a motion picture audience except those located opposite the screen center. At first thought, this problem appears to be closely related to the former one. Both projection at an angle from the horizontal and viewing at an angle other than the normal produce a similar kind of elongation of the screen image, and one might expect that a distortion tolerance set up for the one case might apply to the other. The conditions, however, are somewhat different; a person viewing the screen from an angle is conscious of his point of view, and instinctively makes a correction for some distortion of the image. He is not conscious of the projection angle, and therefore has no means of compensation which will aid him in rectifying his concept of the picture.

It is common experience that motion pictures viewed from extreme front and side seats in some theaters appear badly distorted. At the same time, it is true that one's enjoyment is not adversely affected until the angle becomes fairly large. The author has attempted to determine the limiting angle experimentally by projecting before a group of persons motion pictures of a screen image photographed at different angles.

There seems to be quite good agreement among the persons before whom these and other pictures of the same kind were shown that any angle less than thirty degrees is not objectionable. Forty degrees seems to be passable, but the opinion was unanimous that the illusion is spoiled at angles greater than 40 degrees.

One can not say that these demonstrations adhere closely enough to theater conditions to justify any general conclusions. One is quite justified in questioning: How much does motion in the picture affect the feeling that the illusion has failed? And how much does the angular field of view change one's judgment?

A few trials were made in which a large black border was shown around the rotated picture. This, it was thought, would supply a comparison reference as to the amount of foreshortening to be expected in the picture. The judgment of distortion did not seem to be much changed. Pictures filling the screen appear better to represent the view which a member of the audience has in a seat close to the screen—the only location in which the viewing angle problem is serious. On the basis of a number of observations in theaters during the projection of pictures, it appears that motion in the picture does not affect the result to any great extent.

A seat which forces one to see any part of the picture at an angle greater than 40 degrees is undesirable. For full-length figures the judgment is more critical.

The larger the screen, of course, the worse is the distortion at the farthest edge at a given viewing distance. In recommending practice for the guidance of designers and architects, the specification for the position of the extreme seat should be based upon the angle at which this edge can be seen. Assuming that the distance from the first row of seats to the screen is equal to 1.5 times the screen width, the first row of seats should be not longer than 1.5 times the screen width if the extreme viewing angle for the edge is not to exceed 40 degrees. Data supplied to the author by the chairman of the Projection Screens Committee give the average maximum viewing angle of a number of theaters at 34 degrees at the screen center—an angle which makes the extreme edge viewing angle somewhat in excess of the distortion limit.

DISTORTION REMEDIES

Many attempts have been made in the past to cure the evil of viewing angle distortion—usually by the use of curved screens. Anamorphotic lens systems also have been suggested. The fallacy of such suggestions has been pointed out so frequently that apparently no proposal of this kind has been made for several years. There is, of course, no remedy except proper design of the seating space. Any correction of the screen image for one position can be made only at the expense of the perspective from other positions.

Correction of projection angle distortion is not so impossible theoretically. Partial compensation can be effected by tilting the screen. This means probably presents some mechanical difficulties since it is not commonly used. Other partial remedies are at least theoretically possible.

CONCLUSION

This subject was proposed to the author only a short time ago, and it has not had the consideration which its importance warrants. The principal purpose which this paper can serve is to stimulate the gathering of further experimental data on the whole subject.

Whether distortion limits should be based upon the ideals of truth or upon the ideals of showmanship is the most difficult question to decide. Putting the results of the experimental data in the classic form ascribed to Barnum, most of the people most of the time are totally fooled, up to a projection angle distortion of 10 per cent. All of the people all of the time are dissatisfied with a seat which forces them to see part of the screen at an angle greater than 40 degrees.

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DISCUSSION

MR. SCHLANGER: To evaluate image distortion, it is necessary to consider the cumulative effect of its various causes. There are three distinct stages by which an image or object may appear distorted to the spectator of the motion picture.

The first occurs in photographing, and should be referred to as foreshortening, rather than distortion. In this case, the foreshortened view of an image as obtained by the camera, is an intentional and purposeful one. The cinematographer chooses to tell his story more effectively by a combination of full, unforeshortened and foreshortened views of the objects and images being photographed. Therefore, for best results, the images intended to be unforeshortened or undistorted must remain so to the spectator; and images intentionally foreshortened must not appear any more distorted to the spectator than the cinematographer originally intended.

Distortion in the second and third stages is the distortion due, first, to the projection angle and, second, to the viewing angle in the theater. These two forms of distortion destroy not only definition and beauty, but also, what is more important, the effectiveness of the important foreshortened views, or discords, that are supposed to contrast vividly with the completely unforeshortened or undistorted image. If all objects and images appear somewhat distorted to the spectator, the effect of the value of the well-placed discords is completely lost. The excessive projection angles and poor viewing positions in relation to the position of the screen in motion picture theaters are serious causes of such distortion.

MR. BLIVEN: How many architects, as a whole, take sufficient interest in the work of picture projection, to familiarize themselves with sight lines and other matters to get good viewing angles?

MR. CRABTREE: I think that many architects are very anxious for knowledge. Mr. L. A. Jones and I were appointed by President Goldsmith as a committee to discuss, with a committee of the Institute of Architects, this very problem of educating the architects with regard to fundamentals of theater engineering from the motion picture standpoint. The result was that the Institute proposed that our Society should invite one of our members to prepare a paper on the subject and to present it at one of our meetings, so that it could be discussed and officially authorized by our Society. They promised that they would then re-present the paper at one of their meetings, and see that it was subsequently published in the architectural magazines. All that we have to do now is to get the paper.

MR. JONES: I have always agreed that distortion is a very serious matter. However, in order to go to an architect or to an exhibitor, or to any one else, and ask him to change his mode, we need some evidence to show that the present method is wrong and should be changed.

From the study that Mr. Tuttle has made it does not appear that the geometrical distortion is as objectionable to the observer as might be expected from the computations previously made. He has collected considerable data from a large number of observers, and in many cases those observers were entirely unaware of the presence of this geometrical distortion in the picture. If the observer is unaware of this distortion, and if it does not detract from the enjoyment or appreciation of the picture, it certainly is unfair to say it is very objectionable.

It is probable that more voluminous data must be collected before a final conclusion can be drawn; but certainly if we wish to criticize the quality of projection when large projection angles are used, we should have some tangible evidence that such a practice actually produces a picture of inferior quality; and by that I mean a quality which interferes with the enjoyment of the picture by the audience.

Mr. Tuttle has shown one very definite objectionable characteristic of a picture projected at a large projection angle. I refer to the loss of definition which is unavoidable when the projection angle exceeds 17 degrees. It is quite impossible to obtain good definition from the top to the bottom of the screen if the projection angle exceeds 17 degrees. That undoubtedly interferes with the perception of detail in certain parts of the picture and is a strong argument against large projection angles.

MR. RICHARDSON: What Mr. Jones says is quite correct. Still, at the same time, it seems rather far fetched for any one to assume that a thing that is distorted in three different ways can be as beautiful as a thing that is undistorted.

MR. SCHLANGER: Mr. Jones seems to imply that we have nothing substantial with which to go to the exhibitor or the architect, to inform him that he is not exhibiting motion pictures under the best conditions. Sufficient data may not as yet have been properly organized, but there should be no doubt about there being sufficient reason for improvement in the exhibition of the motion picture. The pictures that we saw today present only one phase of distortion.

As to the lack of complaint concerning the distortion, it is almost impossible to find out how much the public will stand. But it is almost certain that the public usually prefers the better and more beautiful effect when the difference is made evident. Some mention was made that some spectators found that distortion of the image due to projection or viewing conditions is sometimes flattering to the image. All the flattering and good effects of cinematography must be achieved in the production of the master film, and not be subject to the peculiarities of varying theater structures.

MR. TUTTLE: In doing this work I have attempted to find out how much distortion people will tolerate without objecting. I have been surprised to discover that not only are people uncritical of distortion, but that in some instances they actually like it and believe that some faces are more pleasing to look at when they are distorted. It is my opinion that the limits which the Society has attempted to set are a little stringent. That may be one of the reasons why the recommendations of the Society have not been followed. If we are recommending the abolition of something that doesn't turn people away from box-offices, it is questionable whether we should make the recommendation or not.

MR. JONES: I have taken, perhaps, an extreme position, one that was intended to emphasize what we have to contend with. I believe firmly with Mr. Richardson that we should have a minimum of distortion, but we must try to evaluate the distortion quantitatively, if we can, and find out just how much disagreeable effect the several factors produce.

MR. RICHARDSON: There is only one way to compare the beauty of two objects, and that is to observe them side by side. I am sure that if you had projected the distorted picture on one side of the screen and the same picture undistorted on the other side, the difference would have been painfully obvious.

MR. CRABTREE: I am inclined to agree with Mr. Richardson, because there is a certain analogy in color photography. Suppose we photograph a subject by a two-color process. The result is fairly pleasing. But if we compare it with the subject photographed by a three-color process we are much less satisfied with the two-color result.

Mr. Jones asks, is the annoyance sufficient to keep people away from the theater? Personally, I don't think that it is. I don't think that this single matter is very vital, but the integration of many such matters is important in the design of theaters.

MR. RICHARDSON: If a theater patron finds a picture of real beauty on the screen, is it not reasonable to suppose he will attend the theater more often than he would were the picture less beautiful?

MR. CRABTREE: The fact is that most of us don't know how tall or how thin the actors are in real life. As long as they look sufficiently thin and well proportioned on the screen, that is satisfactory.

MEMBER: Many of these factors are subjective, and can not be evaluated easily. I have yet to hear any one say that he went to one theater or another because of better projection. However, it must be granted that a patron may attend a theater as a matter of habit without knowing that he does so because the projection is better.

MR. CRABTREE: When I have to sit in a side front row in a theater I certainly make a rush for a center seat as soon as possible, because there is no question that the beauty of the feminine face, at any rate, is greatly enhanced when viewed from a position perpendicular to the screen. It may be that I am a little fussier than some of the observers of Mr. Tuttle's pictures.

MR. TUTTLE: I do find that the extreme side viewing angles are very detrimental, but I have yet to find anybody who complains about the projection angle.

The fact that 75 per cent of the people who go to motion picture theaters today are seeing projection at an angle which causes a distortion of about 10 per cent, might be taken as an argument against the claim that the box-office receipts would be greater if the present recommendations of the Society were followed.

VOICE AND PERSONALITY IN THE MOTION PICTURES*

IVAH L. BRADLEY**

Summary.—*The stylizing of many motion picture stars and the suppressing of their natural selves has reduced them to mere "fashion comers" and robbed them of their continued popular appeal. We have forgotten that a sincere emotional release is more important. Instead of this training in conventionalized deportment the artist needs instruction in coördinating the various bodily functions rhythmically for vocal production—and release of personality, for a close relation exists between physical obstructions to the free vocal production and psychological obstructions to the release of the personality. The motion picture engineer and the director would find it vastly to their advantage to know more of both the mechanics and psychology of vocal production.*

In the days of the silent motion pictures it seemed to us that the personalities of the actors were more vivid. The acting was perhaps not so smooth, but the actors conveyed to us more of themselves. They *had* to, for they had only the visible expressions of face and body with which to appeal to our eyes and emotions. We received the impression and remembered it. In some respects Charlie Chaplin is wise: you do not forget him; you always see him in front of you, and can recall his image immediately. If you stop to think of it, you will find you can still easily recall certain personalities of the silent films. They could not then rely upon the sound effects which are today so important; they had to make an effort to convey themselves clearly and completely by visual means alone. The majority of my friends seem about equally divided on the subject, but feel that while pictures today have attained a greater dramatic value, the personalities were more vivid in the silent films.

The cacophony that came from the screen between the days of the silent film and those when sound effects became tolerable so lacerated our nerves and taxed our endurance that in our relief we have perhaps forgotten how we felt about the silent film. Then came this immediate and imperative need to charm the ears as well as the eyes of the public. Let us admit at once that the motion

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** New York, N. Y.

picture industry has met this need more quickly, in a more progressive and, let us hope, more scientific manner, than any other group having a vital interest in the field of vocal education. However, in attempting to change so quickly their concept of the movie actor's voice, the motion picture industry has lost sight of the most important element for enhancing the beauty of vocal tone.

It is certain that the public, and perhaps the motion picture producer, is aware that some subtle essence is slipping from some of the artists that no one yet seems to have been able to discover, for very many movie stars gradually slip down the same decline. One actor after another enters Hollywood a vital human being, only to become in a year or two a frozen creature who knows how to slither across the floor as the world's most perfect mannikin, carrying her clothes perfectly, setting the fashions, displaying emotion in artificial, cold movements, speaking with an artificial, cold voice—they are all alike, the same mannerisms, the same manner of speech, the same kisses. The public is so tired of it, and I should think that the engineers who have to look at it every day, year in and year out, would explode in righteous wrath.

To begin with, it is criminal to suppress the natural release of genuine human emotion and to cover it with a meaningless artificiality. Have you forgotten that real, sincere emotion is so much more beautiful? Ruth Chatterton used to thrill us, and we rushed to see her; now she is little more than her clothes. "She has lost something," the people say. Norma Shearer is undeniably lovely, especially in *Smilin' Through;* but she is always the same, and makes one feel that she is so conscious that every move is beautiful, that she works day and night, constantly, to improve the perfection of her every line and gesture. She is a perfect example of superficial beauty; nothing is ever disturbed, not even a hair. Her facial expressions, even when she is supposed to be deeply moved, are always calculated not to disturb her external shell of beauty. Perhaps she works in a room lined with mirrors; but so did Isadora Duncan, and she still retained her positive, creative vitality.

Now let us turn to Katherine Hepburn—a vital creature, certainly. In *A Bill of Divorcement* she was strong, dramatic, magnificent raw material. I ask you, what are you going to do with her? Even in her second picture she has already lost some of her spontaneity. She has apparently two personalities: one masculine, with angular movements and a hard masculine voice; the other feminine, with a truly beautiful emotional feminine voice. The masculine expression is a self-developed protection for her emotional sensibilities. I believe that if we could have an intimate talk with her we should find the roots of that protection in some bitter hurt to her soul in childhood, or in some childish desire to emulate the masculine virility of her brother. To try to eliminate the hard exterior by developing an artificial feminine svelteness will not solve the problem. Her real personality is expressed by the rich, emotional feminine voice that she uses only a few times in the picture.

I have been told that without a doubt the producers realize that they have made a mistake in so quickly elevating her to stardom, and that now she is making another father-and-daughter picture with John Barrymore! I presume she will have to make father-and-daughter pictures for the rest of her life! And the *New Movie* magazine has already labelled her "The Fashion Comer." Could anything reflect so dismally on the motion picture industry than that it should have degraded the finest material it has had in years to the level of a "fashion comer?"

In Katherine Hepburn the motion picture industry has the opportunity to develop an actress on a new basis. Instead of toning her down, it should be the privilege of the producers to help her to become aware of those two distinct expressions of herself, explain why they exist, and help her to realize the fine emotional value of her real self and show her how she might bring to greater fruition this undeveloped essence of her personality. She stands at the crossroads, a strong, individual character; and if the cinema finally succeeds in training her, and forcing her into just an empty shell of herself, they will have killed a soul and impoverished themselves and the public.

Clara Bow is another example of an emotional actress being forced into an artificial mold. In *Call Her Savage* there was a disturbing mixture of rather unconvincing rough behavior, artificial deportment, and beautiful, deep, sincere emotion. I came away from the theater somewhat saddened, saying to myself, "If they'd *only* leave that girl alone!" You may smile, but my mind at once went back to Eleanora Duse, remembering her perfect balance of rhythmic silence, movement, and emotion; and there were moments in *Call Her Savage* when Clara Bow also had that. Her voice is not pleasant, but she has all the material for a very emotional voice. I found that I liked the fundamental Clara Bow, that she was fine and womanly, and at heart a true actress. But will the movie producers insist on this artificial stylization, or help her develop this very rare rhythmic instinct of hers?

Now the motion picture industry seems not to have succeeded in killing the soul of Greta Garbo—she fought to keep it. And in trying to make 250 imitations of her the movie people forgot that it takes something more than a Garbo *exterior* to make another Greta Garbo. She is what she is because she has kept her fundamental being inviolable.

Then we have those remarkably open and frank personalities: Ida May Oliver—beautiful technic, and yet a human being; Mae West, the true vampire—I never have been able to understand why producers consider cold, artificial creatures vampires; Helen Hayes—exquisite personality and fine technic; Billie Burke—a most gracious lady in *Christopher Strong;* Leslie Howard—supreme in *every* way. And just look at what Gary Cooper is doing: he spoke so completely from the depths of himself in *Farewell to Arms* that we almost forgot it was a screen production. You will notice that all these actors and actresses have a voice in keeping with and expressive of their personalities. They may change it to suit different characters, but they themselves have attained a great degree of integration of their being. They are artists sufficiently strong in themselves to resist an external artificial stylization; but others are weaker, and are swamped by this peculiar style of deportment training and direction.

Professor Overstreet has pointed out that "the artist is first of all a human being, and the quality of his art must be related to the quality of his personality. Such a point of view saves the artist from being a creature of pretty tricks and accords to him the high dignity of being a revealer of life." So the problem of the actor is not only to learn a physiological technic, but to develop and organize that subjective power that is the heart and core of the artist's being. To keep alive this center of one's self, to expand his spiritual understanding, should be the primary study of the artist. It is the substitution of mechanical technic, or of "pretty tricks," that has brought artists of all kinds to the present state of emotional inarticulation.

Let me insert here a criticism of the last recital of John Charles Thomas that appeared in the New York *Times:* "Yet despite all this (*i. e.*, the beauty of his voice), one sometimes felt a curious lack of penetration into the inner significance of the lieder. The voice, for all its extraordinary beauty, seemed to traverse the surfaces of the music rather than translate into sound its more searching significance." Anyone who understands the relation of posture to voice would expect nothing more than just that, from the very manner in which John Charles Thomas struts across the stage. It is one more demonstration of the mechanical cultivation of a magnificent voice without a simultaneous integration with the inner personality.

This brings us to the relation of bodily technic to artistic expression, a relation that is highly important, for only through a rhythmic coördination of physical and mental energies can one attain a harmonious integration of one's being.

Let us return to Katherine Hepburn and her dual personality: her masculine phase finds its physical expression in a depressed forward larynx, a slightly protruding jaw, and a rigidity of breastbone, sides of the neck, and roof of the mouth. All this results in a hard, clipped, dry masculine voice. When she becomes emotionally feminine she releases all these contractions and permits the breath to flow freely into the head so as to produce rich overtones. The prevailing speech training does not change such conditions; it devotes itself only to phonetics, which enable the actor to speak clearly, with the proper enunciation, but allows him to retain his peculiar vocal defects.

And again, take Carole Lombard. Several months ago, when this paper was first written, she was accustomed, when speaking, to throw her jaw forward so far as to be ugly; her larynx was pressed so far forward, the fauces and palate pulled down so hard, the back of the tongue so thick and low in the throat, her neck so distended, as to be a serious menace to her appearance. Miss Lombard, however, is a fine example of how we can change. Last week I thought I had better go to see her again and check up on her. Imagine my surprise to find that the lady had corrected her former faults to a very great extent, with the result that the voice was no longer so husky, but clearer and more expressive of herself. People imagine that a protruding jaw is something they were born with, and that it can not be changed. That is incorrect—it *can* be changed, but in her case, as in most others, it was a habit of speech; and when the jaw is brought back into the proper position the pressure on the tongue and larynx is released and they fall into a position for flexibility and consequent melody and beauty in the voice.

The vigor and power come into the voice from the floor of the pelvis, which generates an internal rhythmic flow of breath for the production of tone. In the motion picture industry this is understood fairly well, because everyone keeps himself in such excellent physical condition, which is naturally conducive to vocal power, but it is made use of only in a very shallow manner. For in the majority of actors the breath-power never penetrates to the head cavities, where the overtones and real richness of voice are produced. It is dammed back by the rigid palate and fauces, which choke the personality as well as the flow of breath. We might well think of a securely corked champagne bottle, with all its bubbling effervescence unable to find release for the stoppage in the neck. So it should be clear that the physical coördination of all the parts of the body for the production of rich, sincere emotion and beauty in the voice is the physical correlate of the psychological coördination required for the release of the personality. The finished artist is the unity of these two.

The motion picture industry may feel that this coördination of the physical, mental, and emotional phases of the actor's being toward a unified expression of his personality is not their job. Perhaps not; nevertheless they *did* undertake the responsibility of repressing and eliminating the vital personality from their young actors by forcing them into one uniform, standardized mold and pattern of behavior. Now let them turn about and *lead* in the development of the integrated personality of their rising artists.

I know that it has been publicly stated that it no longer makes any difference how an actor uses his voice, because the engineers have developed apparatus that enables them to mix vocal qualities in any manner that is thought necessary in order to achieve what are considered to be good vocal effects. Mr. Evans of Warner Brothers generously undertook to educate me in this, and I should like to explain to you what that machine does from my point of view.

To most of us the fundamentals of the voice mean the cloudy, buzzy quality produced by most persons, who enunciate by pressing the tongue down on the larynx. The apparatus of the engineer clarifies the voice of that buzz, bringing the enunciation, as it were, up into the mouth, resulting in clear, distinct enunciation but making the voice what I should call white and metallic. When I use the term overtones, I mean the quality produced by the whirling currents of air above the palate. Scientific equipment can not yet produce those overtones; it can *re*produce overtones, where the breath is allowed to flow through into the head cavities, but it does not yet *add* vocal color to a white voice.

Last spring I was talking to a well known engineer; all his comparative vowel calculations were based on a very dark *ah*-color—almost *aw*—the entire pronunciation was very low. I asked him what would happen if I said *ah*. "Oh, you've changed the pitch," he said. Since then I have talked with others. They all used the same *aw* sound to demonstrate vibrations. Of each I asked the same question, and received the same reply. I said nothing, because none of them seemed to realize that I had changed, not the pitch, but the vowel color and the tone color; but finally I got the courage to say to one of them that I didn't think they quite understood those things. He asked at once, "What difference would that make?" I replied that I didn't quite know, but I thought it would certainly change the calculations; for there is no such thing as a pure vowel: they are all *combinations* of other vowels, which make the vowel sound rich and musical. *Ah* is a combination of *a*, *e*, and the upper dome *o*, and all other vowels have an *ah*-color under them. Can a machine be developed that will be capable of so many colors and emotional overtones—or do we have to depend on the human being after all?

I have felt lately that if engineers and producers knew more about the subtleties of vowel color and tone color, they would know better how to secure from the artist what they want. As an illustration of this I might mention the extraordinary production by Maurice Schwartz of *Yoshe Kalb*. There must have been some sixty persons in the cast, all having the most gorgeous voices, each voice completely expressive of the character. I was overwhelmed by the vocal and rhythmic beauty of that production. I know nothing about Maurice Schwartz, but he convinced me that he knows the voice, because he drew from his players the most extraordinary variety of vocal coloring I have ever heard in a theatrical production. It was a veritable symphony, and artistically most satisfying. What a difference it would make if more directors, in the movies as well as in the theater, were as sensitive to voices and to all that goes into vocal expression. If the director were to have such a thorough knowledge, not only of the mechanics but of the psychology of vocal production, he would find it so much easier to mold his artists into the precise shade of characterization he has conceived in his imagination. He knows what kind of character he wants—he should also know the psychology of that character on the voice. He should then be able to work back and tell the actor precisely how to liberate his vocal organs and his emotional self so as to produce the desired voice and character. For just as in life the voice is the expression of the inner personality, so in the theater and the movies is the voice the expression of an inner understanding of the character.

The motion picture industry is the largest, most widely organized, and most progressive in the entertainment world. How magnificently it could lead in demonstrating to millions the value of the unified expression of the body, voice, and personality. I feel that some day education will *begin* with the voice—not dry phonetics or enunciation, but the *voice* as our most vital and beautiful expression. As Professor Overstreet has remarked, "If this psychological approach is widely followed, it will make a profound change in the teaching of art, and consequently in the nature of our artists."

DISCUSSION

MR. EVANS: I should like to explain what I attempted to show Mrs. Bradley when she visited our studio. I reproduced a dialog sound track, first at about normal level, and then some 15 or 20 db. higher, so that the loud speaker fairly shouted. In describing the effect, Mrs. Bradley and I apparently disagreed on what had happened. We soon discovered, however, that the disagreement was one of terminology and that actually we had observed the same effects.

I then equalized the higher level, reducing the level of the low frequencies and the high frequencies, leaving the level of the middle frequencies undisturbed, thereby attempting to show that at the higher sound level the quality more nearly approximated the quality at the lower level than before equalization. In other words, I merely attempted to demonstrate Dr. Fletcher's curves dealing with the effect of loudness on the hearing at different frequencies.

I believe that it would be possible to do electrically what Mrs. Bradley wants to do with the cavities of the head, if all speech were of the same fundamental frequency. It would then be possible to make by electrical equalization the same changes in the relative balance of overtones that can be made by cavity resonance in the head—simply by emphasizing certain overtones. But when the fundamental frequency of speech constantly changes it is impossible to do that, because the equalizers would be constantly affecting different overtones. Due to the nature of speech, the only way to accomplish the results for which Mrs. Bradley is looking is to train the person who is speaking to bring out the overtones that improve the pleasantness of the voice.

MR. FARNHAM: From this paper I take a wider meaning than has been expressed so far. In general the criticism has been that our American movie actors do not know how to use their voices. We have seen and heard pictures this week, in some of which the cast was foreign and in others of which the actors were American. In my opinion, the English actors in general demonstrated that they know better how to use their voices than do our American actors.

MRS. BRADLEY: Yes. Their general manner of speaking is very much higher than ours, and when we try to imitate what we believe they do, we become overly English. The English do not speak that way; but we imagine it is that way, and try to imitate them. The English really speak very much in the mouth. They do not speak with depressed larynx and distended throat.

MR. EDWARDS: Might I ask Mrs. Bradley whether the quality of the tone of the American voice does not depend somewhat on climatic conditions?

MRS. BRADLEY: I think we hide behind that beautiful excuse very much too much. I have not found it to be so.

MR. EDWARDS: While traveling through Wales and England, I was struck very much by the quality of the voice—entirely different from what we hear in this country. I am sure that the environment has a great deal more to do with it than is generally credited.

MRS. BRADLEY: Yes. But that includes our psychological environment and the influence of others on us; it is not simply climate, it is social structure.

MR. EDWARDS: Social structure may vary a great deal. Individuals who come from a poor social district display the environmental influence in their manner of using the voice. But I am thinking of actors. Welsh singers, for example, have much richer tones and enunciate much better than actors in this country; I mean taking them as a whole.

MRS. BRADLEY: Yes, I think you are quite right.

MR. EDWARDS: I personally attribute the difference in the voice more to climatic conditions than anything else.

MR. SHEA: To express what I believe Mr. Edwards has in mind, I should like to ask whether you have any idea as to the reason for the Scotch burr or the so-called London accent, or the Irish brogue. How do such things come about, and what have they to do with good voice production?

MRS. BRADLEY: The action of the back of the tongue is the most important thing in vocal production other than the general vigor of the body; all those people use the back of the tongue much more than we do. Our actions are extremely sluggish, and there is something about our present form of diction, the American form of diction, in which the chin is used and the back of the tongue is kept low, causing a peculiar kind of accent. It is the back of the tongue that is important, and you will find that it is used in varying degrees. The flexibility of the larynx, also, is related to the position of the back of the tongue.

MR. SHEA: It is simply a device that has come into use through long experience.

MRS. BRADLEY: — and association. I did not mention the ear, although I think the training of the ear is most important of all. We do not hear ourselves speak—we hear only an internal head resonance, which is completely different from the tone color that the listener hears. We believe that the voice sounds the same to him as it does to us. If this were true the cultivation of the voice would be very simple. Not until we shall have learned to hear our own voices shall we have any understanding of what to do with them. The ear will influence very much what happens inside the throat. If we could hear ourselves speak, and *learn* to hear our own voices, we would change them. This can be done. It is merely the training of the ear to hear the voice in the room instead of inside the head.

THE EASTMAN TYPE IIb SENSITOMETER AS A CONTROL INSTRUMENT IN THE PROCESSING OF MOTION PICTURE FILM*

GORDON A. CHAMBERS AND IAN D. WRATTEN**

Summary.—*A description of the methods used in the periodic testing of the Type IIb sensitometers used in the laboratories in Hollywood. Data are presented to show the order of agreement among the several instruments.*

With the increased use of sensitometric methods in the control of motion picture film processing that followed the introduction of sound track development, various forms of sensitometers were built. Some of these depended for their modulation of exposure upon some form of step tablet that gave an exposure varying from step to step in the intensity of exposure while the time remained the constant factor.[1] Others were so constructed as to give a series of times of exposure at a constant intensity. The adaptation of the well known Cinex testing machine to sensitometric purposes is an illustration of this latter type of instrument.

The difference between the results obtained with these different types of instruments,[2] coupled with the necessity of some standardization in order to promote the interchange of sensitometric data, led to the development of the Eastman Type IIb sensitometer. This instrument has been described before the Society by L. A. Jones.[3] It was made available to the industry in the Spring of 1931, and at the present time nine of these instruments are in service in Hollywood. The following list is given to show the location of the sensitometers in order to indicate the usefulness which this instrument has found. Type IIb sensitometers are in use at the following: Agfa Raw Film Corp., Roy Davidge Laboratory, Inc., Eastman Kodak Co., Fox Film Corp. Laboratory, Metro-Goldwyn-Mayer Laboratory, Multicolor Laboratory, Paramount Laboratory, Universal Pictures Laboratory and Warner Bros.-First National Sound Department. It might be mentioned that the sensitometer at the Eastman Kodak Com-

* Presented at the Spring, 1933, Meeting at New York, N. Y.

** Motion Picture Film Dept., Eastman Kodak Co., Hollywood, Calif.

pany's laboratory in Hollywood is regularly used by other laboratories not having a sensitometer.

Thus it will be seen that this instrument has become the accepted control sensitometer in Hollywood for making sensitometric strips. This status was recognized by the Academy of Motion Picture Arts and Sciences by the award of an Honorable Mention[4] by the Board of Judges for the Scientific and Technical Award for the year 1931–32. In addition, the Release Print Committee of the Academy has recommended that the Type IIb sensitometer be considered the standard to be used for the compilation and specification of data on Release Print Practice.

The Type IIb sensitometer is regularly supplied for use on 110-volt a-c. lines either 50 or 60 cycles in frequency. It so happens that all instruments in the Hollywood area operate on 50-cycle lines so that the speed of the motor, which controls the exposure time, is the same for all instruments. With the exception of one sensitometer, which has been adapted with a three-phase motor to suit the supply mains of that laboratory, all instruments are functioning with the single-phase autosynchronous motor supplied.

The light sources used are 6-volt locomotive headlight type lamps. A transformer, either with or without a voltage control unit for regulation to $^1/_2$ per cent, is used to supply the lamp current. In the case of two of the sensitometers in Hollywood this has been changed so that the lamps are fed from a storage-battery supply. Of the remaining seven instruments, five are equipped with voltage regulators.

The calibration of the lamps and filters for a sensitometer are given on cards supplied with the instrument. These calibrations are changed, of course, in the event of a lamp or filter replacement. Spare lamps and filters are available in Hollywood in order that such changes as become necessary may be easily made with no loss of time.

The Motion Picture Film Department of the Eastman Kodak Company conducts a photographic check test on each sensitometer bi-weekly. At this time the instruments are checked physically and any adjustments that may be necessary are made. Both the negative and positive exposing conditions are checked. Supersensitive negative and positive film are used to test the respective conditions, the sensitometric exposures being made successively on the rolls with the direction of exposure always the same. When strips are not made in this manner, difficulty is experienced because of the directional effect[5] in machine development. It has become customary in Hollywood to perforate that end of the strip which has had the least exposure, and strips are put into the processing machine with this end entering the developer first. Thus the effect of directional development is discounted for practical purposes by being always in the same direction. When measurements are to be made which must be free from this error, two strips are exposed in opposite directions and the readings from the two are averaged.

There is a phase of the Eberhard effect that may enter here. One laboratory made a change in the template in the exposure plane of its sensitometer so that the steps were separated from each other by an unexposed area. This was done in order to make the positioning of the densities under the nosepiece of a polarization densitometer more easy. It was found that this changed the gamma value obtained from that on a strip having a continuous series of steps. Inasmuch as these results were then not comparable with those obtained by other users of the Type IIb sensitometer and as the purpose of standardization was defeated, this laboratory was persuaded to change the template. The difficulty was solved by cutting small notches along the template so that each step was marked in the manner in which the center step is indicated in Fig. 1. This allowed the same ease as obtained by the other method when the polarization photometer was used.

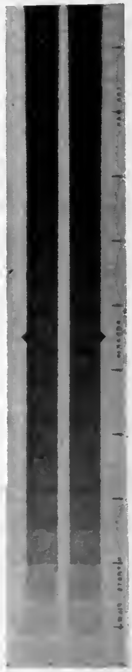

FIG. 1. Showing method of positioning strip by notched template.

The template furnished with the instruments was so made as to allow the exposure of two strips side by side longitudinally on the film. As this exposure fell within the area normally used by the sound track, most instruments now have had new templates fitted, which made a single exposure down the center of the film, thus allowing the exposure of a sensitometric strip on the sound takes without interference.

After the test exposures have been made on all the sensitometers, the two rolls of film are developed on continuous machines under normal processing conditions for picture negative and positive films. The resulting strips are then read and plotted.

In Table I are given the density readings and the gamma values obtained for each of the sensitometers, which are designated by serial number, from a recent test. These values are for the negative exposure condition. The last column gives the maximum variation in density obtained for each step. These values illustrate the close agreement among the different instruments.

TABLE I

Densities and Gammas of Sensitometers in Service in Hollywood

Negative

Serial No. / Step	*502*	*503*	*504*	*505*	*506*	*507*	*509*	*516*	*522*	Maximum Density Difference
1	1.66	1.66	1.69	1.66	1.67	1.67	1.66	1.66	1.68	0.03
2	1.62	1.59	1.62	1.60	1.61	1.59	1.60	1.61	1.62	0.03
3	1.52	1.51	1.51	1.49	1.51	1.50	1.50	1.52	1.52	0.03
4	1.42	1.42	1.42	1.39	1.41	1.39	1.42	1.42	1.41	0.03
5	1.32	1.32	1.34	1.32	1.32	1.31	1.32	1.33	1.34	0.03
6	1.22	1.22	1.26	1.22	1.22	1.22	1.23	1.23	1.25	0.04
7	1.15	1.14	1.15	1.13	1.14	1.12	1.15	1.14	1.16	0.04
8	1.04	1.02	1.03	1.02	1.03	1.02	1.04	1.03	1.03	0.02
9	0.91	0.91	0.92	0.90	0.90	0.89	0.91	0.89	0.91	0.03
10	0.79	0.80	0.80	0.79	0.80	0.77	0.79	0.80	0.79	0.03
11	0.69	0.67	0.69	0.68	0.70	0.67	0.69	0.70	0.68	0.03
12	0.58	0.58	0.58	0.57	0.58	0.58	0.58	0.59	0.58	0.02
13	0.50	0.49	0.50	0.48	0.48	0.49	0.49	0.50	0.49	0.02
14	0.37	0.38	0.40	0.37	0.38	0.39	0.39	0.42	0.42	0.05
15	0.30	0.30	0.31	0.30	0.30	0.33	0.31	0.32	0.31	0.03
16	0.23	0.23	0.23	0.22	0.23	0.26	0.24	0.25	0.23	0.04
17	0.18	0.17	0.19	0.17	0.16	0.20	0.17	0.17	0.17	0.04
18	0.14	0.15	0.16	0.14	0.16	0.13	0.14	0.14	0.15	0.03
									Average	0.03
γ	0.69	0.69	0.69	0.68	0.69	0.68	0.68	0.70	0.70	

Table II contains comparable data from the positive test run on the same date. This table illustrates very well the lack of agreement of one instrument, in this case No. *505*, with the others. It has been found that the failure of a lamp or filter occurs gradually, as would be expected, and for this reason the successive tests are watched closely for any tendency on the part of one instrument to drift from the mean. In order to prevent this, the Eastman Kodak sensitometer is periodically checked against standard lamps and filters that are carefully preserved and used for this purpose alone. When, as in the example shown in Table II, one instrument is found not to agree, careful tests are made to determine whether it is the lamp or the filter that is at fault. When this has been determined, a report is made to the laboratory, on a standard form, suggesting that the necessary replacement be made. Excellent coöperation has been obtained from the laboratories in maintaining the instruments at standard conditions by such replacements as have been necessary to date.

TABLE II

Densities and Gammas of Sensitometers in Service in Hollywood

Positive

Serial No. / Step	502	503	504	505	506	507	509	516	522	Maximum Density Difference*
1										
2										
3										
4	2.90	2.89	2.87	2.86	2.91	2.89	2.89	2.90	2.91	0.04
5	2.66	2.70	2.66	2.65	2.71	2.68	2.69	2.70	2.70	0.04
6	2.52	2.51	2.49	2.46	2.53	2.50	2.51	2.54	2.54	0.05
7	2.31	2.32	2.29	2.24	2.35	2.33	2.28	2.34	2.33	0.06
8	2.12	2.14	2.09	2.02	2.14	2.09	2.10	2.14	2.14	0.05
9	1.89	1.93	1.88	1.83	1.92	1.88	1.88	1.91	1.88	0.05
10	1.65	1.66	1.62	1.56	1.67	1.62	1.62	1.67	1.66	0.05
11	1.39	1.42	1.38	1.31	1.42	1.38	1.39	1.42	1.42	0.04
12	1.10	1.13	1.08	1.01	1.12	1.08	1.09	1.12	1.14	0.06
13	0.83	0.83	0.81	0.74	0.85	0.80	0.82	0.84	0.82	0.05
14	0.59	0.59	0.57	0.49	0.60	0.58	0.57	0.60	0.59	0.03
15	0.39	0.38	0.37	0.31	0.39	0.36	0.38	0.40	0.38	0.04
16	0.19	0.21	0.19	0.14	0.19	0.18	0.21	0.20	0.21	0.03
17	0.08	0.08	0.09	0.06	0.07	0.08	0.08	0.08	0.08	0.02
									Average	0.04
γ	1.81	1.82	1.80	1.83	1.80	1.82	1.78	1.82	1.80	

* Excluding No. 505.

Up to the present time seven positive lamps and two positive filters have been replaced. As the sensitometers are used mostly for the exposure of positive materials, it has been necessary to replace only one negative filter and none of the lamps. It is obvious, therefore, that the maintenance of the sensitometers has not entailed a great deal of expense. From the mechanical standpoint, the sensitometers have been very satisfactory, only two failures of this type having been reported. In both cases the necessary repairs were made by the mechanical departments of the respective laboratories.

It is felt by the writers that this testing service, which is done without charge, is unique in the field of precision engineering instruments. The service is maintained merely to assure agreement in results between the several sensitometers. The agreement among the instruments to date is believed to be excellent, and it is this order of result that is to be desired.

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THE SOUND FILM PROGRAM OF THE UNITED STATES DEPARTMENT OF AGRICULTURE*

RAYMOND EVANS**

Summary.—*The motion picture program of the U. S. Department of Agriculture contemplates a gradual changeover from silent to sound films, largely of the lecture type. A few sound films have been made, but realization of plans for distribution has been slow for these reasons; (1) The depression has hit farmers harder than any other class. Most of our 4000 County Agricultural Agents can not now buy sound equipment at any price; (2) the cost of portable sound equipment has been outrageously high; (3) uncertainty as to the ultimate development of 16-mm. sound-on-film equipment has tended to delay decisions as to the purchase of equipment. The Department feels that there can be no notable development in the field of educational sound films until very cheap and efficient sound equipment is available.*

The theme of this paper, as scheduled, is "The Sound Film Program of the United States Department of Agriculture." After having assembled material for presentation the conviction grows that it should have been called "The Sound Film *Problem* of the United States Department of Agriculture." Manifestly what we have to present is more problem than program. This is largely owing to the fact that the educational talking picture became a factor in visual education just at the time when the farmers of this country were slipping into the slough of the worst era of hard times that they have experienced since 1873, if not the worst in our history. Because corn sells in Iowa at ten cents a bushel and won't pay taxes on the land on which it grows, and because a bushel of barley in the Dakotas has at times been quoted so low that it would barely buy a three-cent postage stamp, our sound picture program languishes. We have made a few talking pictures, and the few copies of these that we have been able to put into circulation are in good demand; but the vast, potential field for agricultural educational talking pictures has barely been touched.

To make this situation clear, we must first outline briefly the pur-

* Presented at the Spring, 1933, Meeting at New York, N. Y.

** Office of Motion Pictures, Extension Service, U. S. Department of Agriculture, Washington, D. C.

pose and scope of the work carried on by our Office of Motion Pictures. This office is a unit of the Extension Service of the Department, and its function is to make and circulate films designed primarily for the use of the county agents who represent the Department and the State Extension agencies in farming communities throughout the country. Altogether there are over four thousand of these, counting both agricultural agents and home demonstration agents. Fig. 1 shows the distribution of these local representatives of our Department. The areas they serve are shown in black.

For the past fifteen years these agents have used motion pictures more or less in their work. Fig. 2 shows the extent to which our

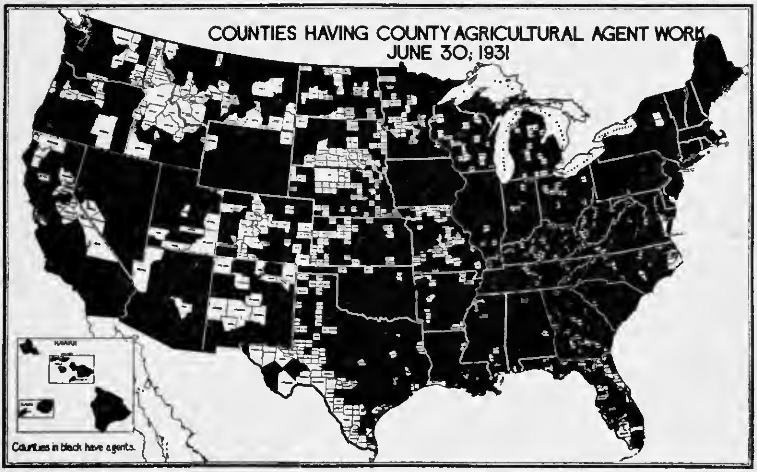

FIG. 1. Distribution of local representatives of the Department of Agriculture.

films are used by the county agents in an average year. Comparing this with Fig. 3, showing the total use of United States Department of Agriculture films for an average year, we see that the county agents are responsible for a large percentage of our distribution. Thirty-five-millimeter silent projectors are owned in a considerable number by the county organizations that contribute to the support of these agents, largely DeVry, Holmes, and Acme portables. Practically all these equipments were bought before the beginning of the era of sound. Since sound came in, the purchasing of projectors for this purpose has apparently fallen off to almost nothing.

This situation, I have indicated, is in large measure attributable to the slump in farm income throughout the country. The county agents, for the most part, are financed locally, and when farm incomes shrink the budgets of the county agents shrink too. For the past two or three years the county agent's very job has been in jeopardy. Naturally, there has not been much money available for motion picture equipment.

This, however, is not the only factor to be taken into consideration. The excessive cost of sound equipment has served to keep sound equipment out of reach of the few county agents who might have

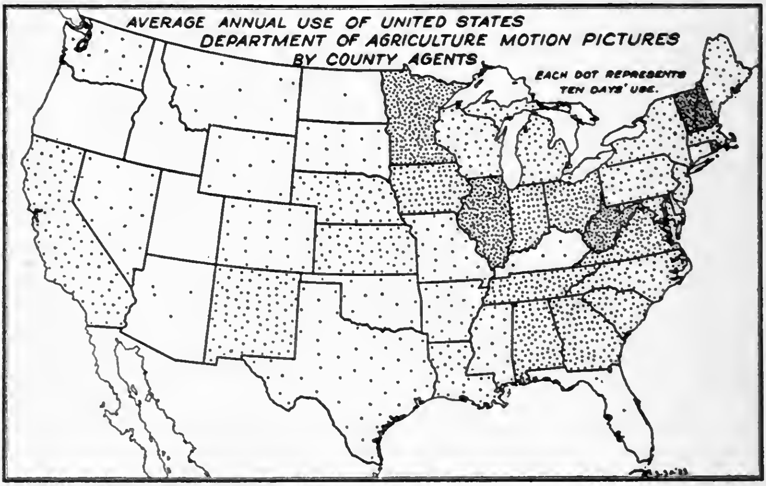

FIG. 2. Chart showing extent of use of films of Department of Agriculture by county agents.

bought sound equipment had prices been comparable to the prices hitherto asked for silent equipment.

When the first sound-on-film portables, so-called, began to come on the market, three or four years ago, the representatives of the manufacturers were doubtless vexed, and certainly incredulous, when we told them that an outfit requiring a half-ton truck to carry it would never be accepted by our clientele as a portable projector. And when we told them that a price of four thousand dollars a pair, or more, was utterly out of the question, that sound projectors would have to sell for five hundred dollars or less, complete, and at the same time be truly portable, before they could hope to do business with those who use our films—they were aghast. In passing, I should like to point out that good portable sound projectors, complete, are now selling for about five hundred dollars. If times were normal, I believe there would be a good market for equipment of this type.

The manufacturer who is accustomed to thinking in terms of expensive professional equipment is not easily convinced that there is not some way in which comparatively expensive equipment can be sold for use in visual education. The fact that funds for equipment for visual education are meager, even in the best of times, can not be too strongly stressed. In this connection may be cited the phe-

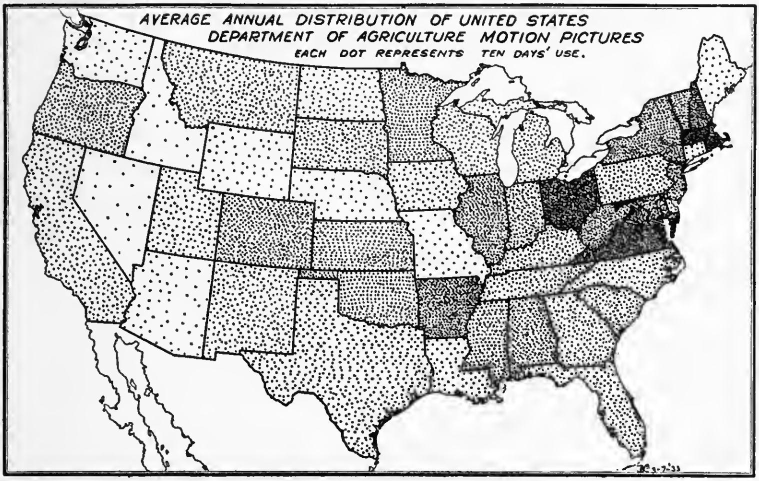

FIG. 3. Chart showing total use of films of Department of Agriculture in an average year.

nomenal success of the film strip in supplanting the glass slide for still projection. The film strip is admittedly a poor and grainy substitute for a glass slide, but a full set can be bought for fifty cents, and the projector can be bought for thirty dollars, more or less. Whether we like it or not, the film strip is going to take the field. It has already taken the field in the work of the United States Department of Agriculture. There is nothing left to do but to hope for finer-grained emulsions and a change to a standard in which the picture runs lengthwise instead of across the film. Similarly, it is folly to hope that the highest grade and most expensive sound equipment is going to find a place in the educational field. It is reasonable, however, to hope that truly portable projectors, with amplifiers and speakers giving pleasing response, will find a good market in the educational field when times get better.

Another consideration that has retarded our progress is the uncertain status of 16-mm. sound-on-film. Coincidently with the marked improvement that was made in 16-mm. illumination two years ago, we began to issue nearly all our new silent films on 16-mm. as well as on 35-mm. stock, and it is our belief that eventually a large proportion of our distribution will be in the 16-mm. field. We have made no 16-mm. sound films, thus far, however, for reasons that are rather obvious.

In the first place there is no demand. The people who use our films have no 16-mm. sound projectors. Furthermore, we would not know what to advise if these people should come to us for advice as to the purchase of 16-mm. sound equipment. We have listened to good 16-mm. sound-on-film produced by re-recording and by both of two systems of optical reduction, and we have heard rumors and representations as to successful mechanical sound track on 16-mm. film, but we have not yet seen on the market any 16-mm. sound system that could be recommended to our clients as representing a standard that could be accepted without question or argument.

Naturally, we have hoped that some system of producing prints at a cost comparable to the cost of silent prints would eventually find general acceptance. Though the quality of sound obtained by re-recording has been satisfactory, we feel that the cost of re-recording, thus far, has been prohibitive, as far as the educational field is concerned. We realize, to some extent, we hope, the engineering and merchandising difficulties to be overcome in making available for visual education 16-mm. sound prints at a reasonable price. We believe, however, that the game is worth more candles than have already been burned, and we hope that we have not yet heard the last word on 16-mm. sound standards.

From what I have said it will be clear, I trust, that our Department, in changing over its motion picture activities to a talking picture basis, has a rather difficult problem to solve.

Our plans then, so far as we can envisage them now, contemplate the continued production of 35-mm. sound pictures on a modest scale, pending development along the lines we have discussed. We feel that the efficiency of the 16-mm. projectors, as far as illumination is concerned, is now such that we can recommend them as suitable for the type of educational work done by our county agents. When and if 16-mm. sound projectors settle down to a generally accepted standard that promises to be fairly permanent, we shall begin issuing our sound films in that size. We trust that we shall find a cheap and satisfactory way of making such sound prints from our 35-mm. negatives. We do not anticipate, however, a quick and general change from 35-mm. to 16-mm. film on the part of our county agents. There are over 1200 silent 35-mm. portable projectors in the hands of county agents, and a fairly large percentage of these agents seem to favor the standard film for serious educational work. It is safe to say that many of the old projectors will be rebuilt for sound or turned in on new 35-mm. portable sound projectors. Thus, it must not be assumed that the 16-mm. projector is destined wholly to displace the 35-mm. portable in this field.

In this connection we must bear in mind the fact that portable 16-mm. sound equipment, irrespective of the projector itself, is as heavy as, or heavier than, equivalent 35-mm. sound equipment. It takes transformers to achieve great amplification, and transformers are made of iron and copper. The 16-mm. projector loses its great advantage over the 35-mm. projector as to portability when it annexes a heavy amplifier and associated speaker. Thus, the relative cheapness and portability of the film remains the only great advantage of the 16-mm. system when it goes over to sound. This is a factor that those who have not actually lifted and carried about a complete 16-mm. sound-on-film outfit may not have taken into consideration.

Our plans, therefore, do not contemplate a one-hundred per cent change-over from silent to sound pictures. The demand for our silent films has fallen off but slightly since the advent of sound, and we expect to be circulating many silent educational pictures for some years to come.

DISCUSSION

MR. RICHARDSON: I notice that Massachusetts, Rhode Island, Pennsylvania, and Ohio are covered by the Department very thoroughly, whereas states like Missouri, Michigan, Wisconsin, and others that are essentially agricultural, are not so thoroughly covered. Why is that?

MR. EVANS: Due to local state extension service: in some states they believe in motion pictures and in some they do not; some have projectors and some do not. For instance, in Ohio every accredited high school has a motion picture projector, which furnishes an outlet. That is not true in Michigan.

THE PRESELECTION OF TAKES FOR PROCESSING FROM EXPOSED UNDEVELOPED NEGATIVE*

DAVID W. RIDGWAY**

***Summary.**—Desired "takes" are preselected from rolls of sound film shot on production, only takes required for printing being developed. Undeveloped "out" takes are reversed, spliced together, and later used for printing "dailies." The methods of "breaking down" the predeveloped negative, necessary precautions, and the economies effected are described in detail.*

In recording sound on film for motion pictures, many takes are usually made on a single roll of negative.† Some of these takes are good and are chosen to be printed; others are unsatisfactory. Previously to the adoption of the method described in this paper, all takes, good and bad alike, were developed, whether prints were to be made of them or not. The only exception occurred when no satisfactory take was made on a roll of film, in which case the entire roll was held undeveloped. After development, each roll was broken down and the takes to be printed were separated from the rejected, or "out," takes. The film that had been exposed on unsatisfactory takes and the cost of developing it were wasted.

By separating the good from the bad takes before development, two savings are made possible. In the first place, the cost of developing film that is not to be used in the finished product is avoided. In the second place, owing to the fact that the sound track occupies only a very narrow area near one edge of the film, the film may be reversed and spliced together, and prints for rushes and editing purposes may be made on the opposite edge.

Method.—The method described was suggested by the writer and is

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* Presented at the Spring, 1933, Meeting at New York, N. Y.

** RKO Studios, Hollywood, Calif.

† Sound is recorded on positive stock (1) because it costs only one cent per foot as contrasted with the usual cost of four cents per foot for negative; (2) because it has a fine granular characteristic. The positive stock upon which the original sound record is made, is, of course, the *sound negative* from which, in turn, prints are made. Prints are also made on positive stock.

now being used on sound film at RKO Studios in Hollywood.* The application of the method to picture negatives and the additional problems involved will be discussed later in this paper.

It has always been customary to expose a ten-foot strip of film to be used by the laboratory for determining development time at the beginning of each roll of sound negative. When takes are to be selected before development, a test strip twice the usual length is exposed. Half this test strip is sent to the laboratory with the takes selected for development, and the other half is retained with the "out" takes, to be used in case any of the latter are later ordered to be printed.

Between takes a notch is punched at the edge of the film. Each take is identified by hand-punched marks designating scene and take numbers. The operator on production makes two sets of reports, one enumerating all the takes that were shot and the other only those takes that are chosen to be printed.

Equipment.—In the breaking-down operation, a small amount of inexpensive equipment is required. The room in which the film is broken down is the usual positive darkroom. It is lighted, however, by a Wratten series *OA* yellow safe-light, which affords sufficient illumination to render easily legible not only the pencil writing on the reports attached to the film magazines by the recorder operator, but the punch marks that identify the individual takes, as well.

A special film rewind, which accommodates simultaneously two separate rolls of film, is used. On one roll are wound the takes selected to be printed, and on the other the rejected or "out" takes. One-half the exposure test strip is separately wrapped and put into the can with the film that is to go to the laboratory. The remaining part of the exposure test strip is put into cans with the "out" takes.

The operator who breaks down the film, wearing gloves so as to avoid making finger-prints, allows the film to pass between his fingers, stopping the rewinds whenever he comes to a notch between takes. The film is broken between the accepted and rejected takes, and each take is wound on its proper spool. No attempt is made to splice takes together in the break-down room. All film to be developed is spliced at the laboratory, where film to

* Experiments were undertaken and the system was placed in practical operation under the direction of the RKO Technical Committee, composed of Messrs. C. Dreher, J. V. Maresca, W. Eglinton, J. Wilkinson, J. Swain, F. Garbutt, L. E. Clark, and John Cass.

be processed is checked for any weakness or breaks and where any film weakened by notches is strengthened.

Risks.—In breaking down the predeveloped negative, there are the usual hazards incident to handling and processing film: (1) scratches and rubs, (2) static, (3) breaks in developing tanks due to faulty splices, (4) abrasions of sprocket holes and edges of film, (5) fog, and (6) dirt.

Precautions.—The danger of scratching and rubbing may be minimized by carefully handling the film and by taking care not to wind it too tightly. Static may be largely avoided by rewinding the film slowly. Little difficulty has been encountered in the form of splices breaking in tanks. The possibility of abrading the film at the sprocket holes or at the edges has not proved to be great. If the darkroom is properly equipped, the danger of fogging is insignificant. Proper ventilation of the darkroom and careful handling of the film are necessary to avoid getting dirt on the film.

Special care must always be taken in all phases of handling undeveloped film. A conscientious and painstaking operator, who will guard not only against the various hazards, but who will also be meticulous about checking and rechecking film and reports, in order to send the proper takes to the laboratories, is, therefore, essential.

Added Safety Factor.—Although certain risks are involved, an important factor of safety is gained as the result of breaking down the negative before development. As was mentioned before, previously to the adoption of this system, all takes of scenes were sent to the laboratory at the same time for development. If a failure should occur in the laboratory, for example, and the negative were stopped in the developer, all takes of a given scene might be damaged. If only one take of a scene is at the laboratory, only that one take can be damaged. Since usually two or more satisfactory takes are made of a scene, the good takes which have been held at the studio can be developed and printed, and retakes avoided. This additional factor of safety ordinarily makes it unnecessary to use two recorder heads and to make duplicate sound records on location or at other places where the danger of damage during processing has to be specially guarded against.

Storage of "Out" Takes.—Storage space for the undeveloped film must be provided and the film in the cans must be indexed so as to be readily available. The undeveloped film is ordinarily kept until the picture has been completely edited and shipped.

Reversal and Use of Printing Stock.—When it has been determined that there will be no further call for the rejected, undeveloped takes, they are removed to a splicing room, which is lighted in the same manner as the positive darkroom. Here the notched portions, the identification marks, and the five feet of film preceding and following, that might possibly have been fogged, are cut out. In practice, no take of less than forty feet in length is used. All the other takes are spliced together into continuous, 1000-foot rolls. The rolls are put into cans labeled according to the emulsion numbers on the film. The laboratory, using the portion of the film opposite the part that was originally exposed in recording, makes prints of daily rushes and prints for editing purposes on the reclaimed stock. This procedure was suggested by Mr. J. Wilkinson of RKO Studios.

Splicing Precautions.—Special precautions must be taken in the splicing operations. Here again, the skill and conscientiousness of the film splicer are all-important. He must wear gloves at all times to prevent finger-prints and grease from getting on the film. The gloves must be changed frequently, as they become soiled or wear through from constant contact with the film. A carefully ground emulsion scraping blade must be used on the splicing machine. It must be set exactly in the scraper so that the blade thoroughly scrapes the emulsion from the portion of the film to be spliced and yet does not cut into and weaken the celluloid base. It must scrape cleanly and evenly. To do this effectively, it has been found that if the emulsion is scraped from the center outward in both directions, a better splice is made possible than when the emulsion is scraped off in complete sweeps from side to side. Well prepared contact surfaces and a film cement of high quality assure the greatest possible strength in the splices. With these precautions, practically no difficulty has been encountered from broken splices.

It has been necessary to make reprints occasionally when spliced stock has been used, because of fogged spots that have been unnoticed by the splicer. However, less than four per cent of the footage of the prints made on reclaimed spliced stock have to be reprinted for any reason. This percentage is being decreased as various minor difficulties are remedied and eliminated.

Economies Effected.—At RKO Studios, laboratory developing charges for sound film have been reduced somewhat more than fifty per cent as a result of processing only selected takes. About ten per cent of the total studio outlay for positive raw stock is saved as a result of using salvaged spliced stock.

Use of System on Predeveloped Camera Negative.—Warner Bros.-First National Studios have been breaking down predeveloped picture negative for several years. The system was adopted there, not primarily as an economy measure, but at a time when the laboratory facilities were not adequate to develop all negative. The situation was met by developing only the good and usable takes. The procedure followed there, with certain exceptions, is similar to that of the RKO Studios on predeveloped sound negative.

Exposure test strips are made each time photographic conditions are changed. While in the camera, the negative is notched at the end of each exposure strip and between takes. Reports are made listing the "selected," the "hold" and the "NG" takes. "Selected" takes are those from which prints are to be made immediately. "Hold" takes are those that are deemed usable, but not ordered to be printed. The "NG" takes are those that probably will not be used.

Camera takes are identified by photographing a slate bearing the scene and take numbers instead of by punching these numbers on the film, as is done with sound negative. The photographed identification is invisible, of course, until after the film has been developed.

The person separating the undeveloped takes into their proper classes must work in almost complete darkness. His only source of illumination is a small flashlight, which makes it possible for him to read the tickets classifying the various takes. Knowing the number of takes and tests on a roll of film, the operator, by counting notches, can separate the takes and the tests that go with them into their proper classes.

The "selected" and "hold" takes are developed. The "NG" takes are put into cans and held until the picture has been edited and shipped.

The hazards that are present while working with undeveloped sound track are greater when working with undeveloped picture negative because the risk of fogging is greater and because the area covered by picture, and consequently subject to damage, is larger than the area covered by sound track. The precautions previously suggested in connection with sound negative should, accordingly, be more painstakingly observed when working with picture negative.

Mr. Fred Gage, in charge of Warner Bros.-First National Laboratories, who furnished this information on the breakdown of predeveloped camera negative, reports that delays and difficulties encountered are negligible and that the savings effected justify the use of the system.

Since the picture covers the greater part of the film, camera negative, unlike sound negative, once exposed, can not be used again. As a consequence, the only saving resulting from breaking down the camera negative before development is the cost of the laboratory processing of the film that is not developed.

At the RKO Studios, a semi-automatic film notching device that may be attached directly to the camera or to the sound recording head is being developed by Mr. T. Winchester. This device will simplify and make possible faster notching of film.

Conclusion.—Faced with the necessity of decreasing the costs of production, the studios have sought economies in every phase of their work. The methods described in this paper are helping to reduce costs without detriment to the quality of the finished product.

DISCUSSION

MR. PALMER: I did not quite understand the purpose for which this sound record was intended. If for prints, would the prints be silent or sound prints?

MR. OELLER: They would be sound prints; the originally recorded negative would show on one side of the picture. For editing that is immaterial, as the prints are not sent to the theater; they are used only for rushes and cutting purposes.

MR. PALMER: I don't see anything of value in the silent print. If there is no sound on it, it is no good anyway.

MR. OELLER: It is not a silent print. The negative take that is good is printed on that stock. The "out" stock, which has been "canned" for use in printing dailies, has the sound print of the good take on one side and the picture on the other, as usual; and then, in addition, it has the originally recorded negative which was "NG." In other words, the originally recorded negative is shown with the picture after the print is made.

MR. MCNAIR: Who is charged with the responsibility of selecting the takes to be developed?

MR. OELLER: That is the director's responsibility. A continuity girl tabulates the takes to be held, those that are "NG," and those that are satisfactory.

MR. J. I. CRABTREE: How would one know that nothing went wrong with the recording?

MR. OELLER: The recordist makes a report at the end of the take, and the girl asks whether the picture and the sound are "O.K." It is the responsibility of the cameraman or the sound man to state at the time whether he believes the take was good or not.

ECONOMIES IN SOUND FILM PROCESSING*

GERALD M. BEST**

Summary.—*The preselection method, which permits sound track negative that has been exposed and rejected to be salvaged and used again, is discussed with particular emphasis on the economies achieved at Warner Bros. Studios by applying the method. Large savings in film and laboratory costs have been made possible without investing additional funds in equipment or changing the ordinary recording, processing, or editing routines in the slightest degree.*

It has been customary at the Warner Bros. Studios to process only the "choice" scenes of picture film, retaining the "NG" and "hold" scenes in storage at the laboratory until it is determined that they will not be required, after which the film is disposed of as scrap, or fogged and used for leader. Until recently, the sound track negative, however, was processed in its entirety, the "NG" and "hold" scenes being set aside after processing, and stored in vaults until the end of the production season. It was not considered advisable to break into the rolls of undeveloped sound track to remove the selected scenes, due to the possibility of damaging the negative in handling.

Hence, at the end of a production season there would be several million feet of sound track negative stored in vaults, for which there was no use. In order to avoid this waste, a system of preselecting the takes, first introduced at the RKO Studios[1] in Hollywood, was adopted at Warner Bros. Studios, and a most gratifying saving has been achieved with no delay in film processing, no impairment of sound quality, and no expenditure for new equipment or modification of existing equipment.

The "NG" scenes are placed in containers marked with the numbers of the rolls from which they were removed, and such other information as is needed to identify them should they be required for reference or emergency use. The "hold" scenes are placed in other containers marked and stored in vaults under the name of the picture

* Presented at the Spring, 1933, Meeting at New York, N. Y.

** Warner Bros. West Coast Studios, Hollywood, Calif.

for which the film was recorded. If at the end of 72 hours the "NG" scenes are not called for, they are removed from their containers, spliced into 1000-foot rolls and used for printing dailies, *etc.* As three feet of film ahead of each scene is fogged when operating the recording machine, this length of film is torn off and discarded.

The splicer has been so adjusted that the scraper does not remove the emulsion over the full width of the patch, but leaves a very small margin on each edge so that there will be no white lines of clear film after the patch has been made. This avoids annoying "pops" in reproduction, and unless the reproduced volume is very great, the patches are not ordinarily audible.

Due to the fact that different emulsions are used in recording, during any period of several months or more, the emulsion number is marked on each roll of film sent to the laboratory, so that each roll of spliced stock can be made up of sections of the same emulsion. If different emulsions are spliced into the same roll, serious variations in print transmission are likely to occur due to differences of speed of the several emulsions. By printing all the dailies with the picture aperture open, the negative track is practically entirely fogged out, so that there is no danger of confusing it with the positive track on the opposite side. Even if the negative track is not fogged out by this means, it can still be readily distinguished, as it becomes extremely dense due to the high gamma to which it is developed.

The "hold" scenes are stored until the picture has been released, as occasionally in the editing of the picture, the action or sound in a choice scene is not suitable; in which case the "hold" scene is ordered processed for inclusion in the picture. When the picture is released, the "hold" scenes not called for are removed from the vault, spliced into rolls as are the "NG" scenes, and used for printing, thereby using all the film that was not originally processed.

The saving represented by the preselection method has been quite appreciable. A total of 4,250,000 feet of positive raw stock was purchased, and of this, 3,100,000 feet were used on actual production, 940,000 feet for music score, dubbing, sound effects, voice tests, *etc.*, and 90,000 feet for recording tests and miscellaneous requirements of studio production routine.

Of the 3,100,000 feet of production recording, 1,487,000 feet were used in choice takes, processed and printed. "NG" or "hold" takes comprised 1,622,000 feet, the "NG" scenes becoming immediately available for splicing and printing dailies, and the "hold" scenes becoming eventually available. Thus a surplus of 135,000 feet over the amount of film required for printing the dailies was created, to which should be added the "NG" takes of music score, dubbing, *etc.* Allowing a 3 per cent waste in splicing, and deducting a small number of "hold" takes later ordered processed after being held for some time, a substantial quantity of spliced stock is thus left over for other uses, such as dupe picture prints occasionally required in dubbing and music scoring, or for conditioning the developer in the laboratory. The only new print stock purchased during the season was for printing music score, sound effects, and other material used in dubbing, where spliced stock would not be suitable due to the possibility that the splices might interfere with the music or the effects.

On this basis, at a cost of 1 cent per foot, it is obvious that an actual saving of more than 50 per cent of the purchase price of print stock was effected; and to this must be added the saving in processing costs, due to the fact that less than half the negative sound track formerly processed is now put through the negative developing machines. It was found that one batch of developer lasted at least 50 per cent longer than before, on account of the smaller quantity of negative film processed, and the saving in chemicals, power, and general laboratory overhead amounted to several thousand dollars during that time. The new method did not reduce labor costs in the processing, as the personnel released from the developing machine crew due to the smaller quantity of film processed was put to work breaking down the film before processing. It did, however, eliminate the large amount of labor required in sorting out, storing, and finally throwing out the millions of feet of "NG" and "hold" scenes that had been processed and stored throughout the season; and incidentally the problem of film storage space has been materially simplified.

The preselection method thus permits large savings in film and laboratory costs without the investment of additional funds in equipment, or changing the ordinary recording, laboratory, and editorial routines in the slightest.

REFERENCE

[1] Ridgway, D. W.: "The Preselection of Takes for Processing from Exposed Undeveloped Negative," *J. Soc. Mot. Pict. Eng.*, **XXI** (September, 1933), No. 3, p. 230.

THE HISTORY OF THE ANIMATED CARTOON*

EARL THEISEN**

Summary.—*The history of the animated cartoon is traced from the earliest devices used to depict motion, before the introduction of photographic processes, to the realistic and artistic colored cartoons of the present day. The various innovations developed for reducing the labor and cost of producing the thousands of different photographs in seriatim for motion picture cartoons, is described briefly in relation to their chronology and application.*

The history of the animated cartoon goes back farther than that of the motion picture; in fact, motion pictures had their beginning as hand drawn pictures. Long before photography had become practicable, many devices were introduced that portrayed motion by a series of cartoon pictures. These early devices were nothing more than toys, and were impracticable for depicting a story; however, they were popular and did much to crystallize the demand for motion pictures.

Five years after the discovery of the "persistence of vision" by Peter Mark Roget, in 1826, the first attempts were made to show motion pictorially by a series of drawings. With a device, called the *Phenakistoscope*, invented by Joseph Antoine Plateau, motion was depicted by a sequence of drawings, fourteen in number, each drawing blending with the next in the series to show some simple bit of action. The device was composed of two disks mounted on a shaft, the front disk having a series of slits around its outer edge, while the rear disk carried the drawings. The drawings were aligned with the slits, and on peering through the slits as the two disks revolved, the illusion of motion was created.

This was followed by the *Daedaleum*, or *Wheel of the Devil* (Fig. 1), invented by William George Horner, in England, in 1834, which consisted of a shallow cylinder, mounted on a stand, having slits

* Presented at the Spring, 1933, Meeting at New York, N. Y.

** Honorary Curator, Motion Picture Division, Los Angeles Museum.

around the top. The drawings, made on strips of paper about $2^1/_2$ feet long, were inserted on the inside of the cylinder. In these drawings, the chief character was the devil, waving his trident. The *Daedaleum* was later re-invented in France as the *Zoëtrope* by Desvignes, in 1860. It came to be known as the *Wheel of Life* because it showed action, and portrayed little every-day happenings, such as a child jumping rope, or a man pumping water, or a cast of actors, including an erring husband, his wife, and her rolling pin. The rolling pin here used may be said to be one of the forerunners of the assorted "props" that are now so valuable to the motion picture. Many other events were faithfully recorded by hand drawings for the Zoëtrope, which were motion pictures $2^1/_2$ feet in length.

The *Wheel of Life* was first introduced in the United States by

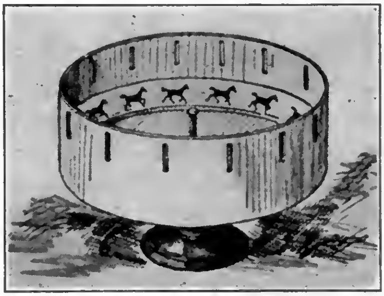


FIG. 1. The *Wheel of Life*, one of the early devices for showing animated pictures.

William Lincoln, in 1867, and was patented on April 23, 1867, which can be said to be the date of introduction of the animated cartoon into this country.

The most notable of the pre-photographic inventions was the *Praxinoscope*, devised by Emile Reynaud, in 1877, in France. To Reynaud goes the credit of drawing short bits of dramatic action in the form of plays, which he projected on a screen in the Reynaud Optical Theater (Fig. 2). His most notable picture was *Pauvre Pierrot*, drawn on a thirty-foot length of a transparent medium which he termed "crystaloid." It should be noted that this was twelve years before either the first Eastman raw stock with celluloid base, or the Edison motion picture apparatus was demonstrated.

Space will permit mention only of the first few pioneers who struggled to make pictures move before photography was available to them. There were a great number of others, some of whom spent a lifetime at the work. One man continued grimly to peer into his devices until he sacrificed his eyesight. Another lost his sight, yet continued his work with the assistance of his wife. To such men as these our gratitude must be extended. The revaluation that followed the perfection of the screen cartoon should not be allowed to discredit those early movie devices; in perspective they may seem

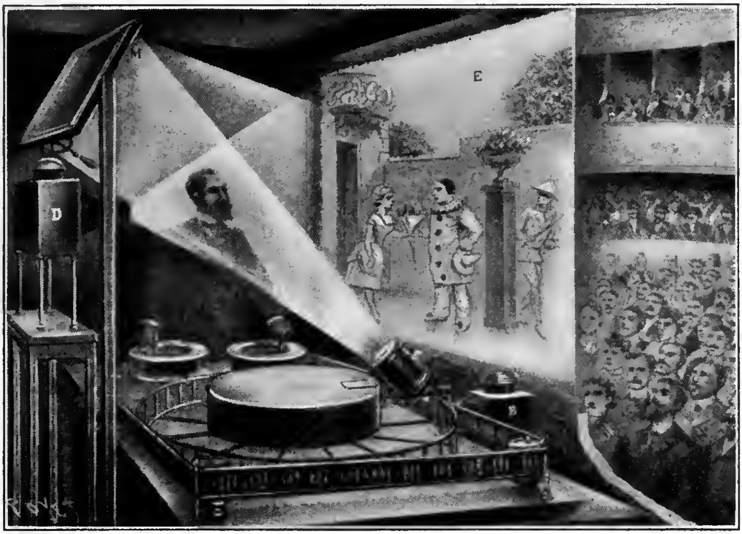


FIG. 2. Reynaud's Optical Theater, showing an audience viewing the play *Pauvre Pierrot.*

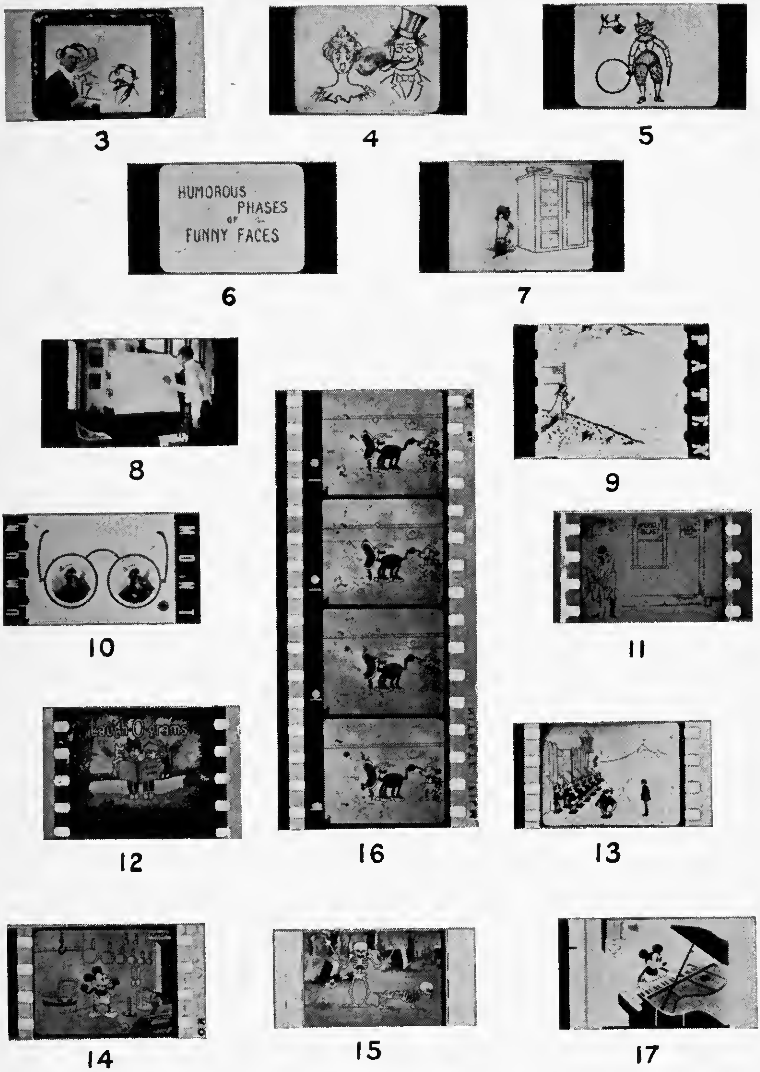
crude. But they were received in their day with all the acclaim accorded to Mickey Mouse today.

It was not until 1906 that the first cartoon was made on motion picture film. It was a picture made by J. Stuart Blackton, for Vitagraph, and was entitled *Humorous Phases of Funny Faces* (Figs. 3–6). A recent screening of this picture, with its 1906 copyright, and Vitagraph trademark, showed it to consist of such cartoon bits as a man rolling his eyes and blowing smoke at his sweetheart, a large-nosed Semite, a dog jumping over a hoop, and ended by showing Blackton doing a chalk-talk type of drawing, in which apparently the cartoon starts as one thing and ends as another. This first cartoon picture required about three thousand drawings and its running for an early-day audience, which was largely composed of the more solid citizenry, was a signal for great mirth. The man blowing the smoke at his sweetheart was the highlight of the picture. Since cartoon technic at that time permitted the girl to show her displeasure only by suitable eye movements, the picture had its elements of humor.

The next man to make animated pictures was Winsor McCay. The first was completed early in January, 1911, and was known as *Little Nemo.* It was photographed in one-reel length by Walter Arthur, directed by J. Stuart Blackton and released by Vitagraph as *Winsor McCay Makes His Cartoons Move.* It contained over 4000 drawings, each complete with a background and was considered a mammoth undertaking at that time, despite the fact that the present cartoon requires as many as 12,000 drawings, which are run for a screen time of only six minutes. McCay's second picture, *How a Mosquito Operates,* was made in December, 1911, in 600 feet and was sold to Carl Laemmle. The third, *Gertie, a Trained Dinosaur,* was sold to William Fox. These pictures were used also as a vaudeville act by McCay, who toured with them and explained their making and technic.

To McCay goes the credit of making the first serious attempt at a dramatic cartoon. *The Sinking of the Lusitania,* released on August 15, 1918, by the Jewel Productions, was a cartoon of feature length. According to the *Motion Picture News,* of August 18, 1918 [it was], "made from 25,000 drawings on gelatin by the famous artist, Winsor McCay, requiring 22 months of work." The picture attracted attention at this time by virtue of its length and because it was a propaganda picture for the war. To date it has been the longest cartoon ever made.

John R. Bray, during the period 1914–16, was granted several patents on making animated cartoons. The first, filed January 9, 1914, and granted the same year as No. 811,165, describes a method of registration so as to hold each picture in correct relation to every other for photographing. The most important claim in this patent, however, relates to the use of a translucent background over the character drawing. It will be noted that this is a departure from the tedious process of drawing each cartoon complete with a background and character, as was heretofore done. With this patent, Bray introduced the idea of making one background serve for all the



FIGS. 3 TO 6. Copies from specimens of cartoon films made by Blackton in 1906 (FIG. 3, picture of Blackton doing a chalk talk in his 1906 cartoon). FIGS. 7 and 8, the first Bray cartoon, *The Artist's Dream*, by J. R. Bray. FIG. 9, Pathé newsreel cartoon of about 1912 (note the Patents Company stencil on the edge of the film). FIG. 10, Gaumont cartoon of about 1912. FIG. 11, Packer cartoon of 1916. FIG. 12, the first Disney series made in St. Louis, 1921. FIG. 13, one of the *Alice Cartoons* made by Disney, 1923; a combination of real-life characters and cartoon. FIG. 14, first Mickey Mouse, *Steamboat Willie*. FIG. 15, first Silly Symphony, *Skeleton Dance*. FIG. 16, first method of synchronizing sound and picture; originated by Disney. The bouncing ball kept time for the musicians when scoring. FIG. 17, a recent Mickey Mouse, showing the sound track.

action occurring in that scene (Fig. 7). He printed his background from a zinc plate on thin translucent sheets of paper, which he laid over the character drawing for photographing. This system did not permit good quality and was used only for the first few pictures, after which he adopted a system similar to the Earl Hurd method. Bray further eliminated unnecessary drawing by introducing the "stationary" drawing, which comprises the use of separate sheets of celluloid when a part of the character is motionless while other parts are moving. One drawing is made for the motionless part, while the action of only the moving part of the character is drawn out.

Cartoon history may be said to date from the announcement, on June 12, 1913, of the first Bray cartoon, *The Artist's Dream* (Fig. 8). This, while not the first of the animated cartoons, was the forerunner of the cartoon vogue. Previously to that, cartoons were largely considered a novelty, or photographic trick. They had been used at the end of newsreels, or vaudeville acts, and were shown more or less apologetically. Now, audiences seeing *The Artist's Dream* were left in a mood bordering on the hysterical, from laughter, and demanded more cartoons. The central character of this cartoon was a dachshund, with the long "wheel base" and the short legs. This dog, which resembles so much an animated sausage, experienced difficulties with a flea, which interrupted the dog in obtaining his sausages for dinner.

Another Bray cartoon, *Col. Heeza Liar*, which was the "Mickey Mouse" of that day, was by far the most popular of the early cartoons. The first of the series, *Col. Heeza Liar in Africa*, was released by Pathé in December, 1913. They were discontinued after about five years, and again resumed in 1922 as an *Out of the Inkwell* combination. Walt Lantz, who draws the Universal *Oswald*, drew the later series, which consisted of a combination of the conventional motion picture into which was introduced *Col. Heeza Liar*.

Bray has the distinction of having made a hand-colored cartoon in 1917; it attracted much attention, but was impracticable because of the high cost of coloring each frame.

Earl Hurd introduced the modern technic of making cartoons. On December 19, 1914, he filed an application for a patent which, on June 15, 1915, was granted as No. 878,091. In this patent, he claimed the use of a transparent medium bearing the moving parts of the cartoon over an opaque background. Hurd was the first to use celluloid for his action drawings, which he laid over a background, as is done today. It will be remembered that Bray, in his first efforts, drew his backgrounds on a translucent medium, which he laid over his characters for photographing, and wherever the background interfered or covered the character, that part of the background was removed. Earl Hurd's first cartoons were the *Bobby Bump* series. Bray and Hurd combined their patents and formed the Bray-Hurd Company early in 1917.

Another early worker was Sidney Smith, who made *Old Doc Yak* for the Selig Polyscope Company. The first of this series was released on July 8, 1913. Wallace Carlson, who made *Dreamy Dubb*, and later the *Caminated News*, which was an *Out of the Inkwell* combination, was prominent at that time. Paul Terry drew *Farmer Al Falfa*. Leslie Fenton drew the *Hodge Podge* series which were released at the end of the Pathé newsreels.

Max Fleischer was the first to make the *Out of the Inkwell* type of drawing. This is a photographed picture to which is added a cartoon character by photographing a series of opaque cartoons drawn on celluloid placed over previously photographed conventional motion pictures. Fleischer's first series was *Koko, the Clown*, released by Paramount in 1917.

During this period Leon Searle made what was known as "cutouts." They were jointed characters cut out of paper and animated across a background. Their animation was rather jerky, as were the marionettes made about the same time by Tony Sarg. The Sarg marionettes were figures illuminated from the rear, thus producing a silhouette effect.

Raoul Barré, who began making the Edison cartoons, introduced the "slash" system, whereby the motionless parts of the characters were drawn once, and the animated parts of the characters torn away. These moving parts were then drawn on another sheet so as to coincide with the stationary parts. The two were then photographed simultaneously, one over the other, thus saving unnecessary drawing. Barré also originated the use of registering pegs and punch holes in the drawings for holding them in place during the photographing.

Bill Nolan, working with Barré, was the first to use a panorama background. The panorama, with the characters moving past the background, was an innovation and made a decided improvement in the action. That was in 1916.

Most of the cartoons shown on the screen in 1917 were greatly inferior to those of today. They were crude and the characters imperfectly synchronized. They would walk either too fast or not fast enough; the leg movements seemed to create the illusion that the feet were being dragged somewhat in the manner of a skater's sliding over the ice. Another characteristic was the "bubble" type of title. This title was similar to the present press cartoon title, in which the wording appears in a balloon with a line leading down to the character. When the title appeared on the screen, the character would come to a pause, face the audience, and "yap" or rapidly open and close its mouth to represent talking. This, of course, greatly interfered with the continuity of the story.

Into this period entered the International Feature Syndicate, formed by William R. Hearst. He placed Gregory La Cava in charge, who immediately set about improving the cartoons. He increased the number of drawings from the 2000 of the average cartoon of the time to 3500, resulting in smoother animation. Further, he changed the animation of the characters from the stiff, angular movements of the legs and arms to a smooth "rubbery" animation, such as is used at present. La Cava also discontinued the "bubble" title for the conventional title of the silent days.

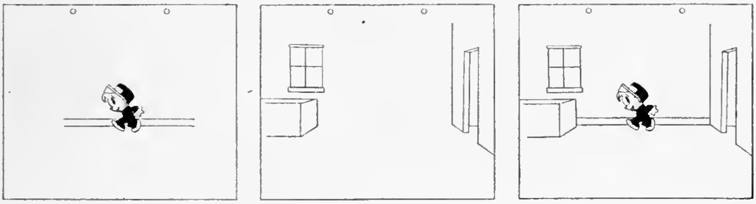
Beginning in 1917, the International Syndicate released such cartoons in series as *Jerry on the Job* (Fig. 18), drawn by Walt Lantz, *Katzenjammer Kids*, by John Foster, *Tad's Indoor Sports*, drawn by Bill Nolan and released at the end of the International Newsreel. *Happy Hooligan*, drawn by Jack King, *Bringing Up Father*, by Bert Green, *Krazy Kat* (Fig. 19), drawn also by Bill Nolan and Leon Searle, and the best of the Internationals, *Silk Hat Harry*, were the principal cartoons released at this time by that company. This last-named was drawn by Walt Lantz and La Cava, and was first released in 1918.

The first International cartoons were made somewhat after the principle of the first Bray cartoons, in which the background was drawn on a translucent medium and the characters on an opaque sheet. The background was then laid on top of the character drawings. Where any part of the background interfered with the character animation, that part of the background was drawn on the same sheet with the character. This system was discontinued after the first few cartoons in favor of the now conventional "celluloid over the background" method.

Other famous cartoons during the 1917–20 period were the *Mutt and Jeff* series, made by Budd Fisher. The Kay Company released the *Terry Cartoon Burlesque*, and Sterling Pictures the *Zippy* series.

Skipping over the years to the sound era, we come to Walt Disney and his *Mickey Mouse* series, which were the first cartoons with sound. *Steamboat Willie* (Fig. 14), was the first of this series and had its première on September 19, 1928, at the Colony Theater in New York. An earlier Mickey Mouse had been made but it was released later as *Plane Crazy*. Mickey Mouse is probably the most popular of any screen character, whether in real life or cartoon. He is certainly the acme of all that the screen has to offer as entertainment.

Disney started cartoon making in St. Louis, in 1921, when he made the Laugh-O-Gram (Fig. 12) series. In October, 1923, he and his brother, Roy, went to Hollywood and produced the *Alice Cartoons* (Fig. 13), which were a combination of real life characters and cartoons.



(*a*) (*b*) (*c*)

FIG. 18. *Jerry on the Job*, animated by Walt Lantz in 1917; the drawing (*a*) is placed beneath the drawing made on celluloid (*b*), and the two photographed together, producing the effect (*c*).

Disney's first Silly Symphony, *The Skeleton Dance* (Fig. 15), was released at the Carthay Circle, in Los Angeles, in July, 1929. It was later shown at the Roxy in New York. It was the first cartoon picture to be rebooked for a second showing at the Roxy.

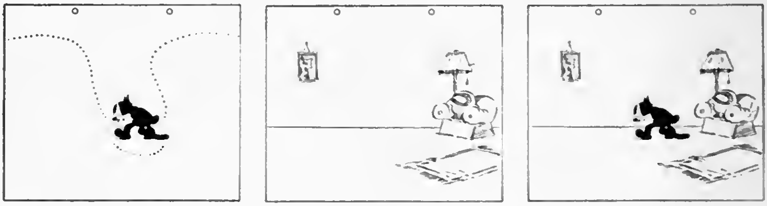
The method of synchronizing the first Mickey Mouse was by the "bouncing ball" method (Fig. 16), in which a ball was made to bounce in time with the music as a guide for the musicians, who watched the picture and the ball as they appeared together on the screen. This ball was photographed along the edge of the film, which space was later occupied by the sound track in the release print. Disney next used a wavy line, and finally adopted an aural method. The last method, employing head-phones, is still in use. Disney controls many of the sound cartoon synchronization patents.

The first Silly Symphony in color was *Flowers and Trees*, first shown at Grauman's Chinese Theater, Hollywood, on July 15,

1932. This was the first cartoon to employ the Technicolor Cartoon Process, a three-color imbibition process. Judging from today's standards it seems that it will be impossible to improve upon the beauty of these Disney cartoons colored by this process.

Many will remember the cartoon sequence that served as an introduction to the Universal picture, *King of Jazz,* released on March 30, 1930. It was colored by the Technicolor two-color process and was the first cartoon on record to be mechanically colored.

Another cartoon to follow this was Ted Eshbaugh's *Goofy Goat,* made by Multicolor and released at the Loew's State Theater, Los Angeles, on March 2, 1932. It had been previewed earlier at the Warner's Alhambra Theater, on July 6, 1931. Many will credit this cartoon with being the first in color, since it was the first complete cartoon story done in color, whereas the earlier Lantz cartoon was only an introduction for a real-life picture.



(*a*) (*b*) (*c*)

FIG. 19. *Felix the Cat,* animated by Wm. Nolan for International in 1917, showing the "slash" system used by Raoul Barré in the early Edison cartoons; the drawing of the cat (*a*) is cut as indicated by the dots and is superimposed on the background drawing (*b*). The photograph of the combination is shown at (*c*).

The current cartoon characters besides those named are *Oswald* and *Pootch-the-Pup,* drawn by Walt Lantz and Bill Nolan for Universal; *Krazy Kat* and *Scrappy* made by the Mintz Studio; *Looney Tunes* and *Merrie Melodies* made by Leon Schlesinger; *Flip-the-Frog,* by U. B. Iwerks for M. G. M. release; *Aesop's Fables* and *Tom and Jerry* by the Van Buren Corporation; *Betty Boop* by Max Fleischer; *Bosko* by Harman and Ising, released by Warners as a "Looney Tune;" *Magazine of the Screen* by Bray; and *Terry Tunes* by Paul Terry. *The Wizard of Oz* will shortly be released as a series, in Technicolor.

Such is the history of cartoons. It is interesting to observe their popularity today and then to recall their reception back in 1911–14, when they were always coupled with real-life characters in order to give a reason for their existence. *The Artist's Dream* had as an introduction an artist who drew a picture, and fell asleep; then the drawing came to life. The McCay cartoon had, as an introduction, a bet that he could not draw motion. He was pictured making the bet, and then the cartoon followed. Pathé, more or less hesitantly, ran a few short, terse bits of action in cartoons on the ends of their newsreels during 1911.

Today cartoons are a source of wonder. Those making animated cartoons lift out and re-shape human experiences in their more lovable form. They instill into the screen a gaiety and glow that depicts human traits in their more desirable form. They re-create again lost childhood. It is a form of entertainment that the screen must never lose.

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WILLIAM C. HUBBARD

Mr. William C. Hubbard, member of the Board of Governors of the Society of Motion Picture Engineers, died at his summer home at Long Lake, N. Y., on July 20, 1933. He had been associated with the Society since 1918, and had been very active in administrating its affairs in the capacity of Treasurer from 1925 to 1930, as Vice-President from 1930 to 1932, and as an elected member of the Board of Governors from 1932 until his death. Mr. Hubbard was born in Plainfield, N. J., on October 15, 1866. He attended the local schools of that city; and, after graduating from Plainfield High School in 1884, attended Alfred University and was later graduated from Rutgers in 1890, with the degree of Electrical Engineer. In his early business life he was connected with the Westinghouse Electric & Manufacturing Company, but in 1905 became associated with the Cooper Hewitt Company, of Hoboken, N. J., now known as the General Electric Vapor Lamp Company.

WILLIAM C. HUBBARD

Mr. Hubbard was also very active in numerous civic, religious, and fraternal organizations. In addition to having been closely affiliated with the Society of Motion Picture Engineers, he was a member of the American Society of Mechanical Engineers, American Institute of Electrical Engineers, and the Illuminating Engineering Society. Mr. Hubbard is survived by his wife, Mabel Potter Hubbard, and a daughter, Dorothy.

The Society regrets very deeply the loss of one of its most esteemed members.

SOCIETY ANNOUNCEMENTS

FALL MEETING OF THE SOCIETY, EDGEWATER BEACH HOTEL, CHICAGO, ILL.

OCTOBER 16–18, INCLUSIVE

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Mrs. O. B. Depue, *Hostess*

assisted by

Mrs. R. F. Mitchell	Mrs. B. W. Depue	Mrs. J. E. Jenkins
Mrs. H. T. Cowling		Mrs. A. Warmisham

OPENING OF CONVENTION

The Convention will convene at 12:30 p.m., Monday, October 16, at the Edgewater Beach Hotel, opening with an informal luncheon, during which the members of the Society will be addressed by several prominent speakers. The morning preceding the luncheon will be devoted to registration, committee meetings, and various organization matters.

SESSIONS

All technical sessions and film programs will be held in the East Lounge of the hotel, where also will be located the registration headquarters. The *Berwyn* room will be provided for the Board of Governors and the technical committees. Technical sessions will be held on Monday, Tuesday, and Wednesday afternoons, and on Tuesday and Wednesday mornings. The film program will be held on Monday evening, and will include several recent outstanding productions, in addition to several reels of the Century of Progress World's Fair, photographed by Mr. H. T. Cowling.

BANQUET AND DANCE

The S. M. P. E. Semi-annual Banquet and Dance will be held in the Ball Room of the Edgewater Beach Hotel, Tuesday evening, October 17, at 7:30 P.M.—an evening of dancing and entertainment, with no banquet speeches. Banquet tickets should be obtained at the registration headquarters; tables reserved for eight or ten persons.

SPECIAL EXTENDED RATES

Excellent accommodations are assured by the management of the Edgewater Beach Hotel, and minimum rates are guaranteed. Room reservation cards should be returned immediately to the Edgewater Beach Hotel in order to assure satisfactory reservations, particularly on account of the heavy advance registration incident to the large attendance at the Century of Progress Fair. Special rates have been arranged by the hotel, which will be effective during the stay of S. M. P. E. delegates and their guests in Chicago, should they wish to visit the Fair before or after the Convention.

CENTURY OF PROGRESS WORLD'S FAIR

Members of the Society who attend the Convention will be able to take advantage of the opportunity of visiting the Century of Progress World's Fair, now being held in Chicago, and which will close October 31. They will also be able to benefit by the special rates provided by the Edgewater Beach Hotel and the reduced railroad fares now in effect because of the Fair.

LADIES' HEADQUARTERS

A reception suite will be provided for the use of the ladies attending the Convention, and an attractive program for their entertainment is being arranged by the Ladies' Committee.

TENTATIVE PROGRAM

MONDAY, OCTOBER 16

9:30 A.M. Committee Meetings, Organization, Registration.

12:30 P.M. *North Room:*
Informal luncheon for members, their families, and friends; speakers.

2:30 P.M. *East Lounge:*
Report of the Secretary, J. H. Kurlander.
Report of the Treasurer, H. T. Cowling.
Convention Announcements, W. C. Kunzmann.
Society Business and Election of Officers.

8:00 P.M. *East Lounge:*
Interesting program of recent motion pictures and views of the Century of Progress World's Fair, produced by H. T. Cowling.

TUESDAY, OCTOBER 17

9:30 A.M. *East Lounge:*
Program of technical papers.

2:30 P.M. *East Lounge:*
Program of technical papers.

7:30 P.M. *Ball Room;*
Semi-annual Banquet and Dance.

WEDNESDAY, OCTOBER 18

9:30 A.M. *East Lounge:*
Program of technical papers.

2:30 P.M. *East Lounge:*
Program of technical papers.
Convention adjournment.

Papers Committee
O. M. GLUNT, *Chairman*

Convention Committee
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HONOR ROLL

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

By action of the Board of Governors, October 4, 1931, this Honor Roll was established for the purpose of perpetuating the names of distinguished pioneers who are now deceased:

LOUIS AIMÉ AUGUSTIN LE PRINCE
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Society of Motion Picture Engineers
33 WEST 42ND STREET
NEW YORK, N. Y.

EXHIBIT OF NEW APPARATUS AT THE FALL CONVENTION

Chicago, Ill., October 16–18, 1933, inclusive

Headquarters—Edgewater Beach Hotel

Arrangements are being made to hold an exhibit of newly developed motion picture apparatus, in order better to acquaint the motion picture engineer with the newly devised tools of the industry that may be of value to him.

It will not be of the same nature as the usual trade exhibit. There will be no booths, although each exhibit will be allotted definite space and all exhibits will be arranged in one large room. The following regulations will apply:

1. The apparatus to be exhibited should be new or have been developed or improved within the past 12 months.

2. Each exhibitor will be permitted to display a card giving the name of the manufacturing concern, and each piece of equipment shall be labeled with a plain label free from the name of the manufacturer.

3. A technical expert capable of explaining the features of the apparatus exhibited should be present during the period of the exhibition.

4. A charge for the exhibit will be made in accordance with the space occupied, as follows: up to 20 sq. ft., $10.00; 20 to 30 sq. ft., $15.00; 30 to 40 sq. ft., $20.00; 40 to 50 sq. ft., $25.00.

Please make requests for space to Mr. Sylvan Harris, Editor-Manager of the Society, 33 West 42nd St., New York, N. Y., stating the number and nature of the items to be exhibited.

Checks should be mailed to the editor-manager at the General Office of the Society.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXI	OCTOBER, 1933	Number 4

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OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

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NATIONAL STANDARDIZATION IN AMERICA*

P. G. AGNEW**

Summary.—*Standardization in America is discussed in relation to the classification of standards as company, association, national, and international standards. The function of the American Standards Association and the standardizing activities of the United States Government are described. Considerable attention is given to the factors that should be considered in deciding whether to standardize, and as to the methods to be followed in standardizing. The paper closes with a discussion of the human factor in standardization projects, and the responsibilities of participating groups and individuals engaged in standardizing.*

The scope of the standardization activities in which technical societies and trade associations are engaged is entirely too great to be covered in a single paper. I shall, therefore, omit from this discussion many important activities in such fields as the standardization of accounting methods, bills-of-lading, trade practices, codes of ethics, methods of arbitrating disputes, *etc.*, and deal primarily with the standardization of things.

In order to be explicit on fundamentals we may say that this type of industrial standardization means to single out specific products and materials, to settle upon their properties and dimensions, and to concentrate upon them in production and in use—all to the end of bringing about the greatest over-all industrial efficiency.

CLASSIFICATION OF STANDARDS

Within this seemingly limited field of industrial standardization there are actually a great many different types of standards which must be included in any complete standardization framework. It will be helpful to classify these various types. It is almost always necessary to start with the standardization of nomenclature, if our subsequent standards are not to be wasted because their terminology is confused. We have, then:

(1) Nomenclature:

(*a*) Definitions of technical terms used in specifications and in contracts, and in technical literature.

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* Presented at the Spring, 1933, Meeting at New York, N. Y.

** Secretary, American Standards Association, New York, N. Y.

(*b*) Abbreviations.

(*c*) Letter symbols for quantities used in equations and formulas.

(*d*) Graphical symbols (ideographs or pictographs) used on drawings, schematic diagrams, and the like.

(2) Uniformity in dimensions necessary to secure interchangeability of parts and supplies, and the interworking of apparatus.

(3) Specifications for quality of materials and products.

(4) Methods of test for materials and products.

(5) Ratings of machinery and apparatus which establish test limits under specified conditions as a basis of purchase specifications, or which establish requirements as to performance, durability, safety, *etc.*, under operation.

(6) Provisions for safety of workers engaged in production or use of machinery and equipment.

(7) Standard processes and operations for industrial establishments.

(8) Standards providing for concentration upon the optimum number of types, sizes, and grades of manufactured products.

This is a simple classification for practical purposes. Other classifications may be and have been worked out on other bases, such as the following, developed by the U. S. Bureau of Standards:

(1) Standards of measurement.
(2) Standards of constants.
(3) Standards of quality.
(4) Standards of performance.
(5) Standards of practice.

Another important classification of standards relates to the scale upon which they are planned and carried out. The process of industrial standardization may be classified roughly into four stages, namely:

(1) By individual companies.
(2) By societies or associations.
(3) On a national scale.
(4) On an international scale.

Every industrial plant is carrying on standardization of its own products and processes, and its competitive success largely depends upon the cleverness and thoroughness with which it has studied and solved these problems. Standardization within the plant has been an essential factor in the development of mass production; and mass production, in turn, has been the chief contribution of the United States to industrial development.

Standardization within individual companies, which had its greatest rate of growth during the last half of the nineteenth century, gave rise to collective standardization for entire industries. Such standardization by industries, carried on by technical societies and trade associations, has for the most part been a product of this century. The present extensive use of electric motors and lamps would have been impossible had it not been for the collective standardization carried on in the electrical industry, not only in fundamentals such as voltages and frequencies, but also in such details as the interchangeability of lamp bases and sockets. To cite another example, the adoption of a standardized track gauge and of a standard system of interchangeable brakes and couplings was a necessary step in the development of our railroad system. Had these standards not been adopted early in the period of railway construction, it would have seriously retarded not only the growth of transportation facilities, but also our entire national industrial development which required these facilities.

Just as standardization by individual companies led to standardization by industries, so standardization by industries has in turn been found insufficient because so many problems affect numerous diverse industries and require common solution. This has led to inter-industry or national standardization in behalf of industry as a whole, technical and trade associations here playing the same role as individual companies in group standardization.

That standardization can not reach its greatest effectiveness until it is treated as a national problem has been recognized in all the leading industrial countries. At present there are national standardizing bodies in 22 countries, all but one of which were organized during or since the War. The American Standards Association, the national standardizing body in this country, was organized in 1918. Just why national standardization is in so many cases necessary—simple industry standards not being sufficient—can best be judged from an actual case.

The establishment of specifications for railroad ties would seem to be a simple and straightforward matter. Yet even this very specialized subject is a striking illustration of the complexity of group interests. Twelve national organizations were officially represented on the technical committee on railroad ties organized under ASA procedure. Representation of three organizations was required to cover completely the steam and electrical railways, five organizations to cover producers, and an additional one for the wood preservers.

Naturally much less has been accomplished in international industrial standardization than in national work. Yet beginnings have been made in several fields, and in some lines there has been substantial progress.

GROUP STANDARDS

Much of the pioneering in group standardization activities has been done by technical societies. Nearly all the group standardization activities have developed during the present century. The interests and activities of associations have, however, been rapidly increasing and the trade association has already become a dominant factor in the movement.

In a trade association, corporate management as such is directly represented. In most professional societies this is not the case, since the basis of organization is the individual. This is, I believe, the basic reason for the steadily increasing role which the trade association is playing in the standardization movement. Decision and authority can not be permanently separated. It is fundamental in human nature that management should wish to be in a position to control decisions affecting its own policies. The normal agency for bringing this about in coöperative work affecting competing companies is the trade association.

These fundamental differences in points of view and in types of organization have, in a number of instances, led to jurisdictional struggles between technical societies and trade associations as to which organization should be in charge of standardization programs. In extreme cases these jurisdictional disputes have been based on radically different philosophies of what the nature of a standard should be; whether it should be an ideal placed before industry as an inspiration and a goal, or whether it should be a day-by-day working tool of industry, forged through the give-and-take necessary in the work-a-day industrial world, and therefore necessarily bearing the marks of the grime of the shop. I once heard this difference in point of view put in this extreme form: Should a standardization process partake of the nature of a gentlemen's tea-party, or must it needs be a business decision worked out under the stress of various, and often conflicting, industrial forces?

It is unnecessary to add that people generally are not much interested in "paper standards," but only in such standards as are useful as working industrial tools.

Nearly all the national engineering societies are carrying on standardization activities, some of them on an extensive scale. While by no means all trade associations carry on standardization work, several hundred of them are active. Of the 474 national organizations participating in the work of the ASA, the great majority are trade associations and technical societies. Four hundred and eleven technical societies and trade associations carry on standardization activities of sufficient importance to have separate summaries of their work in the Standards Year Book issued by the U. S. Bureau of Standards.

AMERICAN STANDARDS ASSOCIATION

The central clearing house of the national industrial standardization movement in this country is the American Standards Association, which provides the forum by which industry carries its standardization work to the national stage.

The ultimate authority for the policies and affairs of the ASA, which is essentially a federation of national organizations, rests in

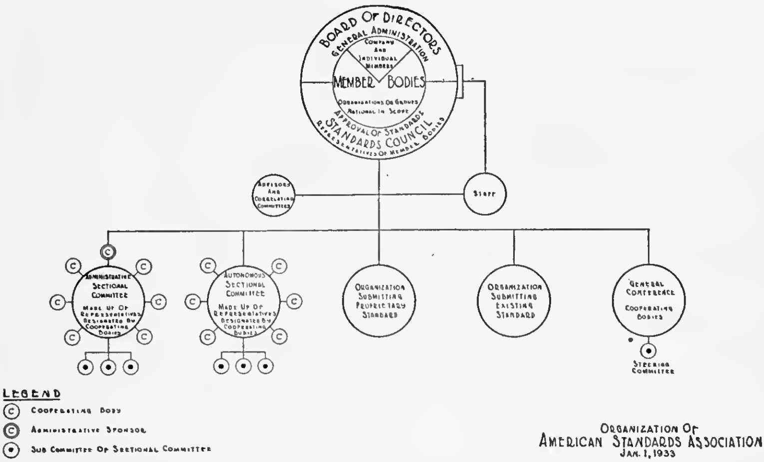


FIG. 1. Organization of American Standards Association.

the hands of the 37 constituent organizations known as Member-Bodies. These include eleven technical societies, eighteen national industrial associations, and eight departments of the Federal Government. Dues for Member-Bodies are $500 a year for each representative on the Standards Council, no Member-Body being permitted to have more than three representatives. Company members pay annual subscriptions based upon a minute percentage of their total annual business.

General direction of the affairs of the ASA is in the hands of a Board of Directors of sixteen industrial executives.

Method of Work.—In its work as an industrial forum or legislature, the ASA brings together all those directly concerned with a project to formulate a workable and acceptable standard, and submit it for approval to the authorized committee representing all the groups having a major interest in the problem in hand—including producers,

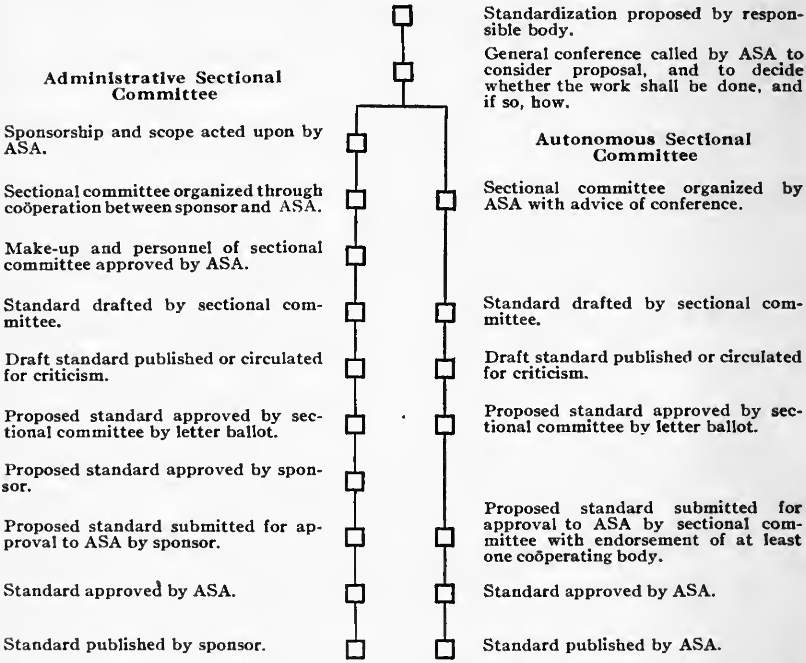


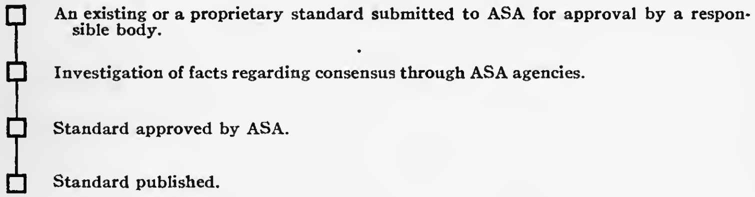
FIG. 2. Development of a standard under sectional committee procedure of the American Standards Association.

consumers, and general interests. When the great preponderance of committee opinion is favorable to the standard in question, it is submitted to the ASA for approval as an American Standard, with the full knowledge that it represents a real national consensus.

Any responsible body, whether a member of the ASA or not, may request the initiation of a standardization project. Opportunity to coöperate in technical work is in no wise contingent upon financial support. A technical staff carries on the central office work in connection with the various projects. The final approval of Standards rests with the Standards Council made up of representatives of the 37 Member-Bodies of the Association.

Some 474 national organizations are officially coöperating in the establishment of American national standards through 2700 technical experts appointed as their representatives.

A Typical Undertaking.—A fine example of the coöperative methods used in national standardization projects relates to specifications for wood poles for power and communication lines, which were drawn up by a technical committee consisting of 40 men representing 23 national bodies. These include representatives of the power, telephone, telegraph, municipal, and steam and electric railway groups, and also such diverse groups as the American Wood Preservers' Association and the Federal Government—all of which



NOTE: Revisions of approved "proprietary" standards are at the discretion of the sponsor. Revisions of approved "existing" standards are made by the sponsor or by the sectional committee to whose charge the standard has been consigned.

FIG. 3. Approval of "existing" and of "proprietary" standards by the American Standards Association.

have a substantial interest in the project. The work was completed on a thoroughly sound basis. Confusing elements intended merely for sales effect were eliminated. Also a false basis of competition between consumer groups was done away with; some of these consumer groups had attempted to rig their private specifications so as to "cut the heart out of the pie," leaving the crust for other groups. The new national specifications have already brought about a much freer national market than ever before existed. The product can now flow from the forest, through the treating plant and into use without having to be earmarked from the beginning for particular consumers. The far-reaching influence on the $60,000,000 industry is indicated by the sale of 30,000 copies of the specifications in a year's time.

Late in 1932 a draft report was issued which contained definitions of some 3500 terms used in all branches of electrical science and industry. On the technical committee in charge of the project, which was initiated in 1928, there are about forty persons representing thirty-three organizations, including national engineering, scientific and professional societies, trade associations, government departments, and miscellaneous groups. This committee has seventeen subcommittees with a total personnel of 120 at work on different phases of the subject, and these in turn have called freely upon nonmember experts, so that in all over 300 men in all the various fields concerned are aiding in the task. An organization chart of the ASA is shown in Fig. 1, and flow charts of the principal methods used in the development of standards in Figs. 2, 3, and 4.

GOVERNMENT ACTIVITY

Various standardization activities are being carried on by the Federal Government which is interested in industrial standardization in two ways: first, as a purchaser it is interested in an extraordinarily wide range of specifications for materials and apparatus; second, through its great research and service bureaus it is interested in innumerable standardization questions.

The Bureau of Standards is the most important of the governmental standardizing agencies. Its activities cover the necessary fundamental scientific research preparatory to the setting up of master standards for units of weights and measures as well as the maintenance of these standards and the derivation of working standards therefrom. Much pure scientific research is involved as well as research of immediate and practical value to industry, such as methods of technical analysis, testing of materials, *etc.* The Bureau acts as technical and scientific advisor on specifications to other departments and to state and municipal governments, and carries on formal liaison work with trade associations and technical societies. Through its Division of Simplified Practice, recommendations leading to the elimination of excessive varieties of products are made, while through its Commerical Standards Unit industry is aided in establishing standards primarily useful in marketing commodities.*

The Bureau of Agricultural Economics of the Department of Agriculture maintains extensive activities in setting up standard grades, inspection, *etc.*, for agricultural products.

The U. S. Food and Drug Administration is charged with the administration of federal acts concerning food, drugs, naval stores, and the like. Fundamental in this work are the U. S. Pharmacopoeia

* See Addendum on p. 279.

and the National Formulary, which are essentially technical specifications for a large number of the more important drugs and medicines. Any drug which is sold by a name or a synonym recognized in the Pharmacopoeia or in the Formulary must conform to these specifications.

The Federal Specifications Board is composed of representatives of the departments and independent establishments of the Federal Government purchasing materials in accordance with specifications. The specifications prepared by the Board are binding upon all government departments, bureaus, agencies, and offices of the government. The extent of this work may be realized from the total of 780 specifications which have been promulgated by the Board.

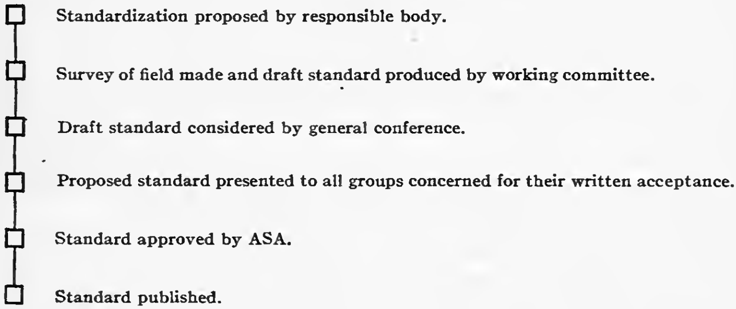


FIG. 4. Development of a standard by the American Standards Association through "general acceptance."

The extent to which departments and agencies of the government are interested in standardization is shown by the fact that in the 1933 issue of the Standards Year Book published by the Bureau of Standards more than one page is necessary in the table of contents to list the various bureaus and departments active in one phase or another of standardization.

The Federal Government is coöperating with industry and the various trade associations and technical societies in their standardization work, and is also tying in with the national movement through the ASA. Coöperative relations between the Bureau of Standards and the ASA are both intimate and active. The Bureau is officially represented on 83 ASA projects, in 14 of which it is taking official leadership. By special coöperative arrangement between the Bureau and the ASA, certain Commerical Standards of the Bureau, at the specific request of the industries concerned, are being submitted to the American Standards Association for approval as American Standards.

INTERNATIONAL COÖPERATION

An important aspect of the national standardization movement is that of international coöperation, which constitutes the fourth and most difficult stage in the standardization process. Naturally, much less has as yet been accomplished internationally than nationally, yet beginnings have been made in several fields and in some of these there has been substantial progress.

Several international bodies are undertaking standardization work in particular fields, and the national bodies are in touch with each other and are interchanging information on many projects in process of development in their respective countries. Through these and other means considerable international uniformity is being brought about in a number of specific subjects.

The International Standards Association is a federation of the national standardizing bodies of eighteen countries, of which the American Standards Association is one. The main object of the international body is to promote uniformity between the national standards of the different countries. Through it an important service has been rendered in the systematic interchange of information between the various national bodies. Some thirty international technical committees have so far been organized.

One of the oldest and most experienced of the international bodies whose primary purpose is standardization is the International Electrotechnical Commission, which was organized in 1906. The Commission consists of national committees in each of the twenty-nine countries represented. Agreements have been reached and published on a considerable number of electrical subjects.

The International Commission on Illumination, which was modeled somewhat after the lines of the International Electrotechnical Commission, was organized in 1913.

The international organization which has the most direct bearing on motion picture work is the International Congress of Scientific and Applied Photography. The S. M. P. E. is coöperating with this organization, which has an American committee.

There are many and serious obstacles in the way of international standards, such as differences in language and industrial background.

On the other hand, there are other important considerations tending to further international coöperation, and a great deal of essential work has been accomplished in the use of fundamental units and methods of measurement, which are prerequisite to nearly all phases of industrial standardization.

Whatever the ultimate outcome may be, it seems that the next step in any case is the same—to develop as full and as free an interchange of information as conditions will permit.

FACTORS FOR CONSIDERATION IN DECIDING WHETHER TO STANDARDIZE

Let us turn now to some of the factors which should be considered in deciding as a matter of policy the attitude of a society or an association toward a particular standardization proposal. Some of these factors are positive and some are negative.

(1) We should never standardize anything merely for the sake of standardizing.

What conceivable merit can there be in uniformity for the mere sake of uniformity? It takes variety and spice from life, it tends to make us walk in lock-step, and is probably one of the chief reasons for the charge that is sometimes made that standardization or even the machine itself is tending to make robots of us all.

(2) We should standardize only when a preliminary analysis of the facts makes it seem fairly clear that doing so may be expected

- *(a) to result in important economies;*
- *(b) to simplify and clarify operations;*
- *(c) to safeguard persons and property from injury.*

Stated in this way we may seem to be drastically restricting the field for standardization, but a little reflection will show that these three categories cover an enormous field.

(*Note:* Let us turn aside a moment to speculate on a phase of social philosophy. These first two principles seem to leave no place for those who are intent on "standardizing our minds." If we accept this easy generalization we are at once swept on to condemn fashions and styles in general—completely and out of hand.

Even more, these principles would condemn not only styles, which play and always have played an unbelievably important role in civilization, but they would as well condemn all other social standards which are also based solely on herd-mindedness—even those folkways which constitute our very strongest social controls, such, for example, as codes of etiquette and moral codes—in so far as these standards are based on herd-mindedness.

While such speculations would carry us to depths which have not been explored from this point of view, one wonders whether such an exploration would not validate the method even in such fields.)

(3) *Standards should as far as possible be planned as a structural part of a coördinated industry, not stuck on as mere patches.*

Unfortunately most industrial standards are as yet of the patch type. It is certain, however, that any fundamental economic planning, whether national, regional, or by industries, must embrace standardization as a basic part of its structure.

(4) *Standards should be developed wherever possible in the logical order, the basic ones and those of most general application coming first, and the more specialized and detailed ones coming later and being based upon the fundamental ones.*

Here again commerical considerations and other realities of the situation often prevent what would otherwise be the most economical and logical order of development.

(5) *Very early consideration should be given to the policy to be followed in the introduction of a new standard into practice. This should be done not only during the process of its formulation, but it should be considered even in arriving at a decision on whether to standardize.*

For example, a company or an industry will frequently find it greatly to its advantage to coöperate fully in the development of a standard, even though it may not be feasible for the company to put the standard into operation immediately. The actual introduction can await an opportune time when other changes make it possible to introduce it economically. Numerous illustrations of this point could be given. For example, some groups are actively coöperating in the new specifications for manhole frames and covers, although they do not expect to adopt them at once, but will rather work toward their introduction at such time as developments make this economical and convenient.

(6) *A standard based on performance requirements is nearly always preferable to one based on construction details.*

The reason for this is that it gives greater freedom in methods of production and frequently stimulates new developments. This is a point which should normally be considered in arriving at the initial decision as to whether a particular piece of standardization work should be undertaken.

(7) *The old idea of making things "special" in order to get the business of supplying parts and making repairs is now pretty thoroughly discredited.*

Under modern conditions such a course usually keeps a firm out of more business than it retains for it. The evolution of industry under mass production methods has outmoded such narrow policies.

(*8*) *Standards dealing with dimensions, specifications, rating, etc., should be sufficiently clear and definite to serve as criteria in determining whether material, work, or products comply with the standard.*

That is to say, the requirements of the standard should be sufficiently sharp to serve as a "go" and a "not go" gauge to accept or reject material, work, or products sold as complying with the standard.

AMERICAN NATIONAL STANDARDS AND ASSOCIATION STANDARDS

"A national standard implies a consensus of those substantially concerned with its scope and provisions.... The basic test to be applied in all cases is the fact of the assent, affirmatively expressed, of the groups having substantial interest in the standard."

This quotation from the first section of the formal procedure of the ASA lays down the fundamental requirements for an American Standard. Approval of a standard by the ASA means that all organizations concerned have had an opportunity to participate in the work, that the work has been carried out under a procedure that has been regular, open, and above board, and that the standard represents a real national consensus on what is best in American industrial practice, and hence that it either already does or may reasonably be expected to play a significant, if not a controlling, role in regard to the materials and processes involved in the standard.

There is a widespread but erroneous opinion that the primary difference between a standard suitable for approval as an American standard and one that should remain a society or association standard is the length of time which is liable to elapse before revision becomes desirable. As a matter of fact, this is a wholly secondary matter. When the ASA was first organized a provision was inserted in the procedure preventing the revision of an American Standard more frequently than once in three years. Experience at once showed that any such a provision was wholly unnecessary and unworkable. The real question is whether industry finds the standard a workable and useful tool. Whenever additional information, new developments, or changing conditions in the industry make it desirable, a revision should be promptly carried through in order that the standard as a tool shall at all times have a good cutting edge.

From the point of view of utility (which is the only reason for setting up a standard) it is immaterial whether a standard be revised in one year or in ten years. Revision should be made when, and only when, conditions make it desirable to resharpen the tool. The National Electrical Code, which is one of the most widely used American standards, is regularly revised once every second year in order to keep it abreast of developments.

It is the business of a gyro-stabilizer to keep the ship on an even keel when it is being buffeted by waves, not to stop the ship. Just so it is the business of a successful standard to help industry to maintain itself in *dynamic equilibrium*, not in a *static* condition. The ASA has for years carried the following statement on the title page of its Year Book:

Standardization is dynamic, not static. It means not to stand still, but to move forward together.

The number of group or association standards is, of course, enormously greater than the number of American national standards, and doubtless will always remain very much greater. This must needs be so, since a vast number of standards are required for highly specialized fields.

As the whole national movement develops, these association standards should be brought into consistency with such national standards as apply to the particular field. Similarly, the standards of individual companies, which in total will be far greater than the number of group or association standards, should in most part be brought into conformity both with the national and with the group standards which apply.

In a great number of cases a standard may be of interest only to a particular consumer interest and to the producer of the product covered. In such cases the standard is likely to remain in the group or association stage. For example, if an American Railway Association specification for locomotive whistles assures a product which is satisfactory to the railways and the manufacturers, there would be little to gain by advancing this specification to the status of American Standard.

It frequently happens that a society or a trade association may wish to assist in carrying out a policy or in bringing about a result by developing a provisional standard which blazes a trail into new territory. This can frequently, but by no means always, best be done by handling the work as an association standard, even though the nature of the work is such that it should be used as a step in the development of a national standard.

There are often situations in which controversies or differences of opinion make it impossible, for the time being at least, to secure sufficient support for a standard for it to attain the status of an American standard. Yet from the point of view of the group, maintenance of such a standard may be desirable, even though lack of support or even opposition makes it impossible to get national recognition.

THE HUMAN FACTOR

The human factor is far more important and far more difficult to handle in standardization work than are the purely technical and industrial sides of the problem. This is widely recognized by those who have had any considerable experience in such work. This applies not only to the negotiations often involving "give and take," necessary in the development of a standard, but to the stage of deciding whether a standard shall be undertaken. The latter is closely connected with the instinctive conservatism, not to say suspicion, of the great majority of men to new developments and ideas.

Standardization is essentially a coöperative undertaking, whether the undertaking be in the company, in the group, or in the national stage. And, whether it be recognized or not, the human factor is preëminently the factor which requires most attention in the administration of any coöperative undertaking. For example, the question of the prestige of an individual, or of a company, or of a society, often overshadows the engineering or even the economic difficulties encountered in the development of a simple engineering standard.

It is unfortunately a fact that as human beings most of our acts are determined by our emotions, when we think that we are making decisions and doing things on a purely intellectual basis.

It seems that the technic of influencing human behavior in such undertakings, which necessarily have to be carried out by conference and committee methods, deserves an almost unlimited amount of study. Perhaps through such studies it may prove possible to transform it from an art into the beginnings of a science. For the present it is essential to remember that true coöperation can only be won; it can not be commandeered.

RESPONSIBILITIES OF PARTICIPATING GROUPS AND INDIVIDUALS

One of the weak points in the whole standardization movement is that the participating organizations and their representatives frequently fail to live up to their responsibilities. Unfortunately, most persons do not fully understand the meaning of representation and the responsibilities which it entails.

It is the duty of each participating organization to carry out with administrative orderliness, competence, and with reasonable promptness, that part of the work for which it has assumed responsibility.

Likewise, each participating organization should assume responsibility before the world for the consequences of the acts of its authorized committees and representatives, scrupulous care being taken that no effort shall be made to shift this responsibility to others or in any sense to "hide behind the skirts" of any other organization or individual.

Furthermore, it is the duty of every representative: (1) to keep sufficiently in touch with his organization, so that he can correctly interpret its attitude in the development of the work and can participate in decisions in committees; (2) to keep his organization informed of developments; (3) to act as a leader in the formulation of the policies of his organization in regard to the matters with which he is dealing; and (4) to refer back to his organization questions upon which he feels unauthorized to speak for it.

As a result of many sad experiences the ASA has included the above principles in a formal statement of the principles under which it operates. Judged by these criteria, the majority of the numerous associations and societies with which it has had contact can not justly claim a consistent record for responsibility.

SUMMARY

Perhaps it may be of advantage to set forth in categorical form what seem to be essential functions in the movement which should be performed by the company, by technical and trade associations, and by the American Standards Association as the national standardizing body.

The Company

(1) Standardization work should be specifically provided for and systematically organized, each department concerned taking an active part.

(2) The company should coöperate actively in standardization work of the trade association and, through it, in the development of national standards.

(3) Conversely, the set-up should be such as to permit an immediate start

in the introduction of each new national or association standard which concerns the work of the company.

(4) The head or heads of the standards organization should act as authoritative spokesmen of the firm in standardization work in their trade association, and should coöperate in the standardization activities of technical societies.

Societies and Associations

(5) Technical and trade associations should have effective machinery for promptly getting a real consensus of all members concerned with a particular subject.

(6) An educational function of the technical and trade associations should be to bring home to their members and to the executives of their member companies the economic importance of standardization, and its significance as a managerial tool.

(7) In consultation with other groups and with the national body, each organization should decide what part of its standardization work is to be handled purely as an association matter on account of the limitation of its scope and influence to one narrow field without reflexes upon other industries, and what part needs coöperation with other groups, from the point of view of national standardization.

(8) The organization should play a thoroughly responsible part, and should require responsibility on the part of its members and committees.

The National Body

(9) In the present state of industrial development a national standardizing body should occupy a pivotal position in the whole industrial standardization movement. As more and more of our industries are becoming so integrated as to function on a national scale, the standardization activities of the company and of the association have arrived at the point where they must head up in a true national movement, centered about a federated clearing-house organization, but one whose functions should extend far beyond mere clearing-house work—a body which should not only strengthen, but which should give a new and broadened impetus and direction to the whole movement, and in particular to company and to association standardization activities.

(10) The national body should provide simple, systematic methods for bringing about acceptable national standards. Its organization and methods should be sufficiently flexible to utilize existing machinery and yet leave free the use of other simple, coöperative methods.

(11) Its methods should make provision so that the organizations within any major division of industry may carry on their standards work more or less as a unit.

(12) In general, each problem should be in the hands of a joint technical committee made up of representatives accredited for the purpose by the various industrial, technical, and governmental organizations concerned.

(13) One of its most important immediate undertakings should be to broaden and unify the great number of existing standards into a consistent system of national industrial standards.

DISCUSSION

Mr. Farnham: When is the proper time to standardize? The question has often come before the Standards Committee of this Society as to whether it should hasten to standardize a certain dimension, when a number of new manufacturers desired to enter the field, or to wait and let the "best man" win. In a particular case, if we standardize a diameter too early, developments may require a very quick change. If we wait for economic forces to bring about unification, it may fail to happen; or if it does, then official standardization on what has already happened will have no meaning.

Dr. Agnew: That depends largely on the state of organization of the industry and the degree of coöperation which is possible. If you have free and active coöperation of all the elements of the industry, official standardization can take place very early. Experience has shown that you should do all the development you can in advance, and then set up a standard with the idea that revision may be necessary next year, or the year after, as development takes place. The assured coöperation will make revision easy. On the other hand, if you do not have real coöperation, you may have to fall back on the competitive method, letting the play of economic forces wreak their way until such time as one or more standards may be agreed upon. That is, of course, a much more costly method, but sometimes the only one possible.

Mr. Beggs: In the lamp socket we have a device that holds many lamps in the course of its life. Is it better to standardize upon the device that is renewable and is consumed, or upon the receptacle into which it fits? Both films and lamps are, for example, consumable products.

Dr. Agnew: That is a case of dimensional standards for interworking parts. Both should be standardized at the same time if they are going to fit together. There may be economies in requiring better workmanship and smaller tolerances on one part than on the other. If a relatively high accuracy, *i. e.*, a smaller tolerance, is provided for the lamp socket, then less accuracy is necessary in the lamp base; and consequently a greater tolerance can be allowed than if the precision of both parts were the same. I think it is clear that the economical way is to require the greater precision in the permanent rather than in the replaceable part; *i. e.*, place the greater burden on the permanent part, and the lesser burden on the replaceable part.

Mr. Beggs: I think I have stressed the lamp socket and the dimensions more than I should. Suppose it is a housing in which the lamp is to be used. It has been argued that if the manufacturers would design the lamp houses to accommodate the standard line of lamps, the users would profit by years of lamp consumption. That is, the burden should be upon the man who makes the lamp house rather than demand that the lamp maker produce a special size of lamp to fit every sort of lamp house.

Dr. Agnew: That is an example of the principle that the more basic standard should be the first to be developed. If we were starting anew, I think the first thing would be to work out a thoroughly satisfactory form of lamp, since it is renewable and is used in much larger numbers; and all housings would then be designed to accommodate that standard lamp. However, we are often faced by the historical fact that it has been done the other way round. This being the case here, I would not attempt to answer off-hand. If the job has gone too far, it will often be necessary to reverse what would otherwise be the normal procedure, since to do so may cost less in the end than to obliterate all that has been done and start afresh, even though that might be the strictly logical course.

MR. SHEA: Is it not almost inevitable that contradiction should come about in many such cases? After all, the lamp was the fundamental invention and not the housing; and the first job of the housing maker was merely to make something to accommodate the lamp. In this case the lamp came first, then the housing.

DR. AGNEW: Just as in England the bayonet instead of the screw base has been adopted. We are here facing the realities of a commercial situation.

ADDENDUM

Since this paper was prepared, the Secretary of Commerce, on July 19, 1933, made the following announcement concerning the standardization activities of the Bureau of Standards:

"Actuated by economy requirements and the desire to place the responsibility for a unified national industrial standardization program in a single national organization representative of both governmental and private interests, arrangements have been completed to transfer certain of the commercial standardizing activities of the Bureau of Standards to the American Standards Association in New York.

"The task of turning over this work of the Divisions of Simplified Practice, Specifications, and Trade Standards, and the Sections of Safety Standards and Building and Plumbing Codes, will be effected gradually under the direction of the Secretary of Commerce and the Director of the Bureau of Standards."

A HISTORICAL SUMMARY OF STANDARDIZATION IN THE SOCIETY OF MOTION PICTURE ENGINEERS*

LOYD A. JONES**

Summary.—*The history of the Society in respect to its standardizing activities is traced from the date of organization, July, 1916, to October 5, 1932. One of the principal reasons for the formation of the Society was "the standardization of mechanisms and practices" employed in the motion picture art, the constant application of which principle has resulted in a large group of standards formulated by the Society for the motion picture industry during the sixteen years of its existence. The standards so formulated have become recognized internationally, and undoubtedly have contributed enormously to the rapid advancement of the art.*

The Society of Motion Picture Engineers was organized at a meeting held in Washington, D. C., in July, 1916, which had been called by Mr. C. Francis Jenkins. The meeting was attended by a group of some ten or twelve men vitally interested in the then relatively young art of motion picture engineering. At this meeting, which may be regarded as the organization meeting, a constitution and by-laws were drawn and adopted, in which the aim of the Society was set forth as "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."

Those responsible for the drafting of this paragraph consciously and wisely made the aims and the purposes of the Society rather broad, providing for a development of activities into many and diverse fields of an industry destined to grow to enormous size and to cover in its activities a wide range of scientific and artistic endeavor. There is little doubt, however, that the one thing uppermost in the minds of those men who formed this Society, the one thing which they considered paramount, of prime importance, and of immediate necessity for the welfare of the industry, was the standardization of materials, mechanisms, and practices. Although the phrase

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* Presented at the Spring, 1933, Meeting at New York, N. Y.

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

in the above quotation relating to standardization does not occupy the first place in the sentence, but is placed secondary in order of mention, all the evidence as gleaned from the early activities of the Society shows that the founders of the organization in mentioning the advancement of theory and practice were really thinking that this advancement was primarily to result in standardization. The history of standardization by the Society of Motion Picture Engineers is therefore of itself the history of the development of the Society.

At the first meeting, so far as the author can learn, only one paper was presented, one by Henry D. Hubbard, which consisted entirely of a discussion of standardization and of the necessity for standardization in the motion picture industry.

At the second meeting, which was held in New York, N. Y., on October, 1916, the officers and directors were elected, Mr. C. Francis Jenkins being chosen as president. At that time the membership numbered twenty-five. The president's address was a plea for standardization, and two out of three papers on the program dealt directly with the standardization of motion picture film and mechanisms. One of these, *Motion Picture Film Perforation*, by Donald J. Bell, of Chicago, Ill., discussed in considerable detail the dimensional characteristics of 35-mm. film. As part of the paper a dimensional drawing was included, which represents the first step taken by the Society of Motion Picture Engineers in the direction of standardization. This drawing is reproduced in Fig. 1. It is interesting to note that the dimensions as proposed by Mr. Bell are those which at the present time remain as the dimensional standards adopted by our Society and, moreover, adopted by the entire world.

Immediately upon the completion of the organization, four committees were appointed by the president. These were not called at that time "standards committees," but, in fact, their chief function was to study their various fields from the standpoint of developing standards. The four committees in question were those dealing with "Cameras and Perforations," "Motion Picture Electrical Devices," "Picture Theater Equipment," and "Optics." No "standards committee" as such existed.

So far as the author is able to ascertain from records available, there was no clause in the original constitution and by-laws, nor has there been in any of the subsequent revisions any clause specifying the mode or method by which the Society shall adopt standards. In the very early days, of course, the membership was small, numbering approximately twenty-five members in October, 1916. It was a simple matter, therefore, for the entire membership to function as a perfect democracy in such important matters as the adoption of standards, and, in fact, such was the custom. The procedure to be followed for the adoption of standards by the Society has at all times been specified by the Board of Governors.

The third meeting of the Society was held at Atlantic City, N. J., April, 1917. Again the president in his annual address reiterated

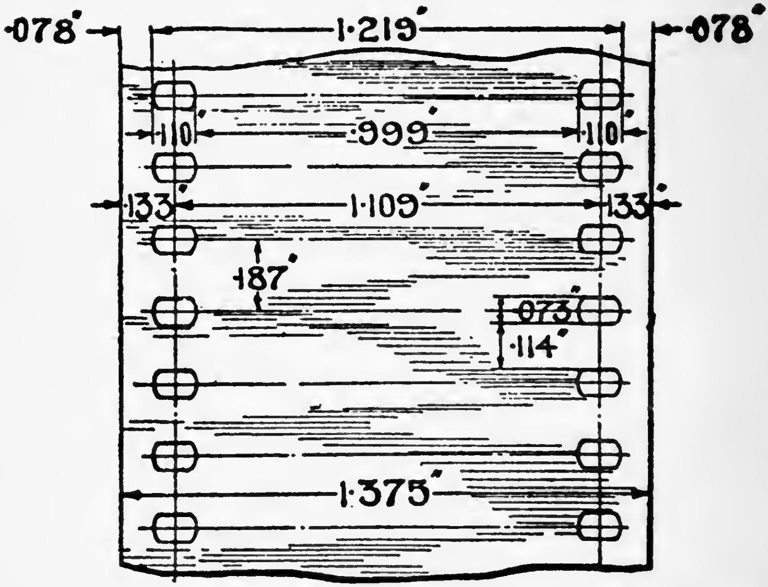

FIG. 1. Reproduced from *Motion Picture Film Perforation*, by D. J. Bell, presented at the second meeting of the Society, October, 1916, at New York, N. Y.

his previous statements as to the prime objective of the Society—that of standardization. For instance, we read, "Now, the prime purpose of the organization of this Society was to standardize our industry. The way to standardize is to standardize. We will not accomplish it all this session, but without leaving this room there is plenty that can be done to help the industry wonderfully.

"There are many looking to us to establish these standards. Most of those who have written to me say they do not care so much what the standards are, being ready to accept any standards so far as they can be assured that it is the consensus of opinion of the engineers of this Society. In fact, they are anxious to do so as they have no other authoritative body to consult.

"So let's get busy now and tabulate the majority opinion of our members on the several subjects to come up for consideration at this session."

In spite of Mr. Jenkins' high hopes that something definite would be accomplished at the Atlantic City meeting toward the establishment of dimensional standards, the records do not show that any standards were actually agreed upon. However, the nomenclature list, which in later years was to assume considerable importance, was initiated; and a list of definitions of some thirty-six words and phrases was "adopted in committee of the whole Society."

The fourth meeting of the Society was held in Chicago, Ill., July, 1917. The president, again, in his opening address reiterated emphatically the pressing necessity for the adoption of standards, and at this meeting the first action by the Society in the adoption of dimensional standards was taken. This first list of standards includes twelve items, as follows: film speed, frame line, projection angle, projection lens foci, projection lens mounting, projection lens height, picture aperture, film perforation, standard picture film, lantern slide mat opening, thumb mark, and lantern strip. The introductory paragraph to this group of standards is interesting; it reads as follows:

> "The following have been adopted as standards by the Society of Motion Picture Engineers, and are promulgated to encourage uniformity and standard practice throughout the industry as a whole. Their early universal adoption will save the industry a great deal of present annoyance and monetary loss."

The various items included in this list were proposed by the standing committees as previously mentioned. Each item was discussed at length by the whole Society and each standard was voted on separately by the entire Society, the list as published being prefaced by the remark "adopted in committee of the whole Society."

Fig. 2 shows the drawing which was adopted as a part of this group of standards. This conforms precisely to the dimensional drawing presented as a part of Mr. Bell's paper at the October, 1916, meeting, and all dimensions shown thereon are in agreement with the present standard.

The fifth meeting of the Society was held in New York, N. Y., October, 1917, and at that time a few additional items were standardized, again the adoption being "by committee of the whole society."

In about 1917 or 1918, the demand for portable motion picture equipment became insistent. Due to the inflammable nature of the nitrate film which was universally used for standard 35-mm. film, rather stringent restrictions were placed on the use of this film outside of fire-proofed "booths." Cellulose acetate base, at that time referred to as non-inflammable film, was available, and it was proposed that only this should be used in portable equipment.

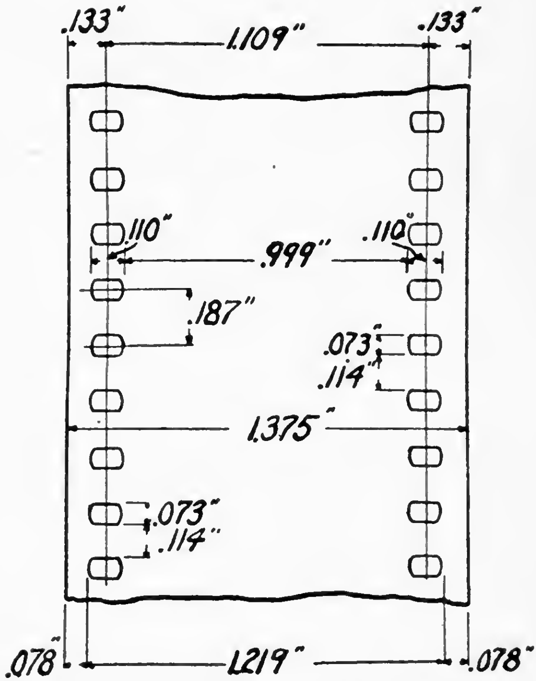

FIG. 2. Reproduced from report on standards approved by the Society at Chicago, Ill., July, 1917.

At the sixth meeting of the Society, held in Rochester, N. Y., in April, 1918, Mr. A. F. Victor presented a paper on *The Portable Projector; Its Present Status and Needs*, in which he made a strong plea that the Society establish a substandard film width and that this be made only on non-inflammable base. In Fig. 3 is shown the original dimensional diagram proposed by Mr. Victor in the communication mentioned. The *Transactions* of the Society do not contain a definite statement that this dimensional standard was accepted at the April, 1918, meeting, but, according to a statement by Mr. W. B. Cook, in a paper presented at the Cleveland meeting (November, 1918) and published in *Transactions* No. 7 (p. 86) this action was actually taken, "At the last meeting in April at Rochester your Society adopted a new size of narrow width, slow burning film as the standard for all portable projectors." In the *Transactions* No. 10, 1920, p. 5, the standards "adopted in committee of the whole

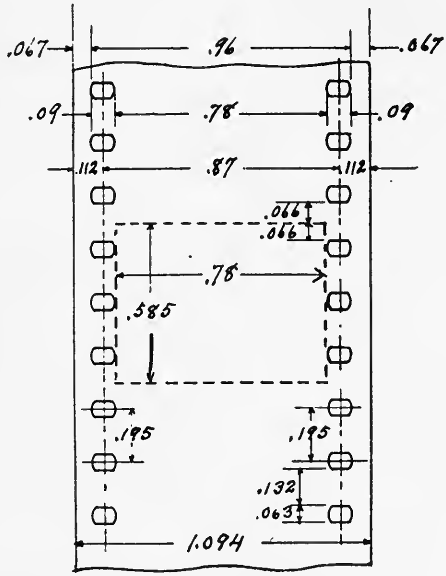

FIG. 3. Original dimensional diagram for sub-standard film, reproduced from *The Portable Projector; Its Present Status and Needs*, by A. F. Victor, presented at the sixth meeting of the Society, at Rochester, N. Y., April, 1918.

Society" were again published and this list contains for the first time a diagram for the 28-mm. "safety standard" film as an officially adopted standard.

Until this time no committee to deal specifically with standards had been appointed but, in fact, practically all the committees were working upon matters of standardization. Moreover, each standard was adopted after discussion by the whole Society. Such procedure worked very satisfactorily as long as the membership of the Society was fairly small and practically all members attended all meetings at which the standards were decided upon. By 1921 the membership had grown to about eighty, and this method of adopting standards began to be cumbersome and unsatisfactory.

In May, 1921, the Board of Governors passed a resolution creating a standardization committee, and at about the same time the board also passed a resolution that negotiations be opened with the American Engineering Standards Committee and an effort be made to have that body recognize the standards adopted by the Society of Motion Picture Engineers. Shortly after the May, 1921, meeting, the first standards committee was appointed; the members of this committee were W. E. Story, Jr., *Chairman*, A. R. Dennington, A. C. Roebuck, and A. F. Victor.

At about the same time it was found expedient to alter the procedure by which standards were adopted, and the Board of Governors passed a resolution providing that recommended standards should be presented to the Society and receive tentative approval at a regular stated meeting of the Society, and that after a lapse of six months these standards should again be presented to the Society and receive final validation. This procedure was adopted with the idea that it would prevent the too hasty adoption of proposed standards which might possibly be ill advised, and that it would give all members an opportunity to know just what was going on in the standardization work.

The first report submitted by the standards committee, published in *Transactions* No. 13, 1921, p. 160, dealt largely with the question of submitting the 35-mm. standard and safety standard film dimensions for approval to the American Engineering Standards Committee.

Following its organization, the first standards committee became very active, and during the subsequent year or two the previously adopted standards were revised to some extent, this revision in most cases consisting not of actual changes but merely changes in the form of expressing the standards. Due to the procedure prescribed for the adoption of standards, progress was slow, and some confusion exists in the records as to the exact date on which some of these standards were finally and officially adopted.

Late in 1923, the newly elected president appointed a new standards committee consisting of L. C. Porter, *Chairman*, J. G. Jones, H. Kellner, F. F. Renwick, and F. H. Richardson. The same committee was given responsibility for nomenclature, the committee being called the "Committee on Nomenclature and Standards." In spite of the great care that had been exercised throughout the Society's life in the adoption of standards, certain minor inconsistencies had been perpetuated and, in order to clear up the matter, the new standards committee, under Mr. Porter's direction, made a complete study of the entire work beginning with the formation of the Society.

In *Transactions* No. 18, May, 1924, p. 236, a detailed report was made on the status of the standards at that time and, in order to clarify the whole situation, all standards with regard to which any doubt existed as to their having been officially adopted by the Society and all those requiring modification in any detail were redrafted and presented to the Society at the May, 1924, meeting. The dimensional standards for newly cut and perforated film were prepared in the form of dimensional diagrams, including standard 35-mm. positive film, standard 35-mm. negative film, safety standard, 28-mm. positive and negative film, and standard 16-mm. positive and negative film. The 16-mm. film for amateur use had been introduced to the trade shortly prior to this date, and this represents the first recognition by the Society of the dimensional standards for this material.

For some little time prior to this date various proposals had been made to modify the form of the perforation, especially for use on standard 35-mm. positive film. It was maintained by some that the use of perforations with rounded corners afforded better wearing quality in the case of positive film. Evidence supporting this contention seemed very strong and the Standards Committee, on the date mentioned, therefore proposed the adoption of the rectangular perforation with rounded corners as standard for 35-mm. positive film. At the May, 1924, meeting, however, the Society was not prepared to give this proposed change its initial approval and the question was referred back to the standards committee.

The other proposed dimensional standards for film were given initial approval. The dimensional diagrams in question will be found in *Transactions* No. 18, May, 1924, p. 238.

At the following meeting, October, 1924, the Society gave its final approval to all of the standards which had been accepted at the previous meeting. The question of positive film was again taken up and the Society gave initial approval to the proposed dimensions, with the exception of perforation size and shape. Agreement could not be reached on this and the matter was referred back to the committee. One other point which had been under discussion for some time was the maximum cutting width for 35-mm. film. At this meeting (October, 1924) the Society gave its initial approval to 1.378 inches instead of the 1.375 inches, thus making this width correspond as precisely as possible to 35-mm. rather than to $1^3/_8$ inches.

The committee had made a careful study of camera and printer apertures, the projector aperture having already been standardized as 0.725 inch high by 0.950 inch wide. At the next meeting, May, 1925, the question of camera and printer apertures was again raised, but the Society refused to give final sanction and it was referred back to the committee.

In the latter part of 1925, the incoming administration appointed a new standards committee consisting of J. G. Jones, *chairman*, H. P. Gage, H. Griffin, L. C. Porter, F. H. Richardson, C. M. Williamson, and C. A. Ziebarth. It is interesting to note that as the Society grew in membership, the number of individuals on the standards committee was steadily increased. This was done in an effort to make the standards committee represent as many as possible of the diverse interests and special fields.

At the meeting held in October, 1925 (*Transactions* No. 24, p. 5), the question of shape and size of perforations for positive film was again raised. The committee had consulted with the English, German, and French interests, and as a result of this correspondence it was decided to recommend the adoption of two forms of perforation for positive film, one known as the Kodak standard and the other the Pathé standard. The Society at that time gave its first approval to these two standards.

The committee also had given exhaustive study to the problem of standardizing sprockets for film handling mechanisms but was not prepared at that time to make a final recommendation. The same subject was discussed again at some length at the October, 1926, meeting (*Transactions* No. 27, p. 20). Tentative dimensions for sprockets of various types had been formulated which were based largely on an exhaustive study of the subject by Mr. J. G. Jones (*Transactions* No. 17, October, 1923, p. 55). No definite recommendations were made, however, by the committee at that meeting and hence no formal action was taken.

At the following meeting, April, 1927 (*Transactions* No. 30,

p. 402), the second and final approval was given to the Kodak-Pathé perforations for positive film. The proposals for standardization of sprockets were put into final form and the Society voted to give these proposed dimensions the initial approval. This proposal involved somewhat different dimensions for feed and take-up sprockets, since it was pointed out by the committee that these sprockets function under somewhat different conditions and most perfect handling of film could be achieved only by using sprockets of slightly different dimensions. Camera and projector apertures were again discussed but the dimensions proposed by the committee were not accepted.

At the September, 1927, meeting (*Transactions* No. 31, p. 443), the Society gave its second and final approval to the sprocket dimensions previously accepted. At this time the camera and projector speeds for use in connection with sound film were first discussed, but no definite recommendations were made by the committee.

At the meeting held in Hollywood, April, 1928 (*Transactions* No. 34, p. 258), a complete summarized report of standards adopted up to that time was prepared and published in the *Transactions*, and, in addition, dimensions for the three varieties of 16-mm. sprockets (feed, take-up, and combination) were presented and received the first approval of the Society. The committee prior to this meeting had given considerable study to the standardizing problems arising as a result of the introduction of sound into the motion picture industry, but opinion had not sufficiently crystallized to permit the formulation of definite proposals for dimensional standards.

Some months prior to the April, 1928, meeting, contact had again been made with the American Engineering Standards Committee. All the dimensional standards and recommended practice which had been formally adopted by the Society had been collected and published in a booklet which was submitted to the American Engineering Standards Committee and received that body's approval April 9, 1928. This booklet represents the first publication by the Society, outside of its *Transactions*, of its dimensional standards and recommended practice.

In September, 1928 (*Transactions* No. 36, p. 899), dimensional standards relating to 16-mm. sprockets, camera, and projector apertures, and 16-mm. splices, which had received the first approval at the preceding meeting, were again presented to the Society and received the second necessary approval. In the report presented at that time, tentative dimensional standards for 35-mm. sound-film positive were discussed but no definite recommendation was made by the standards committee for adoption.

At the May, 1929, meeting (*Transactions* No. 37, p. 29), the committee presented to the Society proposals for standardization of taking and projecting speed for sound pictures, a dimensional drawing indicating the position of the sound track, and a definition of the term safety film. All these were given the first approval by the Society.

The procedure as set forth by resolution of the Board of Governors for the adoption of standards had proved to be very cumbersome and a source of great delay in the prompt adoption of standards. On the recommendation of the chairman of the standards committee, the Board of Governors on July 26, 1929, passed a resolution modifying this procedure. It reads as follows:

"Resolved that the Standards and Nomenclature Committee shall prepare and present their report and recommendations at a convention. After this report shall have been thoroughly discussed, the report with discussions shall be published in the first issue of the *Transactions* following the convention. Approximately two weeks after the distribution of these *Transactions*, a letter ballot shall be sent to the active membership."

The adoption of any proposed standard depended upon the receipt of a majority affirmative vote, and no second approval was required. It was thought that this method would appreciably accelerate the action of the Society in the adoption of proposed standards and, at the same time, would also give an opportunity to members unable to attend the convention to vote and express an opinion as to the wisdom of the proposed standards.

During 1930, the official standards booklet was brought up to date by the addition of those standards which had been approved by the Society subsequently to the publication of the standards booklet mentioned previously. This booklet, the contents of which were published in the JOURNAL of May, 1930, p. 545, was submitted to the American Standards Association, which was the new name of the organization previously operating under the title of American Engineering Standards Committee. The standards contained therein were approved by the American Standards Association on September 28, 1930.

During 1930, the problem of standardizing a film wider than the standard 35-mm. material was given lengthy study by the committee, but no definite recommendations were made or action taken.

The procedure for the validation of standards as set up by the Board of Governors in the resolution passed July 26, 1929, continued in force until May 8, 1932. On that date a letter addressed to President Goldsmith, by M. C. Batsel, chairman of the standards committee, which had been formulated as a result of a lengthy discussion by the standards committee, pointed out that the procedure was still too complicated and involved unnecessary delay in the validation of standards. It was the opinion of the standards committee that the necessity of presenting a report on standards at a meeting of the Society might on occasion cause undue delay in the adoption of standards. As a result of this letter, the Board of Governors, on the date mentioned, rescinded the action of the board taken on July 26, 1929, which prescribed the mode of adopting standards. The Board of Governors then passed a motion as follows:

"The Standards Committee shall prepare a formal resolution, proposing in detail the method of validating and approving standards, to be presented at the next convention; but that the present report of the committee, to be presented at this convention shall be presented for validation in the manner prescribed in the Minutes of the Board of Governors' meeting of July 26, 1929, on page 4."

The standards committee, acting in accordance with the above motion, presented to the Board of Governors on July 7, 1932, a proposal for improvement in the technic of validating standards. After a somewhat lengthy discussion by the Board, the following motion was made and passed:

"The Board of Governors will consider proposals of the Standards Committee that are supported by a three-fourths recorded affirmative vote of the ballots received from members of the committee within thirty days after the date of mailing those ballots to the entire membership of the committee. The Board may then accept or reject the report. If accepted, the report will be published in the JOURNAL, accompanied by an invitation to members of the Society to submit their comments. At the next meeting of the Board of Governors, not sooner than thirty days after the appearance of the report in the JOURNAL, the Board may consider the comments received from the membership and take final action upon the validation of the proposals for standardization."

The action of the Board of Governors was communicated to the standards committee and evoked criticism from some members of that body. These members felt that the procedure still was somewhat cumbersome and that the likelihood of holding up the adoption of standards still existed. It was felt by them that to demand a three-fourths vote of the members of the standards committee voting, in order to obtain publication of a proposal favored by a majority of the committee, might, in some cases, result in unfortunate delay. Moreover, the procedure required an initial and a final approval by the Board of Governors. It seemed doubtful whether this would be much more expeditious than requiring an initial and final approval by the Society. The standards committee, through its chairman, M. C. Batsel, therefore, again communicated with the Board of Governors, setting forth its objections to the resolution as passed and suggesting certain changes. This letter was considered by the Board in its meeting October 5, 1932, and as a result a motion was made and passed that the method of validating and approving standards be reconsidered. A motion was then made and passed which reads as follows:

"That a majority affirmative vote of letter ballots received within thirty days on specifically stated recommendations of the Standards Committee shall be authorization of early publication of corresponding material in the JOURNAL, together with an adjoined request for comments from all those interested. It should be the duty of the office of the Society to bring to the attention of the Board at its earliest meeting, all communications relative to the published recommendations. Such recommendations, if later approved by the Board, shall be re-published as S. M. P. E. Recommended Practice."

This paper, as indicated by its title, is intended to be a historical summary of the standardization work of the Society. An attempt has been made to fix, as nearly as possible, the dates of the adoption of the more important dimensional standards. Other items falling within the category of dimensional standards and many other actions in the general category of standardization, such as recommended practice, nomenclature, *etc.*, have been taken by the Society from time to time. The last issue of the standards booklet, which has been mentioned previously, published in 1930, and which has received the approval of the American Standards Association, may be regarded as an authentic collection of all the standards which had been officially adopted up to the time of its publication. The author regards the publication of the 1930 Standards booklet as terminating the period with which this report is intended to deal. Standardization occurring subsequently to the publication of the booklet is regarded as current rather than historical, and something, therefore, to be dealt with more appropriately by the current standards committee rather than in a historical summary.

DISCUSSION

MR. CARVER: Has there been any close coöperation between this Society and the European societies in international standardization?

MR. JONES: We have been in contact with them from time to time, but the contact has not been close and the coöperation has not been good. The problem of bringing standardization to the international stage is probably much more difficult than bringing it to the national stage. The differences of language and the difficulties of communication, the lack of actual meetings at which the men can talk things over, make it much more difficult to reconcile differences of opinion which in many cases are very slight and immaterial.

The only organization through which we have been able to operate at all in the direction of international standardization is the International Congress of Photography, which meets at intervals of several years, depending upon conditions. The organization of the International Congress is rather loose, and for some reason or other we have not succeeded in actually setting up a smoothly working arrangement to bring forward international agreement.

SOUND FILM PRINTING*

J. CRABTREE**

Summary.—*The production of sound-film prints from variable density negatives by the Model D Bell & Howell printer has been studied from the point of view of high-frequency response and uniformity of product. Differences in frequency response are noted between prints made in different commercial laboratories. Individual prints in the majority of cases show variations in unmodulated track density and in the amplitude of wave envelope at high frequencies. The former are due chiefly to irregularities in the film drive and possibly to some extent to variations inherent in film.*

The effect of simple mechanical filtering by the addition of a flywheel is discussed. High-frequency wave envelope irregularities result from momentary loss of contact at the printing aperture. The influence of threading, gate adjustment, printing speed, air pressure, type of illumination, degree of shrinkage, and variations in aperture height are discussed. The changes in high-frequency response produced by modifications of mechanical parts do not cover the range of difference observed among commercial prints. A part of this difference in loss characteristic is likely to be found in the developing operation.

It is known that a sound print may show a loss of photographic definition as compared with the definition of the negative from which it is made. This condition will result in a loss of modulation increasing in amount with the frequency.

The extent of the loss appears to be indefinite, and few statements relative to it can be found in the literature. Lewin† states "the loss at 6000 cycles is at least 4 db." Verbal expressions of opinion by other observers in commercial studios confirm such a figure and imply that the loss is variable, the variation not being ascribable to any known cause. In a series of frequency prints made from negatives exposed in the Sound Picture Laboratory of Bell Telephone Laboratories, Inc., but developed and printed in several commercial laboratories, the loss at 7000 cycles, derived from a comparison of the frequency response of negatives and prints, varied from zero to 8 db. This loss of amplitude is usually attributed to the printing process;

* Presented at the Spring, 1933, Meeting at New York, N. Y.

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

† *Electronics*, January, 1931.

but it can not be assigned wholly to that cause since some loss of definition in the print must occur because of the limit of resolving power inherent in positive emulsion.

The greater proportion of sound prints produced in the motion picture industry are made on the Bell & Howell Model *D* continuous printer; therefore, in experiments that were conducted to determine the extent and cause of printing loss, and the possibility of its being reduced, our attention was confined to that make of printer with the

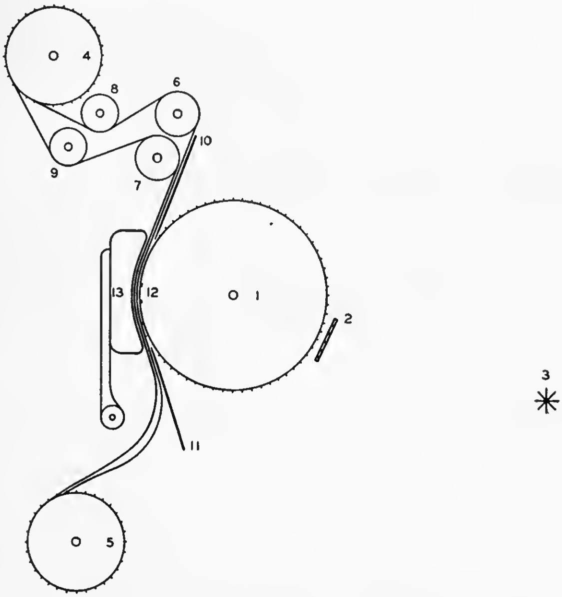

FIG. 1. Schematic arrangement of Bell & Howell Model *D* continuous motion picture printer.

idea that the findings would be directly applicable to commercial laboratory practice and with the expectation that conclusions could be drawn with regard to the fundamental problems involved.

The B & H printer consists essentially of a split sprocket *1* (Fig. 1), a portion of the periphery of which is illuminated by light from the diffuse light source *2*. The effective area of *2* is controlled by a diaphragm and is illuminated by the source at *3*.

In addition to the above are the sprockets *4* and *5*, the idlers *6* and *7*, and the weighted idlers *8* and *9*. The area of film illuminated is restricted by means of plates *10* and *11* and an aperture at *12* consisting of a pair of jaws having the same curvature as the sprocket *1*. The mechanism is so housed that light reaches the negative and positive films only at the aperture *12*. A polished steel shoe *13*, the face of which has the same radius of curvature as the printing sprocket, is held by appropriate means against the rear surface of the positive film and at a distance from the sprocket that can be varied by an adjusting screw. The sprocket *1* is driven by means shown in Fig. 2.

The negative and positive films are propelled past the light aperture by the sprocket *1*, the leading edges of the perforations being held against the faces of the driving teeth by the tension effected by

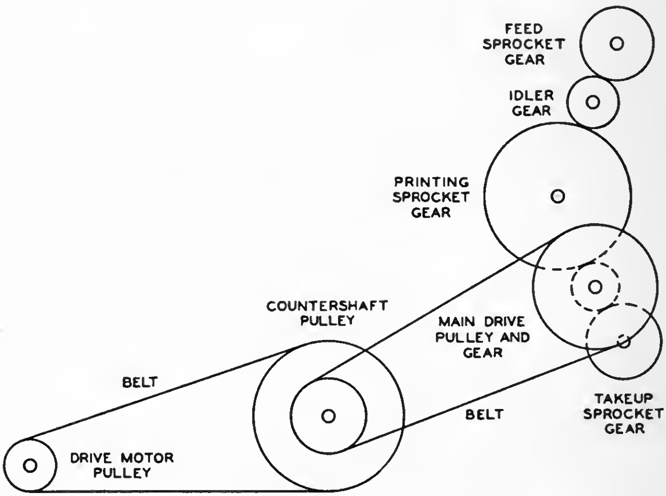

FIG. 2. Mechanical drive system; Bell & Howell Model *D* printer.

the weight of the idlers *8* and *9*. The films are also held in contact by this tension and presumably by the contact of the shoe *13*. The paths of negative and positive films are shown on Fig. 1.

In the experiments to be described two stock B & H Model *D* printers were employed; and, except where indicated later, no changes were made in the mechanism. In certain motion picture laboratories printers are dismantled and the mechanical parts checked and corrected, when found necessary, before being placed into service. For the present purpose, however, it was considered preferable to study the machine as received from the manufacturer.

In choosing the type of negative image to be used in making the experimental prints it is obvious that a modulated film with a perfectly defined image would be best. It would be difficult to produce such a film and to translate the results of such tests into quantitative terms applicable to sound recording. In order to make the results of more practical value it was decided to use constant-frequency records of the variable density type for the negative image and to consider the high-frequency response of the positive made therefrom as a measure of the effectiveness attained at the printer.

Negatives of different types were used, varying from those made with the standard recording system at constant input to equalized negatives made with a recently developed recording objective of improved design. The range of frequency covered was 500 to 9000 cycles. The prints were made on Eastman positive film and developed in Eastman *D16* developer in an Erbograph machine, all operations being conducted in the Sound Picture Laboratory of Bell Telephone Laboratories.

Frequency measurements were made in a re-recording machine, the output being measured both by vacuum tube voltmeter and by thermocouple and milliammeter.

The first requirement in a contact printer is that perfect contact between the negative and positive films be effected to ensure that no spreading of the printed image takes place, as will occur when space exists between the two emulsion surfaces.

It is known that contact between two pieces of film is best attained at the printer gate by bending the films together longitudinally at the region of the printing aperture. By reason of the properties of sheets of materials, curvature in the transverse direction is thus prevented and under, the correct conditions, contact of the two films may be assured.

This principle is embodied in the B & H printer; but the question remains, in view of variations among commercial prints, whether perfect contact is attained and whether imperfections in the surfaces over which the films pass do not militate against the desired condition.

When the printers under observation were threaded in the usual way, the gate assembly removed, and the film at the aperture viewed with a low-power microscope while the machine was in operation, it was seen to flutter irregularly. The same fluttering could be seen with the gate in place—a window being cut in the side of the shoe to permit observation—except when the gate clearance was quite small.

Mechanical Adjustment.—Loss of contact during operation being thus suggested, prints were made (*a*) under varied conditions of loop settings, such as might be expected to result from faulty threading, and (*b*) with different gate clearances and adjustments. Measurements of the frequency characteristics of the prints showed:

(*a*) *Loop setting.* That no difference in high-frequency response could be detected between prints made with different settings of upper and lower loops except in one case, wherein no tension existed in the upper loop with a shoe setting of 85 mils' clearance, when a loss of 2.5 db. at 7000 and 9000 cycles resulted. The same tension condition with 37 mils' clearance showed no loss from the normal conditions.

(*b*) *Shoe setting.* That no difference in high-frequency response could be detected between prints whether made with a tight or slack gate (up to 85 mils' clearance), or with a wrongly adjusted shoe that made contact with the film on one side only.

It would appear from these results that, in general, losses of high frequencies are not likely to occur in printing through maladjustment of the printer gate or errors in threading, and that contact is maintained under quite widely varying conditions. That loss of contact between negative and positive does cause a loss of high frequencies in this printer was established by making prints definitely separated from the negative by interposing different thicknesses of film base. Separations of 5, 10, and 15 mils were used in printing a negative recorded on the standard Western Electric System, resulting in losses at 9000 cycles of 2.5, 4.0, and 5.0 db., respectively, greater than those from the regular print.

Air Pressure.—Though these results suggest that loss of contact is not easily attained in the normal operation of the Bell & Howell printer, they do not demonstrate that the contact is perfect and can not be improved. A series of experiments was therefore conducted in which the positive and negative were forced against one another under air pressure in an endeavor to improve the contact.

In certain commercial laboratories, air pressure is applied to the base side of the positive films to ensure contact with the negative. Where this is done, some modification of the gate or aperture has usually been made, so that the results of the following experiments do not necessarily apply to such cases.

A brass shoe was constructed, identical in contour with the stock shoe, but perforated with three $^1/_{16}$-inch holes having $^1/_{32}$-inch separations immediately opposite the gate aperture at the location of the sound track. These three holes were suitably connected to an air pressure line. On the negative side, an air jet with a $^1/_8$-inch orifice was arranged so as to direct a stream of air on the negative at a point immediately opposite the jets from the shoe. Both air lines were provided with valves and gauges. In this manner air pressure could be applied in any desired amount to either the positive or the negative or to both, at the point where the printing was being effected. Prints were made from a high-quality negative at a film speed of 60 feet per minute. In the following table the pressures shown are in pounds per square inch in the pipe supplying the jet in question.

AIR PRESSURE
(*in Pounds*)

	Negative Side	Positive Side
1	0	0
2	2	0
3	7	0
4	16	0
5	0	2
6	0	7
7	0	16
8	2	2
9	7	7
10	16	16

Two series of prints were made: one with a gate clearance of 13 mils and one with a clearance of 37 mils. In no case was any measurable difference of frequency response noted, leading to the conclusion that forcing the film together by air under the pressures used does not improve the contact in a stock model Bell & Howell printer.

Static Prints.—In all the above tests no method has been indicated by which the contact may be improved. It does not follow, however, that the normal print produced by this machine is a "perfect" print in so far as the contact is concerned. A comparison was made, therefore, between prints made in the printer and so-called "perfect" prints made statically under conditions of contact and illumination that probably could not be surpassed in a continuous printer.

Two methods were employed, both utilizing a printing frame in which short lengths of negative and positive were held in static contact under pressure. Exposure was made to a point source at a distance ensuring nearly parallel light.

In the first method 6-foot lengths of constant frequency negative were used, carefully aligned with corresponding lengths of positive and exposed, in a Cirkut printing frame, to light from a 250-watt projection bulb at a distance of 60 feet. These exposures were spliced together and developed in the developing machine along with prints from the same sections of negative made in the Bell & Howell printer. The resulting positives were run through the re-recording machine at one-third the normal speed, and the output measured by a volume indicator in the usual way.

In the second method one-inch sections of the various frequencies of the negative were cemented to the glass of an 8- × 10-in. printing frame in correct alignment (Fig. 3). Positive film was placed in contact with the negative assembly, the back of the frame plated in position, and exposure made to the light of a 3-cp. automobile lamp at a distance of 8 feet in a black-velvet-lined tunnel to ensure specular illumination.

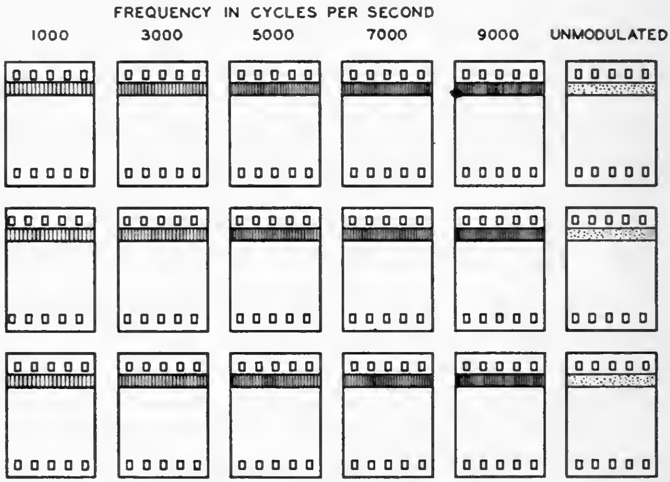

FIG. 3. Method of mounting negatives for production of static prints.

A number of exposures were made, spliced together, and developed along with the corresponding prints made in the Bell & Howell printer. These latter were from 12-inch sections of the negatives immediately adjacent to the portions selected for the printing frame exposures. These sections were spliced together, printed with a close gate setting, and developed along with the printing frame exposures. The frequency response of the resulting prints was derived from their microdensitometric traces, the response being computed from the amplitudes of the wave envelopes. A specimen record made in this manner is shown in Fig. 4.

Three different types of negatives were examined in the above manner. In each case the printing frame print gave a slightly higher response than the print obtained from the Bell & Howell printer, the maximum difference shown being 1.5 db. at 9000 cycles. This difference, however, is not greater than the loss that would be expected to result from slippage in the printer due to the pitch dimensions of the negative, positive, and printing sprocket (negative shrinkage 0.21 to 0.27 per cent, positive raw stock 0.16 per cent) and from the type of illumination employed.

The conclusion is therefore indicated that the printing losses observed are not due to loss of contact in the printer.

It was noted, however, that when prints were made with greater clearance between the shoe and the gate, the envelopes of the wave of the high frequencies, as recorded by the microdensitometer, exhibited occasional constrictions. More extended records were,

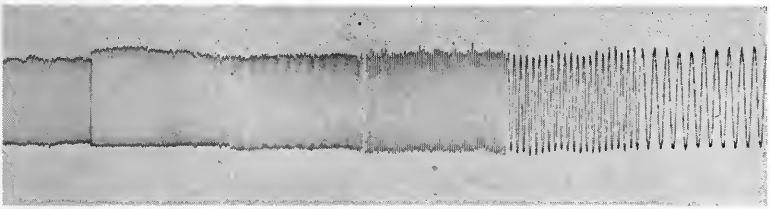

FIG. 4. Specimen microdensitometric record for measurement of frequency response.

therefore, made to determine the nature of these constrictions. From the prints made in the printer it was observed that the envelopes of the higher frequencies were quite irregular, the extent of the irregularities increasing with the frequency. Scannings of sections, three frames in length, of such a print are shown in Fig. 5 for the frequencies shown. The constrictions are obviously not due to density variations but result from a loss in modulation, *i. e.*, a blurring of the positive image, since microdensograms of the negative from which the print was made showed no such losses (Fig. 6). This blurring can not be a result of slippage due to shrinkage since such an effect would be periodic with a frequency equal to that of the perforations and of very short duration, whereas the losses in question extend over as much as half a frame in length. They are, therefore, probably due to momentary loss of contact between negative and positive at the printer aperture.

An effort was made to determine whether it would not be possible to prevent the loss of contact by mechanically forcing the films to-

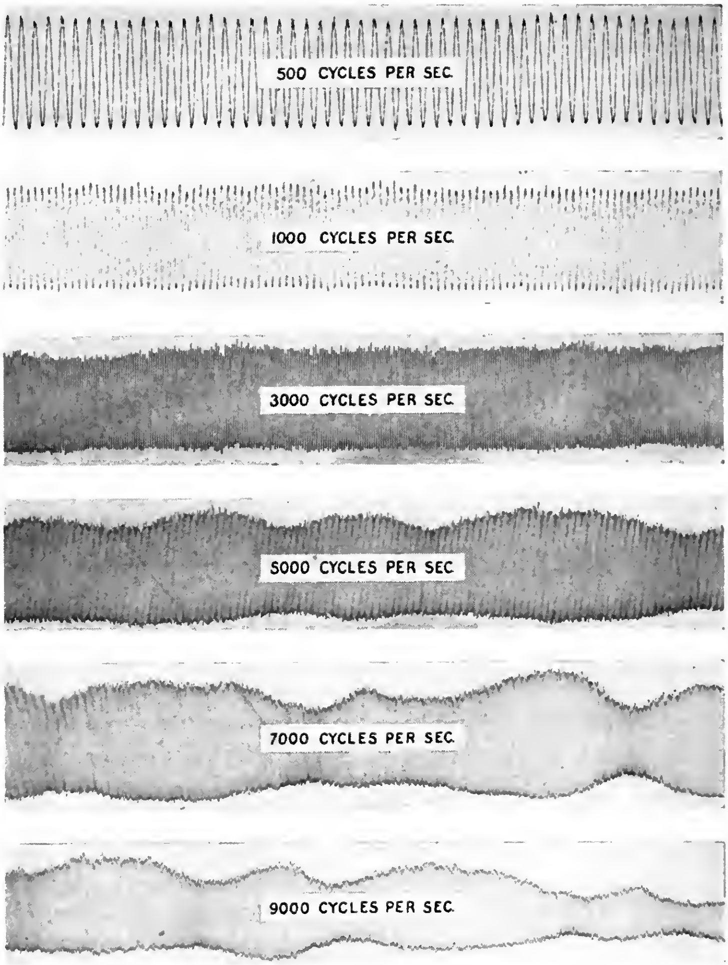

FIG. 5. Relation of print irregularities to frequency; each frequency to be developed as shown on diagram, *i. e.*, 500, 1000, 3000, 5000, 7000, 9000 cycles, in order from top to bottom.

gether. From a number of tests it was found that operation of the printer with the shoe set for no clearance (*i. e.*, riding on the base of the positive) gave an improved envelope. Equally good was the case wherein the shoe was removed entirely and pressure applied by the finger to the base side of the positive at the aperture over the

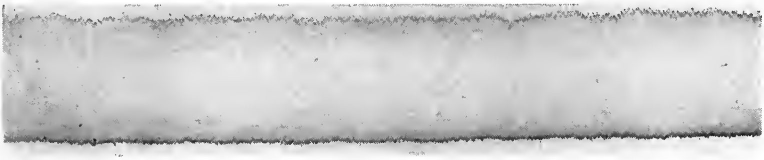

FIG. 6. Negative; 9000 cycles.

sound track region. Fig. 7 shows representative records of these conditions; also of normal operation, and of operation without shoe or pressure of any kind.

It is important to determine how prevalent are the above-described

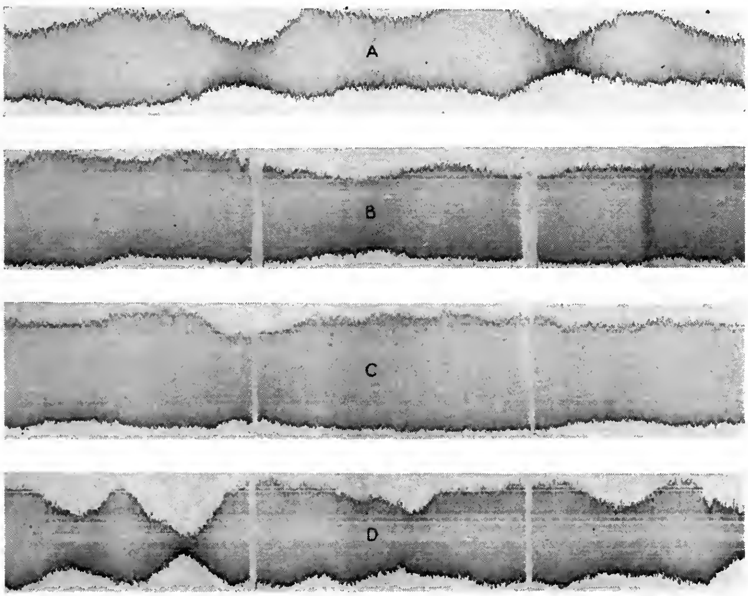

FIG. 7. 9000-cycle prints: (*A*) gate clearance, 18 mils; (*B*) no gate clearance; (*C*) no shoe, pressure by finger at aperture; (*D*) no shoe, no pressure.

defects in prints made in commercial laboratories. A series of prints was available, made in the Fall of 1931 by twelve commercial laboratories on the east and the west coasts from a frequency negative recorded in the Sound Picture Laboratory. Unfortunately, the highest frequency usable for the purpose of scanning was 5000 cycles, a much less sensitive index than the 9000-cycle records in Figs. 5, 6, and 7. Microdensitometer graphs of 3-frame sections of these prints are given in Fig. 8.

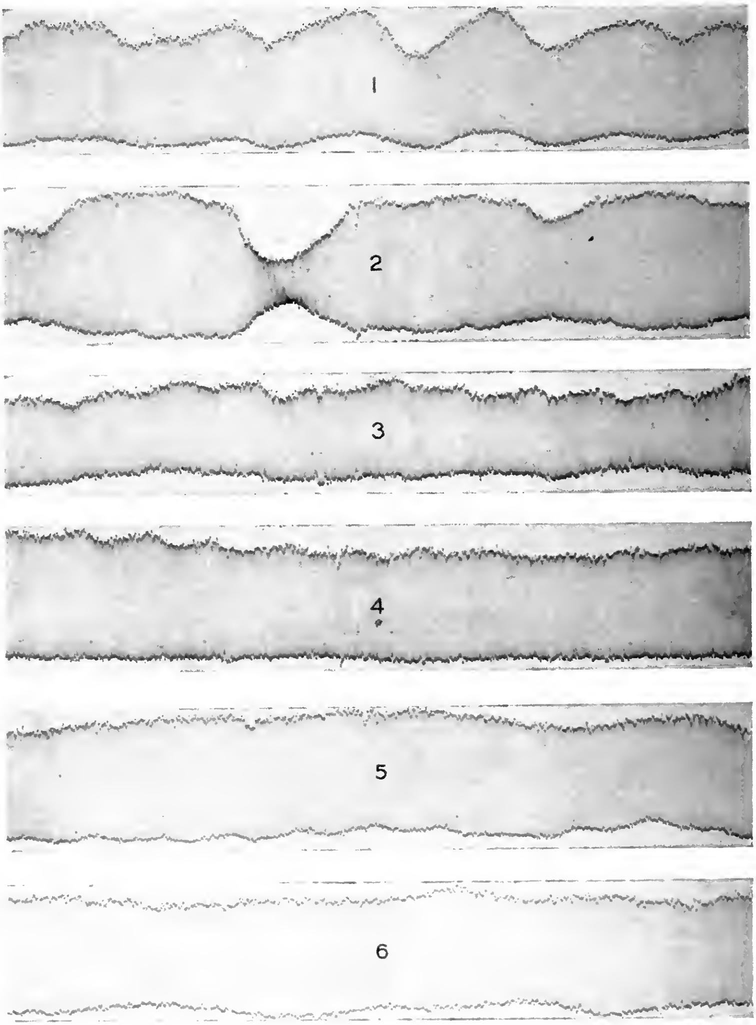

FIG. 8. Envelopes of 5000-cycle prints from industrial laboratories.

The majority of these prints show irregularities in high-frequency output, some of which are of the type discussed; that is, they result

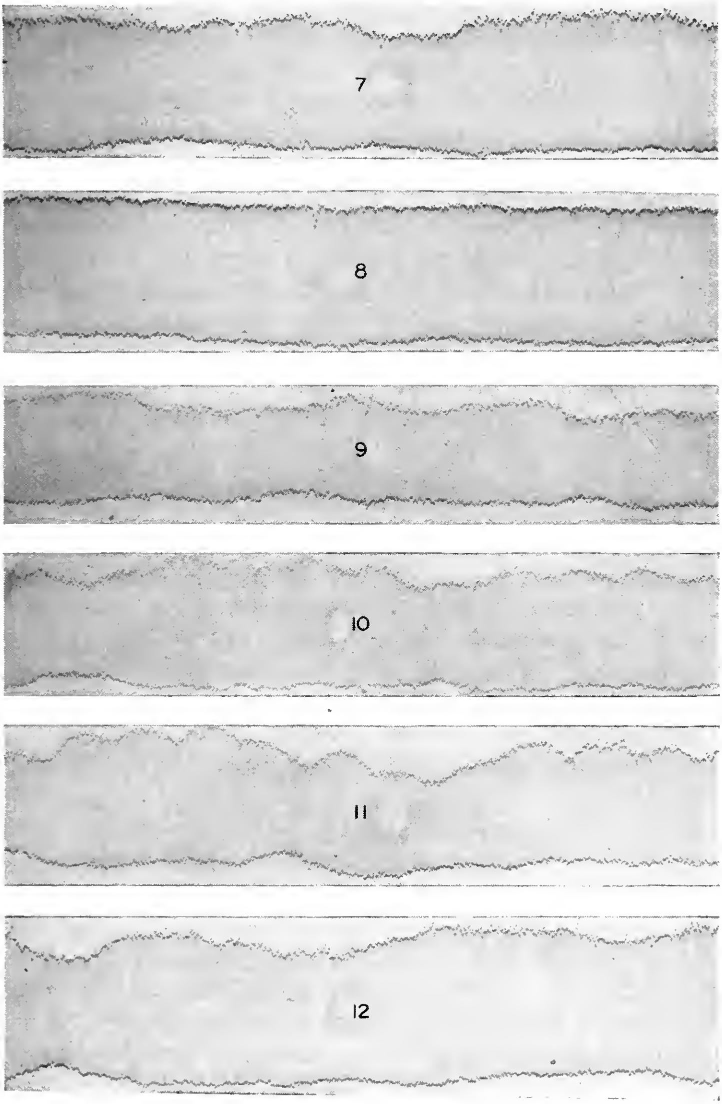

FIG. 8 (Continued). Envelopes of 5000-cycle prints from industrial laboratories.

from the loss of contact between the negative and the positive. Others show variations in output due to changes in average density (*e. g.*, no. *1*), a defect which will be referred to later. Fig. 8 suggests that variations in high-frequency amplitude of prints occur widely and merit consideration.

It should be noted that an apparent discrepancy exists between the results shown in Fig. 7 and the observation on page 303 that no loss in high-frequency response results from operation of the printer under different conditions of gate adjustment, *etc.* The 9000-cycle prints shown in Fig. 7 vary obviously in *average* output, yet volume indicator measurements of these and similar prints failed to disclose differences between the several conditions. A range of 1 db. difference in output at 9000 cycles was noted, but the direction of the differences bore no relation to the quality of the print as shown by microdensitometric traces. Measurements by thermocouple and milliammeter showed the same order of difference but here the direction was such as would be predicted from the envelopes. It is evident, when using the vacuum tube voltmeter, that so long as the duration of the constriction in the wave envelope is less than the period of the meter needle, the movement of the latter will be little affected, and discrimination between uniform and non-uniform prints, up to a certain point, will not be shown. If the print is projected at half speed, or less, then the irregularities of the wave become apparent in the needle deflections. It is probable that where a measure of *average* response is desired, use of the thermocouple and milliammeter is to be preferred.

Illumination.—The respective merits of specular and diffuse illumination for printing purposes are apparently debated points, although there seems to us to be a definite objection to the use of diffuse illumination for the following reason:

Consider, for the sake of simplicity, the case of an image consisting of alternate, uniformly dark and clear spaces simulating a frequency of 10,000 cycles. These spaces would, at 18 inches per second, have a finite length of 0.0018 inch per cycle, or approximately 1 mil for each dark or light space. The approximate thickness of the emulsion layer is 1 mil, and, assuming that the image occupies the whole depth of this layer, we have, on printing, the condition shown in Fig. 9, where the blackened areas represent the darkened areas of the negative. Where the printing illumination is normal to the surface, as at *S*, no image spread will occur from this cause. With diffuse illumination, those rays not normal to the surface, as at *D*, will cause a spread of the image. This, of course, is a consequence of the fact that the thickness of the emulsion is of the same order as the width of the density area under consideration. With perfect contact, therefore, we should expect a print from negative images of this order of frequency (10,000 cycles per second) to suffer appreciable loss if printed with diffuse as compared with specular illumination and this loss will be accentuated by any lack of contact between films.

As stated earlier, the light source that illuminates the printing

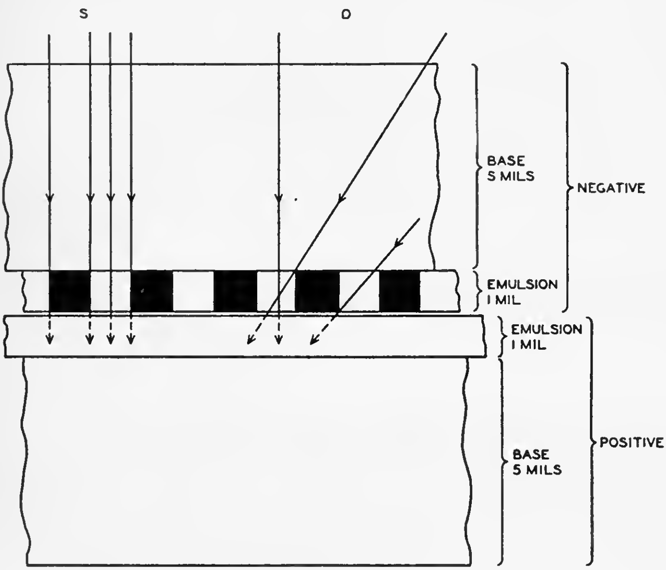

FIG. 9. Specular *vs.* diffuse illumination in printing.

aperture of the Bell & Howell printer is an illuminated area of ground glass. The area of this diffusing screen exposed by the diaphragm at the highest "printing point" depends to a certain extent on the ratio required between the lowest and highest printing points and is, in our case, $^3/_4$ inch high by $^{15}/_{16}$ inch wide. At the lowest printer point it is $^1/_8$ inch high. The angles subtended at the center of the printing aperture by the height of the ground glass at printer points 22 and 1 are 12 degrees and 2 degrees, respectively. The illumination received at the printing aperture is, therefore, reasonably specular; but reflections from the inside surfaces of the printing sprocket may modify this condition.

In order to determine whether any improvement could be effected in the Bell & Howell printer by the use of more nearly specular illumination, and to check the above conclusions respecting diffuse illumination, two high-quality negatives were printed under conditions of (*a*) specular illumination; (*b*) normal printer illumination at full shutter opening; (*c*) diffuse illumination as follows:

(*a*) Specular illumination was provided by a 3-cp. automobile lamp at the extreme rear of the printer lamp house. This latter was lined with black coffin paper, and the inside surfaces of the sprocket were painted with optical flat black. A practical "point source" of illumination was, therefore, attained; and since the angle subtended by the aperture at the source was only 1.5 per cent, the illumination beam may be considered as essentially parallel. The ground glass in the light change shutter was removed. Control of the intensity of the source was effected by voltage change.

(*b*) Full shutter opening (step *22*) was used; light change was effected by voltage change.

(*c*) Diffuse illumination was attained by mounting a thin piece of pot opal glass at the printing aperture, the glass being secured to the lower jaw of the gate by a small piece of modeling clay.

The results showed an average gain in high-frequency response at 9000 cycles of 1 db. by using the specular illumination. Diffuse illumination showed a loss at the same frequency of 3.5 db. as compared with specular illumination, confirming the deduction made above.

Printing Speed.—The Bell & Howell printer was originally equipped to print at a linear speed of 60 feet per minute. The speed of printing is generally increased beyond this value in industrial laboratories for production reasons. To determine whether the higher speeds might increase the printing losses, comparative tests were made at normal speed (60 feet per minute), 90 feet, 120 feet, and 180 feet per minute, with gate shoe clearances of both 20 and 35 mils, using high-quality negatives.

No differences in output could be measured except at treble speed (180 feet per minute) with gate clearance of 35 mils. In this case the prints showed at 9000 cycles a loss of 1.5 db. by vacuum tube voltmeter and 2.0 db. by thermocouple over normal operation. Envelopes of the 9000-cycle print made at 180 feet per minute with both the close and wide gate settings are reproduced in Fig. 10. They show that apparently the increased centrifugal force at the higher speeds aggravates the momentary losses of contact unless checked by a close gate setting that prevents the film from bulging away from the aperture.

Since a speed of 180 feet per minute on this type of printer is excessive from the standpoint of film breakage, it is not likely that such speeds are in actual use. It would be reasonable, from the standpoint of frequency response, to print at such a speed if the gate setting were sufficiently close.

Reflections from Shoe.—The standard printer gate shoe is constructed of polished steel and thus affords a light-reflecting surface. This surface being in contact with the base surface of the positive film, it follows that a portion of the light passing through the positive emulsion will be reflected back to the positive film. The photographic light transmission of positive film is about 20 per cent, so

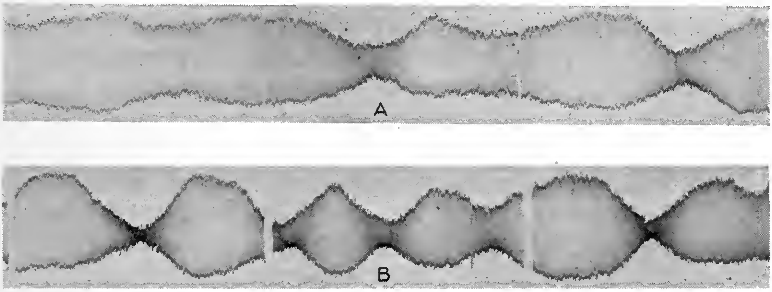

FIG. 10. 9000 cycles printed at 180 feet per minute: (*A*) gate clearance 18 mils; (*B*) gate clearance 35 mils.

that this proportion of the light transmitted by the negative will be incident on the shoe. The reflection factor of the shoe being about 50 per cent, we see that 10 per cent of the total amount of light falling upon the positive film will be reflected back to the emulsion layer of the film, where it will reënforce the primary image if the reflected rays are normal to the film surface; or degrade the definition if the reflected rays are scattered, as they will be to some extent by passage through the diffusely transmitting positive emulsion layer.

Assuming a reflected ray normal to the surface, we can readily determine from the H&D characteristic of the positive material whether the reflected component is of sufficient intensity to be of importance. Calculations made in this way show that under normal conditions for "straight-line recording," an increase in signal of about 0.2 db. will result from the use of a reflecting shoe. This is a negligible factor, and the resulting change in wave-shape may be assumed to be negligible also.

In the same manner it can be shown that no appreciable volume distortion of noiseless recording can result from the difference in the reflected components of the light during printing of the biased and unbiased portions of the negative.

To verify the above conclusions, prints were made on several occasions, using (*1*) the normal polished steel shoe; (*2*) a brass shoe having an inlay of hard rubber opposite the aperture (Fig. 11*A*), the contour of the shoe being the same as in (*1*); (*3*) a stock shoe in which a slight recess (5 mils at the deepest point, and $^3/_8$ inch in height) was ground opposite the aperture (Fig. 11*B*). This recess

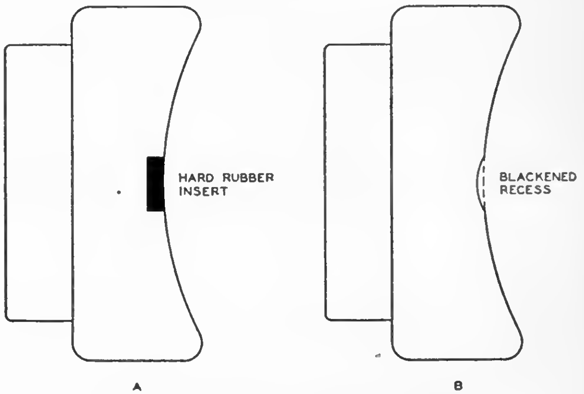

FIG. 11. Printer gate shoes (elevation).

was painted with flat black lacquer. Shoes (*2*) and (*3*) have a very low reflected light component due to the black material opposite the aperture in each case.

Prints having unmodulated track densities from 0.50 to 1.10 were made with each shoe. No differences in frequency characteristic, measured by vacuum tube voltmeter or thermocouple, could be detected between the prints made with the various gates either at low or high densities.

The polished shoe is, however, undesirable in one important respect. When making a combined picture and sound print bearing constant frequencies, the levels of the latter were affected by the character of the picture scene used and by the printing light required. This was found to be partially due to the spreading of reflected light incident at the position occupied by the black separation line between the picture and the sound track. This line is printed through clear film, and, the light intensity on the positive being high, the reflected light spreads over to the adjacent portion of the sound track. The density thereby added to that of the sound track proper has been found sufficient to affect the level of the latter in the case of thin sound prints by as much as 2 db. between picture scenes which required exposures that differed by several printer points.

Shrinkage.—It is well known that motion picture film shrinks slowly in storage after being perforated. Measurements of Eastman positive film made at the Sound Picture Laboratory have shown shrinkage varying from 0 to 0.16 per cent, averaging about 0.1 per cent. When film is processed, some of the residual solvents or plasticizers in the film base are dissolved or evaporated in the drying cabinets, resulting in further shrinkage. The negative is therefore, in general, shrunk to a greater degree than the positive on which it is later printed; and, in consequence, the perforations of the two will not match. If, however, negative and positive are curved over a circular form, with the negative on the inside, that side of the negative that is in contact with the positive will be stretched by virtue of its curvature, so that if the radius of curvature be properly chosen, the stretching can be made such as to bring about a match in pitch of the contacting emulsion surfaces.

This principle is utilized in the design of the printing sprocket and gate of the Bell & Howell printer. The curvature has been so chosen, according to the manufacturers, that with a positive film having a shrinkage of 0.079 per cent and a negative film of 0.368 per cent, the perforations will match perfectly in the plane of contact. With any other value of negative shrinkage one film will slide over the other as each successive sprocket tooth assumes the drive, until the leading edge of each perforation of both films makes contact with the driving face of the tooth. Since printing is continuous, some image blurring must take place as a consequence of such slipping.

The value of negative shrinkage assumed by the printer manufacturer seems to be excessive for modern sound negatives, which in this laboratory show an average shrinkage of only 0.10 per cent from standard pitch. When printed on the Bell & Howell printer, designed for approximately 0.3 per cent shrinkage, slippage during printing is unavoidable.

The amount of slip occurring each time the film drive is shifted from one driving tooth to the next is the difference between the negative and the positive pitches at the surface of contact of the two films; *e. g.*, if we print a negative of zero shrinkage (pitch 0.187 inch) on a positive of zero shrinkage (0.187 inch) then, due to the curvature at the printing plane, the pitch of the negative at the surface of contact with the positive will be 0.187 inch + 0.3% of 0.187 = 0.1875 inch. Every time that a perforation passes the aperture the positive must slide back along the negative by 0.0005 inch.

With an infinitely narrow aperture, demodulation of the print would occur over this distance only; but with apertures of finite size, the new space relationship of negative to positive after slippage will affect the images already formed, and the manner in which the latter is affected is a function of the height of the printing aperture. With a very narrow aperture only very short distances will be affected by the slippage; the demodulation over these distances will be abrupt and appreciable, but the average signal will be little affected. As the aperture is increased, the average signal will decrease, but the amount of variation will also decrease.

The Bell & Howell Company adopted $^5/_{16}$ inch as the standard height of the printing aperture height of the Model *D* printer. To determine whether any measurable increase of high-frequency response could be gained in prints made from negatives of various degrees of shrinkage by the use of smaller apertures than this, the following tests were made.

The printer aperture was reduced in height by the insertion of a small piece of sheet metal of the necessary size attached to the lower jaw of the aperture by modeling clay and arranged just to clear the film plane. Aperture heights chosen were $^3/_{32}$ inch, $^3/_{16}$ inch, and the full opening of $^5/_{16}$ inch. These values correspond approximately to $^1/_2$ perforation pitch, 1 perforation pitch, and $1^2/_3$ perforation pitch. The negatives used were a high-quality equalized negative having a shrinkage of 0.21 per cent from standard pitch, and a negative made by the standard recording system having a shrinkage of 0.16 per cent. Sections of the latter were taken and shrunk to the following values: 0.43, 1.13, and 1.81 per cent, respectively. The positive film used had a shrinkage of 0.16 per cent. By reason of printer design mentioned earlier, the negative that would print on this positive without slippage would have a shrinkage of 0.16 + 0.30 = 0.46 per cent. The 0.21 per cent shrunk negative then, printed on the 0.16 per cent shrunk positive, would cause an effective slippage of 0.16 + 0.30 − 0.21 = 0.25 per cent; and so on, in like manner, for the other negatives.

Prints were made from these various negatives in the printer using the three aperture heights mentioned above. The frequency loss values of the resulting prints, referred to 1000 cycles as zero, were as given in Table I.

TABLE I

Variation of High-Frequency Loss with Size of Aperture

Aperture (Inches)	1000	3000	5000	6000	7000	8000	9000
			Experimental Negative*				
			(Shrinkage, 0.21%. Effective Slippage, 0.25%)				
$^5/_{16}$	0	−1.0	− 1.0	+1.0	− 0.5	−1.0	− 3.0
$^3/_{16}$	0	−1.0	− 0.5	+1.5	+ 0.5	0	− 1.5
$^3/_{32}$	0	−1.0	− 0.5	+2.0	+ 0.5	0	− 2.0
			Standard Negative				
			(Shrinkage, 0.16%. Effective slippage, 0.30%)				
$^5/_{16}$	0	−1.0	− 5.5	...	−10.5	.	−16.5
$^3/_{16}$	0	−1.0	− 5.0	...	− 9.5	.	−15.5
$^3/_{32}$	0	−1.0	− 5.0	...	− 9.5	.	−15.5
			(Shrinkage, 0.43%. Effective slippage, 0.03%)				
$^5/_{16}$	0	−1.0	− 5.0	...	− 9.5	.	−16.0
$^3/_{16}$	0	−1.0	− 5.0	...	− 9.5	.	−15.5
$^3/_{32}$	0	−1.0	− 5.0	...	− 9.5	.	−15.5
			(Shrinkage, 1.13%. Effective slippage, 0.67%)				
$^5/_{16}$	0	−1.0	− 6.5	...	−15.0	.	−22.5
$^3/_{16}$	0	−1.0	− 5.5	...	−12.0	.	−20.0
$^3/_{32}$	0	−1.0	− 5.5	...	−12.0	.	−18.0
			(Shrinkage, 1.81%. Effective slippage, 1.35%)				
$^5/_{16}$	0	−1.5	−10.0	...	−19.0	.	−25.0
$^3/_{16}$	0	−1.5	− 6.0	...	−14.0	.	−23.0
$^3/_{32}$	0	−1.0	− 5.5	...	−12.0	.	−19.0

* An experimental negative not representative of commercial recording.

The results show that with negatives having shrinkages such as are ordinarily encountered (0.10 to 0.20 per cent), a slight improvement in high-frequency response (about 1 db. at 9000 cycles) is obtained by reducing the aperture height from $^5/_{16}$ inch to $^3/_{16}$ inch, but no advantage is to be gained by reducing to a dimension below this figure. With negatives of high shrinkage, large gains in high-frequency response are obtained by further reducing the aperture size (6 db. at 7000 cycles with slippage 1.35 per cent and aperture $^3/_{32}$ inch). Such negatives, however, will but seldom enter into consideration in sound printing.

It should be noted here that a print made with a very narrow aperture is viewed favorably by the volume indicator, since here the period of the demodulated portion is so small a fraction of the whole that the volume indicator needle is not able to follow the change.

Factors other than high-frequency response, however, enter into determining the optimum aperture height to be used. Irregularities in the rate of movement of the film past the aperture will obviously affect the degree of exposure it receives from point to point, and this will be the more apparent the shorter the time occupied in traversing the aperture relative to the period of the irregularities.

Such irregularities may be expected to enter from errors in the gearing that serves to drive the printer sprocket, as well as from any errors of tooth spacing or of tooth contour in the drive sprocket. That these exist is readily seen by observing the movement of gears and sprocket teeth with the aid of a stroboscope.

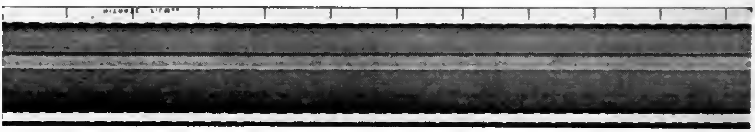

FIG. 12. Film flashed in printer using an aperture 5 mils high.

Density Variations in Prints.—As mentioned above, the film moves past the aperture of the Bell & Howell printer in an irregular manner, which may be demonstrated stroboscopically or by making "flash" exposure of film for which the printing aperture has been reduced. Fig. 12 shows such a piece of film exposed through an aperture 5 mils high. Variations in transmission of a film flashed in the printer to a low density may be seen visually even when the standard aperture of $^5/_{16}$ inch is used. These variations, as measured on film exposed to produce a density of 1.0 in the printers used in this laboratory, show a maximum variation of density of approximately ± 0.05, *i. e.*, ± 1 db. in transmission. Greater variations have been observed in "flash" exposures made in printers in commercial laboratories, amounting in one case to a maximum of ± 3 db.

Variations in density of the print cause a volume variation of the signal in the reproducer and a flutter in the sound from the horn. Such a flutter, though not always obvious in a first print, can usually be detected in the print made from a duplicate negative. The variations aggravate the unsteadiness of the output meter needle when measuring constant-frequency records with the vacuum tube voltmeter, particularly at the higher frequencies, when the amplifier gain must be raised to bring the needle to the zero reading.

It was felt that the production of such irregularities is a distinctly undesirable feature in a sound printer and remedial measures were therefore sought.

Variations in density of the print (assuming a perfectly uniform negative) may result from:

(1) Variation in exposure from irregularities in the rate of motion of the film past the exposing aperture due to mechanical defects in the driving mechanism.

(2) Unevenness in development.

(3) Irregularities in the light-sensitive layer of the photographic film on which the print is made.

Mechanical Defects.—As might be expected, a certain amount of flutter results from the train of commercially cut gears used in the

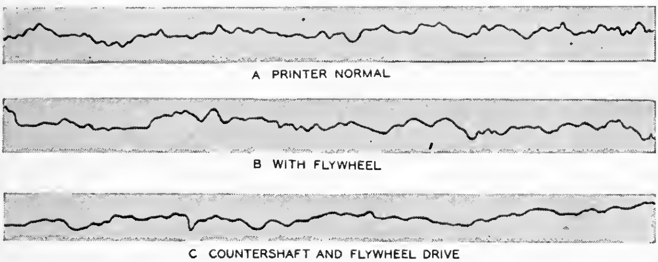

FIG. 13. Densograms of printer flashes made through normal aperture; length, 4 feet (lines of zero transmission located 2.2 cm. below line of mean transmission).

speed-reducing mechanism. Some commercial laboratories attempt to improve this condition by "lapping" the gears with a very fine abrasive. Although this may polish off fine irregularities on the face of the teeth, it was felt that such were but minor causes of flutter and that any improvement gained would be more than offset by the change of contour of the gear teeth caused by the wear thus brought about.

The substitution of expensive, specially cut gearing was not regarded as a "commercial" solution, so an attempt was made to smooth out the film movement at the printing sprocket by placing a heavy, carefully balanced flywheel of 30 pounds in weight and 20 inches in diameter, on the shaft of the printing sprocket. The drive was otherwise unchanged, except that several types of belt were compared with the standard leather belt. Examination by the stroboscope revealed no improvement from the use of the flywheel or from the different types of belts. "Flash" exposures on positive film scanned in a recording densitometer revealed no differences that could be ascribed to the flywheel, the type of belt, or to reductions in the load imposed by the feed and take-up mechanism.

The effects produced by gear inaccuracies were then eliminated by driving the printing sprocket directly by means of a fabric belt around the periphery of the flywheel.

The necessary speed reduction was attained through a countershaft driven from the driving motor by means of a pulley and fabric belt. The take-up mechanism was driven by a separate belt. Stroboscopic examination showed a change in character of the motion of the sprocket with some improvement, but "densograms"* of flash exposures indicated this to be but slight in the print (Fig. 13). Prints made from constant-frequency negatives showed little improvement in irregularities, as shown by the degree of output meter needle unsteadiness.

It seemed, then, that in the printers under test, little is to be gained by the addition of a flywheel to the printing sprocket when the latter is driven through the normal gearing; nor is much more to be gained when the flywheel is driven directly.

This may not be the case where the sprocket drive irregularities have become accentuated by gear wear, such as must occur in many of the machines in commercial use. Fig. 14 shows "flash" exposures of density 1.0 from twelve different printers representative of a total of 28 examined from commercial laboratories on both the east and west coasts, and illustrates the wide variation in performance. Many of these could doubtless be improved by the addition of a suitable flywheel.

The "flutter" at the sprocket teeth observed stroboscopically was irregular and of low period (about $^1/_2$ to 1 second), and with an aperture of $^5/_{16}$ inch seemed of too small an amplitude to account for the variation in density shown in the density records of the flashed exposures.

It had been observed that volume indicator readings of prints made

* The "densograms" in Figs. 13 and 14 show the variations in transmission of the particular record from point to point longitudinally over a distance of 4 feet. The distance from the datum line of zero transmission to the line of mean transmission is shown on each chart. The graph thus shows directly the comparative degrees of modulation of transmission of the samples regardless of their density.

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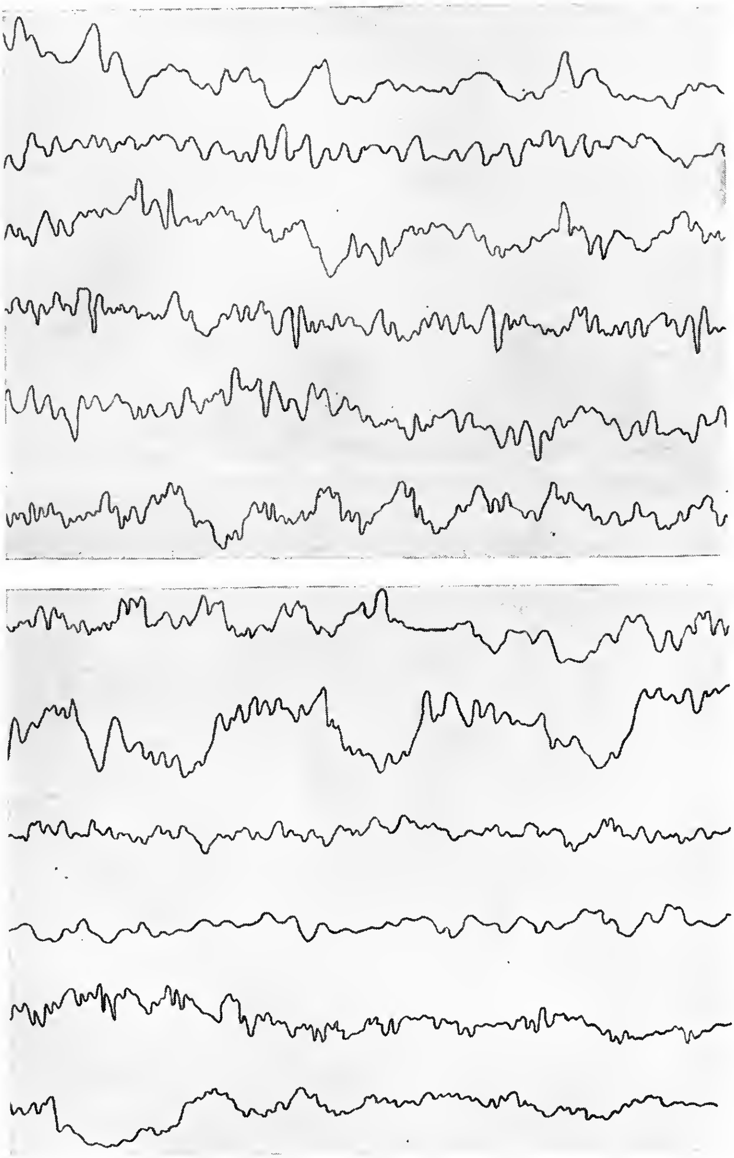

FIG. 14. Densograms of flashed exposures: density, 1.0, length, 4 feet; made in printing machines in twelve different motion picture laboratories (line of zero transmission located 2.2 cm. below line of average transmission in each case).

with or without filtered drive from constant-frequency negatives showed increasing unsteadiness with increase in density, being satisfactory from this standpoint below a visual diffuse unmodulated density of 0.40 and increasingly unsatisfactory above this point. "Flash" exposures to produce a range of density were therefore made in a recorder known to be in good condition from the standpoint of mechanical flutter. These were scanned in the recording densitometer and also in a standard reproducer using a modulated light source. In the latter method the variation in signal resulting from density irregularities was observed in the output meter. Comparisons were made with similar exposures made in the printer and developed under different conditions. The variations in signal level were found to increase from ±0.25 db. at a density of 0.10 to ±1.0 db. at a density of 1.10, and the order was the same whether the tracks were exposed in the recorder, stock printer, or "filtered" printer, and whether developed under conditions of poor or of good circulation of the developing bath. This progressive increase in irregularity of needle response with increase in density is borne out by the densograms (Fig. 15*A*, *B*) as is also the lack of definite superiority of one exposing device over the other.

If these variations result from modulation of the record by uneven motion of the film past the exposing aperture, then the smaller variations at low densities may be explained by the smaller slope of the H&D curve of the material for values up to a density of 0.4 or 0.5. Above this point, however, the variation should not increase with density, as was usually found to be the case. The particular recorder used in making these tracks was stroboscopically observed to be free from low-frequency flutter of the period of variation of the volume indicator needle or of the irregularities shown in the "densograms." These considerations suggest the presence of a factor of variation approximating the order of the exposure irregularities existing in any of the machines used in the experiments.

To obtain a record in which any possibility of variation of exposure from point to point was excluded, positive film was exposed statically in a 6-foot printing frame to a point source of light. No glass was interposed between the light source and the film. A number of such exposures was made which would give on development a series of tracks of various densities. These tracks were developed by a machine having a very efficient developer circulating system and then scanned in the recording densitometer.

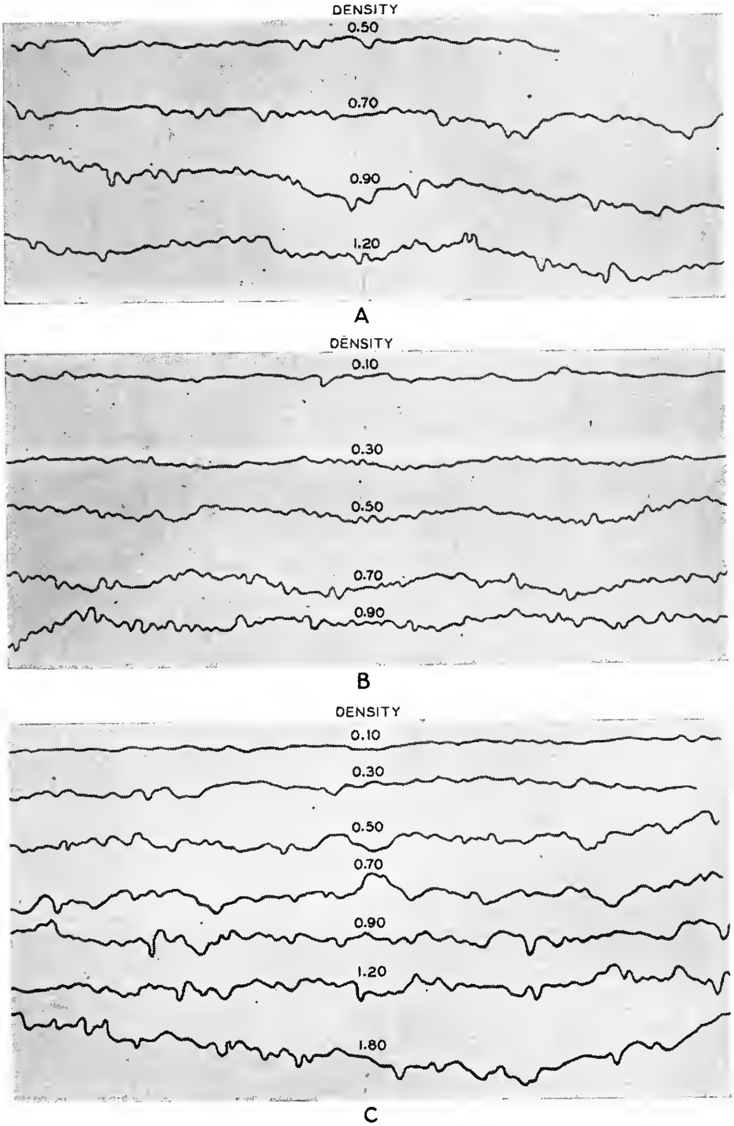

FIG. 15. Densograms of positive film (length, 4 feet), uniformly exposed in (*A*) recording machine; (*B*) normal printer; (*C*) mechanically filtered printer (line of zero transmission located 2.2 cm. below line of average transmission in each case).

The "densograms" of a typical series of such static exposures are shown in Fig. 16. They reveal the fact that irregularities occur even when the light exposure is uniform, and that the irregularities usually increase with density. These variations are, therefore, probably inherent in the photographic emulsion itself. It should be

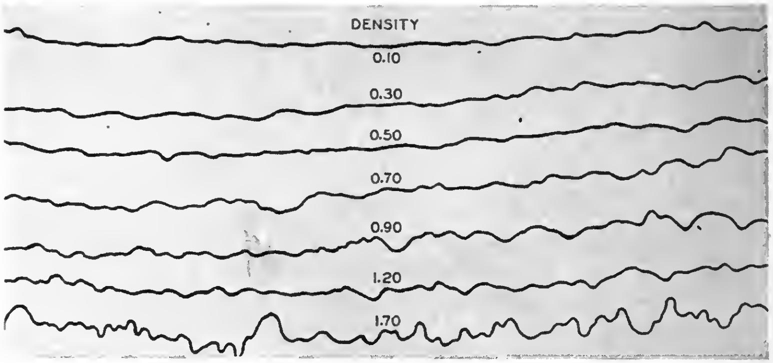

FIG. 16. Densograms of static uniform exposures on positive film; length, 4 feet (line of zero transmission located 2.5 cm. below line of average transmission in each case).

mentioned here that a number of such exposures were scanned and that the order of variation in respect to density was not always the same. Occasionally records were obtained in which an increase in density did not show increased variation. The average, however, showed a decided trend in the direction indicated.

The reason for the density variations in the film lies possibly in the variation in thickness of the sensitized emulsion layer. That the

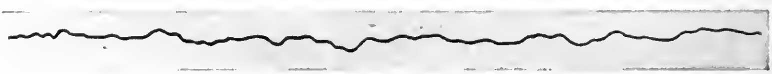

FIG. 17. Densogram of positive raw stock; length, 4 feet (line of zero transmission located 2.5 cm. below line of average transmission).

thickness does vary in a manner similar to that of the photographic density resulting from uniform exposure is seen from Fig. 17, which shows the variations in transmission of a 4-foot length of positive raw stock. It is not unreasonable to assume that where the image resulting from exposure and development of such a film is of a low order of density, it will be little affected by the thickness of the emulsion coating, since, as is well known, such an image is largely confined to the upper surface of the sensitive layer. With increasing density, the image penetrates more deeply into the emulsion layer, and hence will be increasingly affected by variations in thickness of the latter. The variations in coating thickness doubtless vary from sample to sample, as does the order of variations in the image density.

These facts suggest that little would be gained by further refinements in the mechanical filtering with the $^5/_{16}$-inch aperture. Of course, with narrower apertures irregularities in exposure will be accentuated. With any given aperture and filtering device, only operating tests would reveal whether the limit imposed by the film irregularities had been reached.

Frequency Characteristic.—Although the preceding discussion covers many phases of the printing operation, it will be noted that no satisfactory explanation has been found that would account for the widely varying print losses (0 to 8 db. at 7000 cycles), noted on page 304 as measured on prints of the same constant-frequency record, developed, and printed in different commercial laboratories.

The prints made in the Sound Picture Laboratory from the same series of negatives showed less spread in 7000-cycle loss, suggesting a real difference in printing efficiency among laboratories. However, a decided tendency was noted in our prints toward the production of a more or less constant high-frequency output. Negatives having a higher 7000-cycle level showed a greater printing loss than did negatives of lower 7000-cycle level. This fact suggests the presence of a limiting factor in print response level in this and probably other laboratories, the most likely factor being the developing operation.

DISCUSSION

MR. MITCHELL: We have done considerable work along somewhat similar lines, using a different method, in connection with the new fully automatic printer. We found the very minute differences in the pitch and shape of the teeth of the main sprocket to be so important that we installed a special machine exclusively for making the printing sprockets. We now can control the pitch of the teeth, and the shape of the teeth, to within 0.0002 inch; so that in the new printer, with synchronous drive, we can reduce the picture printing aperture to almost $^3/_{16}$ inch now and obtain a very satisfactory response, without the "dips" mentioned by Mr. Crabtree. We use $^3/_{32}$ inch on the sound printing aperture.

I should like to ask Mr. Crabtree whether he has the new sprockets in the printers in his laboratory.

MR. J. CRABTREE: We have the new sprocket.

MR. J. I. CRABTREE: Since when have they been available?

MR. MITCHELL: They have been available commercially for about nine months or a year. They are now made of stainless steel, as we find that in constant use the chemicals in the film tend to erode ordinary steel. The use of stainless steel seems to afford the possibility of maintaining efficiency over a long period of time. Stainless steel sprockets have been available only within the last week or so.

MR. J. I. CRABTREE: I am glad you have done this. We had to work several weeks on the sprocket of our printer to put it into condition. Are sprockets available calculated for shrinkages other than 0.3 per cent?

MR. MITCHELL: As far as I know 0.3 is still the standard. We find the present sprocket is almost ideally suited to the film shrinkages normally met with at the present time.

MR. J. CRABTREE: I did not make it clear that the data presented are all on the basis of the old sprocket.

MR. SHEA: Have you data on the improvement that the new sprocket represents?

MR. J. CRABTREE: Yes, but not here.

MR. SHEA: What is the general order of improvement?

MR. J. CRABTREE: A flatter envelope.

MR. MITCHELL: Some idea of the improvement may be gathered from prints made in Hollywood with the new printer in which are incorporated these various improvements. The difference was so great that it was found impossible to print one reel on the new printer and the other reels on the ordinary printers. They all had to be printed on one type of machine or the other. So in practice there is a very decided and definite difference.

MR. O. SANDVIK: The transmission of ciné-positive film varies with the wavelength, being practically opaque to the ultra-violet, and increasing as the wavelength increases. In transmitting a wavelength of 400 millimicrons then, we have a transmission of the order of one part in 10,000 to one part in 100,000; that is, from a hundredth of one per cent to a thousandth of one per cent, depending on the emulsion.

Regarding the vacuum tube volume indicator, it can be made to indicate approximately r.m.s. values, average values, or peak values. I believe Mr. Crabtree said that the vacuum tube volume indicator, as used in these measurements, indicates peak values. Is that correct?

MR. J. CRABTREE: Both vacuum tube voltmeter and thermocouple with milliammeter were used as volume indicators. The former was a peak voltage device. The thermocouple integrates the output better, but we could not always detect the differences due to constriction of the envelope.

MR. SHEA: Is it your feeling that experimentally it is within the 2 db. that you mentioned?

MR. J. CRABTREE: Yes.

WAVE FORM ANALYSIS OF VARIABLE WIDTH SOUND RECORDS*

O. SANDVIK, V. C. HALL, AND J. G. STREIFFERT**

Summary.—*The results of a study of the relation between sensitometric conditions and the harmonic content introduced in the photographic process are described. Sinusoidal wave-forms of very low initial harmonic content were recorded, varying the negative exposure, negative development time, and positive exposure so as to cover a range of negative densities, negative gammas, and print densities. Sets of such records were made at several levels of modulation and several frequencies from 100 to 4000 cycles per second.*

The records were analyzed on a recording microdensitometer which automatically recorded the transmission of the sound track. These traces, after being enlarged to the appropriate size in order to determine the harmonic content, were analyzed with a harmonic analyzer. The results show that sensitometric conditions for good quality are much more critical at the higher frequencies and that in general the harmonic content does not increase at those frequencies.

The two general types of photographic sound records and the methods and processes used in making them are so well known that they need not be described here. This paper describes the results obtained during a study of the relation between the sensitometric conditions, harmonic distortions, modulation and frequency characteristics of variable width sound records.

The problem was first considered by Hardy,[1] who concluded that when the width of the image of the recording aperture is small compared with the wavelength of the record, the quality of the sound reproduced does not depend on the conditions of exposure or development of either the negative or the positive. Cook[2] has investigated the effect of a finite aperture on the quality of the reproduced sound. More recently this problem has been treated by Foster.[3] He concludes from his theoretical investigation that by proper choice of the conditions of exposure and development, sound can be recorded and reproduced which is practically free from non-linear distortion. When the image of the recording aperture is rectangular and uniformly illuminated, the following conditions are necessary:

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* Presented at the Spring, 1933, Meeting at New York, N. Y. Communication No. 518 from the Kodak Research Laboratories.

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

(1) Complete exposure in recording and printing corresponding to the upper extreme of the straight-line portion of the H&D curve; (2) the transmission of the dense part of the record is negligible; and (3) the over-all gamma is equal to unity.

Maurer[4] has investigated the problem from the point of view of determining the conditions of exposure and development that give the least film loss over the required frequency range. From his experimental results he concluded that the process is relatively independent of the negative gamma and that for motion picture positive, a density of 1.3 in both the negative and the print gave the best compromise between volume and frequency characteristic.

More recently, Dimmick[5] has investigated the problem in somewhat the same manner except that he was interested in determining the conditions which would give a maximum of signal; that is, a minimum of film loss at 6000 cycles per second. He found that when using Eastman motion picture positive film and *D16* developer, the greatest volume resulted from a print having a density of 1.6 and a gamma of 2.00 printed from a negative whose density and gamma were 1.8 and 2.18, respectively.

Neither of the two latter workers investigated the non-linear distortion present. The writers are not aware of any experimental work having been published on this phase of the problem, and as the employing of a wider range of frequencies has created a somewhat greater interest in this question, it appeared desirable to subject the problem to a systematic study. The results below were obtained on regular motion picture positive film used both as the sound recording negative and the printing stock. The frequency range investigated ranged from 100 to 4000 cycles per second for a series of negatives ranging in density from 0.6 to 2.1. Several negatives were made, so that in each case there were groups of negatives all of the same density but ranging in gamma from 1.0 to 2.0. Here again for each density and gamma there were several negatives in each group ranging in modulation from 1 to 10 db. below 100 per cent. From each one of these negatives was made a set of prints of densities 0.6, 0.9, 1.2, 1.5, and 2.0, respectively, at a fixed gamma of 2.0. The developer used in all cases was *D16*.

The image of the recording aperture was rectangular, its height on the film being 0.0005 inch. Great care was exercised in obtaining uniform illumination along the length of the image, and also in obtaining a very sharp edge and a minimum of illumination on the film beyond the geometrical edge of the image. The non-linear distortion introduced by the electrical system and the recording galvanometer was considered sufficiently small to be neglected.

The method of analyzing the records was similar to that previously

TABLE I

Second and Third Harmonic under Various Negative and Print Conditions

			Print Density									
			0.6		0.9		1.2		1.5		2.0	
			Harmonic									
Negative Density	Negative Gamma	Frequency	Second	Third	Second	Third	Second	Third	Second	Third	Second	Third
0.6	1.0	100	4.3	3.0	1.5	3.4	2.5	3.5	2.8	4.4	10.2	3.7
1.0	1.0		6.2	1.5	5.3	1.6	2.9	2.2	2.9	3.3	9.7	3.1
0.63	1.5		3.3	0.7	1.0	3.1	1.1	3.9	5.5	5.0	11.5	4.3
1.0	1.5		6.3	0.7	4.2	2.1	2.8	2.6	4.2	4.0	8.3	4.5
1.43	1.5		7.1	1.2	6.6	1.0	7.3	1.5	3.4	2.4	0.9	3.6
1.58	1.5		8.5	1.3	7.5	1.1	6.5	0.7	2.5	1.6	3.3	2.1
0.85	2.0		2.4	2.4	0.8	3.0	2.5	4.2	8.4	4.4	13.8	4.0
1.0	2.0		5.1	2.7	2.4	2.3	0.8	4.7	4.7	4.5	9.4	5.5
1.3	2.0		7.1	0.9	4.5	2.3	3.1	0.4		5.0	5.6	5.2
1.5	2.0		6.8	0.5	6.1	0.8	4.5	1.3	4.2	2.0	2.0	3.7
2.1	2.0		8.6	1.1	7.5	1.1	6.9	0.7	6.1	0.3	5.0	1.6
0.8	1.0	2500	7.3	1.4	0.4	1.4	4.9	2.0	10.4	1.9		
1.0	1.0		9.0	0.7	3.6	0.6	1.6	1.3	3.3	2.2	13.0	0.6
0.64	1.5		1.5	1.5	3.8	1.1	10.7	2.5	14.0	1.6		
1.0	1.5		7.2	0.5	2.5	0.6	2.5	1.4	9.1	2.8	15.5	2.3
1.2	1.5		12.0	1.3	9.8	1.2	3.6	0.7	3.6	1.4	8.9	0.6
1.55	1.5		12.8	0.5	11.1	2.8	10.0	2.1	7.4	2.5	0.8	1.5
0.8	2.0		2.2	1.2	5.9	2.1	11.8	1.0	17.0	2.1		
1.0	2.0		5.7	1.8	3.6	2.1	8.2	0.9	13.2	2.6	22.6	0.7
1.2	2.0		6.0	0.7	4.3	0.7	4.0	2.5	8.2	1.5	17.2	2.7
1.54	2.0		10.9	1.1	8.3	0.7	5.6	2.2	3.1	1.5	9.2	2.8
2.15	2.0		11.1	1.0	14.5	1.6	9.5	0.3	9.4	1.1	13.1	0.4
0.75	1.0	4000	1.6	1.6	1.3	0.9	5.9	1.3	14.1	0.7		
1.13	1.0		9.3	1.4	4.3	1.7	4.1	1.2	6.9	1.1	18.2	1.2
0.70	1.5		1.4	0.5	7.3	1.1	13.7	1.1	20.5	0.8		
1.05	1.5		6.7	0.9	3.9	0.8	3.0	1.7	10.1	0.2	16.3	0.7
1.62	1.5		10.7	0.5	7.5	0.8	3.5	1.2	4.4	0.9	8.2	1.9
1.34	1.5		12.4	0.5	7.3	0.4	5.1	0.7	2.1	1.6	7.7	1.2
1.66	1.5		12.7	1.2	11.2	0.7	8.5	1.7	5.0	0.4	2.1	0.5
0.8	2.0		1.5	1.8	6.3	1.5	8.8	1.1	15.8	1.2		
1.0	2.0		2.6	0.8	3.8	1.3	7.7	1.7	13.6	0.8	21.4	1.4
1.25	2.0		6.7	0.6	4.5	0.6	2.6	1.1	9.4	1.4	19.0	1.1
1.46	2.0		10.3	3.7	8.3	0.8	4.0	0.5	1.3	1.3	8.5	0
2.1	2.0		14.7	3.4	11.3	0.0	7.1	1.0	4.9	0.4	4.7	0.4

used by two of the authors in analyzing variable density records.[6] The results are given in Tables I and II.

Table I shows the values of the second and third harmonic found for a wide variety of negative and print conditions at frequencies of 100, 2500, and 4000 cycles per second. In compiling this table, values of higher harmonics were omitted, as under conditions which give results approaching satisfactory quality their values are less than one per cent of the fundamental amplitude. A study of the table shows that for a given print density and negative gamma the second harmonic goes through a minimum, while in general the third harmonic remains sensibly constant or decreases progressively with higher negative densities, particularly at the higher print densities.

A consideration of the appearance of the records made under various conditions indicates the reason for these two effects. For a given printing light, such as to produce a density of 1.5, say, in the positive image printed through the relatively clear negative areas, a noticeable density will be produced by printing through the blackened part of the negative, provided the negative density is low. This, of course, leads to a lowering of modulation of the print transmission. The nature of the image at low negative densities is such as to have little or no filling in of the valleys of the waves. When sufficient printing exposure to produce a density of the order of 1.5 at a gamma of 2.0 is given in this region, the developed image shows considerable spreading instead of coming to a narrow peak as required for perfect reproduction. This effect flattens the peaks of the positive wave while leading to even harmonic distortion, the second being the only one of practical importance, since values of the fourth and higher harmonics are less than one per cent except under negative and print conditions causing sufficient loss of modulation of print transmission as to be useless in practice. As the negative density increases, the amount of printing through on the positive peaks decreases, leading to a corresponding decrease in the second harmonic, the value going to zero for some particular negative and print condition. As the negative density is further increased, the valley of the print begins to fill in, causing a flattening of this side of the wave and re-introducing even harmonic distortion in a phase 180 degrees from that occurring on prints made from lower negative densities. If the filling in became appreciable while there was still some printing through, then the wave-form would be flattened at both ends. Since a distorted wave-form symmetrical with respect to the axis contains only odd harmonics, the existence of this phenomenon should lead to a peak in the third and fifth harmonics at the point of minimum even harmonics. The absence of any such tendency shows that under the conditions of minimum even harmonic distortion the reproduced wave-form is a faithful copy of the original signal, since the amount of third harmonic which is present due to lack of perfection of the photographic image in both peaks and valleys

TABLE II

Modulation of Print Transmission in Decibels below 100 Per Cent

Negative Density	Negative Gamma	Frequency	Print Density 0.6	0.9	1.2	1.5	2.0
0.6	1.0	100	5.2	5.7	9.4	12.4	18.4
1.0	1.0		4.0	4.0	4.7	5.8	11.3
0.63	1.5		5.5	6.9	9.1	14.1	21.8
1.0	1.5		4.7	3.9	4.4	4.6	9.9
1.43	1.5		4.0	3.2	3.2	3.4	4.9
1.58	1.5		4.0	3.2	3.1	3.1	3.7
0.85	2.0		4.4	4.7	6.6	8.4	15.9
1.0	2.0		3.9	4.0	4.3	6.0	10.2
1.3	2.0		4.1	3.7	3.5	4.2	6.1
1.5	2.0		3.9	3.1	3.2	3.4	3.7
2.1	2.0		3.8	3.1	3.1	3.2	3.2
0.8	1.0	2500	6.8	7.0	9.1	12.5	
1.0	1.0		6.5	5.7	6.8	8.2	15.3
0.64	1.5		7.3	8.4	11.1	15.4	
1.0	1.5		6.1	5.7	6.2	7.9	13.8
1.2	1.5		6.5	3.9	5.0	5.2	7.6
1.55	1.5		8.3	5.8	4.9	6.0	5.2
0.8	2.0		6.2	6.6	8.2	11.4	
1.0	2.0		5.7	5.7	6.6	8.3	13.4
1.2	2.0		5.7	5.4	5.2	5.5	12.0
1.54	2.0		6.2	4.4	4.4	5.2	6.6
2.15	2.0		8.2	6.4	5.2	4.7	5.2
0.75	1.0	4000	8.6	8.4	9.9	14.4	
1.13	1.0		8.6	7.8	7.6	9.5	13.7
0.70	1.5		9.1	9.6	12.8	16.5	
1.05	1.5		8.1	6.8	7.3	8.6	14.0
1.62	1.5		8.9	7.3	5.3	6.9	8.7
1.34	1.5		9.4	7.1	6.9	8.1	10.5
1.66	1.5		10.8	9.4	7.8	7.6	7.6
0.8	2.0		8.2	8.9	10.4	14.4	
1.0	2.0		8.2	8.0	8.9	11.7	16.7
1.25	2.0		8.0	7.8	7.4	8.3	11.1
1.46	2.0		8.9	7.6	7.3	7.0	8.2
2.1	2.0		11.4	9.9	9.1	8.4	7.7

is negligible under the conditions existing for minimum even harmonic distortion.

Table II shows the amount of peak modulation of print transmission obtained for the negative and print conditions tabulated. Since no correction was made for wave-form, the values may be slightly in error in cases where there is considerable harmonic content; but since these cases are also far enough from maximum signal conditions to make them valueless in practice, no corrections were applied.

As in Table I, for a given negative gamma, there is a value of negative density giving maximum modulation for each print density, although the maximum region is very broad at a frequency of 100. The film losses found under the best conditions are 3.1, 4.4, and 7.0 db. at 100, 2500, and 4000 cycles per second, respectively. Since the modulation of input signal was 1 db. below 100 per cent, and since the film base itself causes approximately 1 db. loss, the actual losses are about 1, 2.4, and 5 db., for the three frequencies 100, 2500, and 4000, respectively.

Table III shows the results obtained from the analysis of the negative records made in the same way as the print analyses. The harmonic values here are the combined second and third harmonic amplitudes, being the square root of the sum of the squares of the two quantities. The last column shows the modulation of negative transmission in decibels below 100 per cent, and in general it can be noted that the harmonic content is directly related to the loss of output signal. This is especially true at the higher frequencies, where the filling in of the valleys of the record cuts down the amplitude of the signal, by flattening the bottom of the wave. This introduces considerable second harmonic distortion into the values given. It is noticeable that it is possible to obtain a better print from the standpoint of both modulation and harmonics than can be obtained as a negative, particularly at the higher frequencies, where the even harmonics can be balanced out in printing as noted in consideration of Table I.

The general properties of these data can now be more readily discussed by the aid of a few curves. Thus, Fig. 1 shows the relation between the total harmonic content and the print density for prints made from a group of negatives, *A*, *B*, *C*, *D*, and *E*, whose densities were 0.85, 1.0, 1.3, 1.5, and 2.1, respectively, at a frequency of 100. These curves show that the harmonic content is a function of the print density, and wherever a sufficient range of print densities was

TABLE III

Characteristics of Negative Records. Total Harmonic in Percentage of Fundamental. Output Modulation in Decibels below 100 Per Cent Used as Print

Density	Gamma	Frequency	Harmonic	Modulation
0.6	1.0	100	5.5	4.3
1.0	1.0		4.9	3.6
0.6	1.5		4.3	5.4
1.0	1.5		4.7	3.5
1.4	1.5		7.1	3.6
1.6	1.5		11.1	3.0
0.85	2.0		4.1	5.0
1.0	2.0		5.8	3.7
1.3	2.0		5.9	3.6
1.5	2.0		6.0	3.6
2.1	2.0		7.9	3.9
0.5	1.0	1000	3.2	4.9
0.72	1.0		4.1	4.2
0.9	1.5		3.5	4.4
0.65	1.5		4.6	4.2
0.80	1.5		3.2	3.5
1.25	1.5		5.1	4.3
0.8	1.0	2500	6.9	4.6
1.0	1.0		11.3	5.2
0.65	1.5		5.8	4.4
1.0	1.5		10.0	4.2
1.2	1.5		14.0	5.2
1.55	1.5		13.6	7.3
0.8	2.0		4.6	4.0
1.0	2.0		7.7	4.3
1.2	2.0		12.4	3.9
1.55	2.0		13.9	4.6
2.1	2.0		14.4	8.0
0.75	1.0	4000	13.5	6.8
1.13	1.0		13.0	10.1
0.70	1.5		7.5	6.0
1.05	1.5		13.3	6.5
1.35	1.5		14.0	7.3
1.65	1.5		17.8	9.9
0.8	2.0		5.8	5.7
1.0	2.0		10.7	5.8
1.25	2.0		13.9	5.8
1.5	2.0		15.2	7.0
2.1	2.0		17.6	10.4

used the amount of harmonic content passes through a well-defined minimum. The position of the minimum with respect to print density depends on the negative density. The curves indicate that for the lowest harmonic content the print density should be equal to or slightly less than the negative density. Fig. 2 shows a similar set of curves from records made at a frequency of 4000 cycles per second. Again, it is seen that the position of this minimum point depends on the density of the negative from which the prints were made, and that its position again falls at a point where the densities of the negative and the print are about equal. It should be observed that, in general, the harmonic content increases at a somewhat greater rate above than it does below the optimal value.

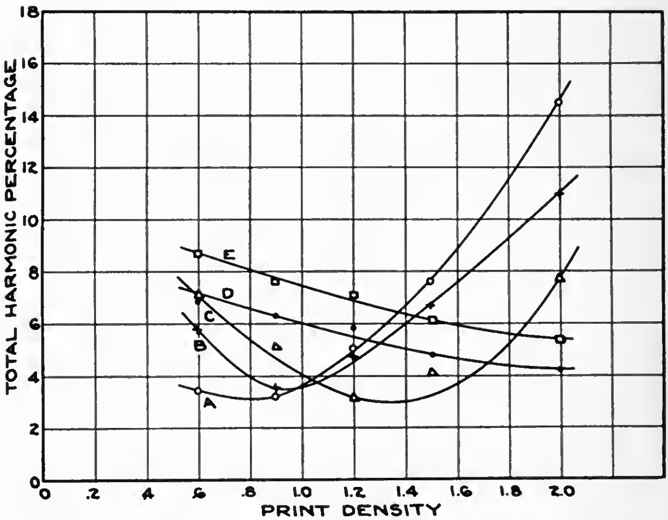

FIG. 1. Harmonic distortion at 100 cycles per second as a function of print density for various negative densities. Negative densities 0.85, 1.0, 1.3, 1.5, and 2.1 for curves *A*, *B*, *C*, *D*, and *E*, respectively. Negative gamma 2.0.

Fig. 3 shows the relation between print density and modulation in print transmission or volume of prints made from negatives *A*, *B*, *C*, *D*, and *E*, as above, that is, densities of 0.85, 1.0, 1.3, 1.5, and 2.1, respectively, at a frequency of 100 cycles per second. These curves show a definite relation between the print density and the modulation. It is seen that modulation, like harmonic content, is a function of the print density, and that its optimal value falls at a point where the print density is a little less than that of its negative. The conditions which produce the smallest amount of non-linear distortion are fortunately in close agreement with the conditions which produce the greatest modulation in the print transmission, that is, output volume.

That this should be true becomes more or less evident when one considers the structure of the developed photographic image. That is, the loss in modulation is due primarily to light scattered beyond the geometric edge of the image of the recording aperture, thereby causing a "filling-in" in the valleys of the waves. Now any process of printing and developing which cancels out this "filling-in" will also affect a partial or complete restoration of the original wave-form. The remarkable feature is the degree of cancellation which is ob-

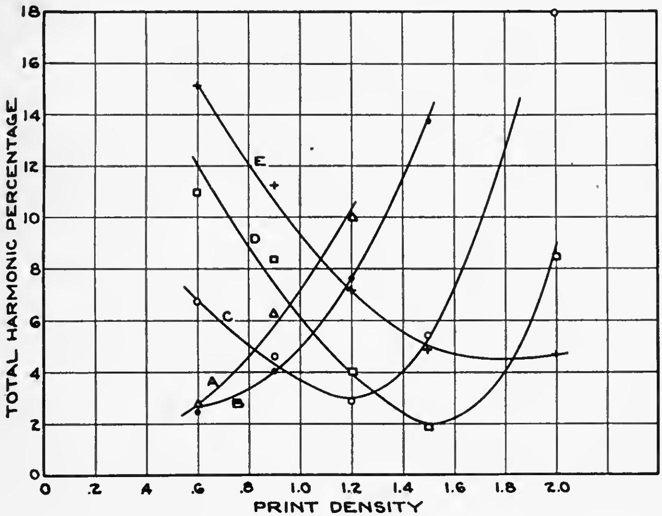

FIG. 2. Harmonic distortion at 4000 cycles per second as a function of print density for various negative densities. Negative densities 0.8, 1.0, 1.25, 1.5, and 2.1 for curves *A*, *B*, *C*, *D*, and *E*, respectively. Negative gamma 2.0.

tained by a proper choice of print density. Thus, from a dense negative which is filled in sufficiently so that the modulation in the transmission is very low, a print can be made by proper choice of print density, whose modulation of transmission approaches nearly the theoretical maximum value.

Fig. 4 shows a set of curves similar to those of Fig. 3, but for a frequency of 4000. At this frequency the print density for maximum modulation is better defined than at a frequency of 100. In all cases studied, the conditions for maximum modulation and minimum harmonic content are met by making the print density equal to or slightly less than the negative density.

The actual records made included four modulations for each recording condition, namely: 1, 3, 6, and 10 db. below full modulation. These records were all analyzed, and a study of the results indicates that under satisfactory recording conditions there is little change in the harmonic distortion for different recording modulations. The curves of Fig. 5 show some of the effects obtained. Curve *E*, the highest, was taken at a frequency of 4000, negative density 1.2, print density 1.5, and shows a decreasing distortion as does the second

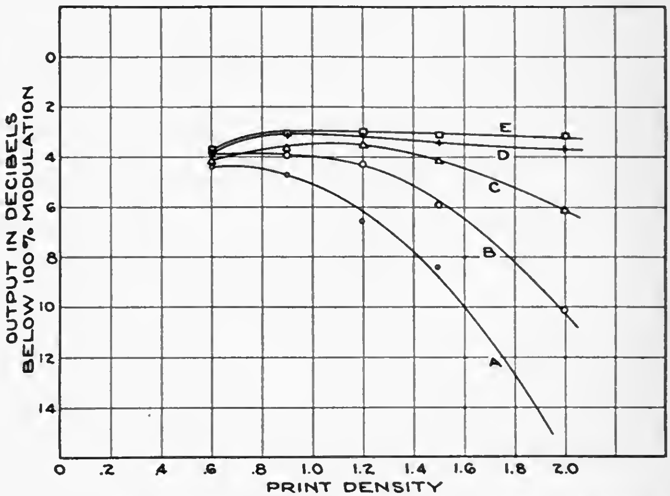

FIG. 3. Modulation as a function of print density for various negative densities; 100 cycles per second. Negative densities 0.85, 1.0, 1.3, 1.5, and 2.1 for curves *A*, *B*, *C*, *D*, and *E*, respectively. Negative gamma 2.0.

curve *A* for a frequency of 100, negative density of 1.5, and print density of 1.5. The other curves, *B*, *C*, and *D*, show approximately constant values of about 2 to 4 per cent total harmonic, the curves being for 1000 cycles, negative density 1.3, print density 1.5; 4000 cycles, negative density 1.5, print density 1.5; and 4000 cycles, negative density 2.0, and print density 2.0. For abnormal negative or print conditions, the harmonic values may decrease somewhat with decreasing modulation, particularly at lower frequencies. In view of the fact, however, that these abnormal conditions also introduce greater losses in modulation of print transmission, they were not investigated further. It might be noted here that even under rather bad conditions of harmonic distortion, the volume distortion at all frequencies remains negligible, the output levels keeping exactly the same ratio as the input levels.

From the standpoint of surface noise alone, the density in the exposed area of the sound track should be infinite, or at least sufficiently high so that the amount of light transmitted by it is negligible. For practical purposes, this condition is sufficiently well fulfilled in the neighborhood of a density of 1.5. At this value of negative and print density the percentage of total harmonic content is nearly at

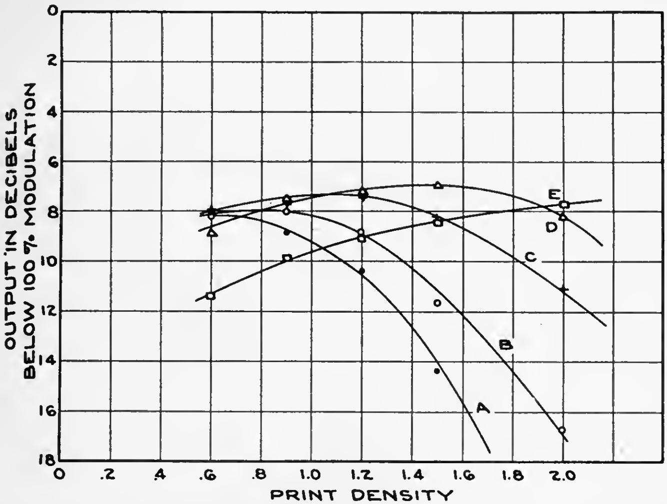

FIG. 4. Modulation as a function of print density for various negative densities; 4000 cycles per second. Negative densities 0.8, 1.0, 1.25, 1.5, and 2.1 for curves *A*, *B*, *C*, *D*, and *E*, respectively. Negative gamma 2.0.

its minimum value, as will be seen by again referring to Figs. 1 and 2.

Now referring to Figs. 3 and 4, one sees that a density of 1.5 is also approximating the most favorable over-all value from the point of view of film loss. It may be found necessary to alter this condition slightly in order to get the best possible response at the frequencies 8000 and 10,000. Such a modification, if any, will very probably be toward lower negative and print densities. However, any such modification would not materially affect either the modulation or harmonic content, since the above data show that by changing the print density to conform to the density of the negative, one can obtain equally satisfactory results over a wide range of densities. It would, however, affect the relative level of the surface noise somewhat. If, however, the conditions which lead to the least film loss at the highest frequencies to be reproduced are not in agreement with the conditions which give the smallest amount of distortion in the frequency range where the harmonics generated by non-linear distortions would be transmitted by the reproducing systems, then a further compromise must be made. It is generally agreed that a certain amount of harmonic distortion may be present before it

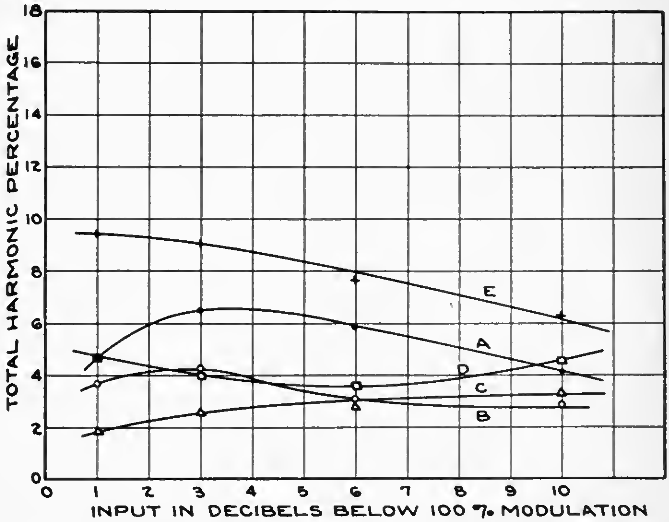

FIG. 5. Harmonic distortion as a function of recording amplitude: *A*, 100 c.p.s., negative density 1.5, print density 1.5; *B*, 1000 c.p.s., negative density 1.3, print density 1.5; *C*, 4000 c.p.s., negative density 1.5, print density 1.5; *D*, 4000 c.p.s., negative density 2.1, print density 2.0; *E*, 4000 c.p.s., negative density 1.2, print density 1.5. All negatives at gamma 2.0 except *B*, which is at gamma 1.5.

becomes apparent to an observer. The actual amount which can be present before becoming perceptible is a subject which has led to a certain amount of controversy among investigators, the amounts being variously stated from 2 per cent to 10 per cent. If one assumes the latter value to be the superior limit, considerable latitude is allowed in negative and print conditions.

The results given here should serve only as a general basis on which to operate, making the necessary modifications to suit any particular case. Thus, for example, the quality of the image of the recording aperture, the ratio of light on the film within the geometric boundary of the image to the light in the sound track outside that boundary as well as the distribution of illumination within the boundary and outside the boundary, and the type of film and developer used, would modify the above results somewhat.

In general, it might be stated that the process is not critical to over-all gamma, in fact that the term over-all gamma has very little significance. The gammas of the negative and the print within wide limits are of importance primarily because they serve as a measure of the density that will be obtained for a given predetermined exposure. For any given negative density developed to any gamma lying within relatively wide limits, there is a corresponding print density which gives the smallest amount of non-linear distortion. There is also a print density which produces the greatest modulation in the print transmission or output volume. The print conditions required to satisfy these two conditions are in general mutually agreeable.

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DISCUSSION

MR. COOK: Mr. Sandvik has referred to some work which I did at one time on a problem related to the subject which he has investigated. Because I have been asked many times why experimental results differ from the values supposedly predicated in my paper, it would seem desirable to call attention to the assumptions underlying that work. Infinite sensitivity of the photographic material was assumed; in variable amplitude film, all exposed parts were to be uniformly opaque, all clear parts uniformly transparent. The reason for that assumption lay in the fact that if the edges of the exposed parts were assumed to be of a variable density, as exists in practice, some laborious numerical integrations would be encountered; and at the time the work was done, some time in 1927, it was more important commercially to know an upper limit for the loss of fundamental output than to be able to calculate exactly the harmonic content. Since the above idealizing assumptions made the integrations simple, the upper limits for these latter effects were also given, but the more general problem was given up.

Since that time Donald Foster has found occasion to extend the analysis further. His investigation yields much more exact results in practical problems. I have had occasion to check Mr. Foster's work approximately and find good agreement between test results and his predictions. Particularly good agreement was found between test and calculation for the variation of average transmission. Now, I should like to ask Mr. Sandvik, first, how were the prints made from the original negatives? I would assume that they were contact prints made in a printing frame, since that would seem to be the obvious way to make them. Second, was the distribution of light along the length of the aperture, as well as transversely, examined; and if so, what was found? Third, on what type of recorder were the original records made? And last, what was known about the wave-shape of the oscillator used? The amount of distortion in some cases was small enough to make one wonder about that element or even the amplifiers used.

MR. SANDVIK: Prints were made both in printing frames, and on a continuous contact printer in order to see whether the results obtained by the two methods differed. We found that when care was taken to insure good contact and eliminate slippage on the continuous contact printer, the results in the two cases were essentially the same.

As to the uniformity of illumination across the image of the recording aperture, we measured the illumination along the longer dimension, and made it as uniform as possible along the entire length of the image. The maximum deviation at any small section of the image from the average of all other similar sections was of the order of one to two per cent. As to the other dimension, I can't give you any definite information. Due to diffraction at the two edges the distribution of illumination across the slit image is, of course, not uniform.

MR. PALMER: Are these harmonics produced by a spreading of the image, due to a longer time of development?

MR. SANDVIK: The chief cause of the distortions is due to the spreading of the image. There are other secondary causes, such as aperture effect, which I consider very small compared with the spreading within the emulsion.

Regarding the distortion due to spreading within the emulsion, it doesn't make much difference how the density is obtained—whether by exposure or by development. Spreading would be of approximately the same order, although since the sharpness of the edge or the density gradient is a direct function of the gamma of development, it is better to get the density by development.

MR. BATSEL: What percentage of complete modulation was used in making these measurements?

MR. SANDVIK: We found that for a "normal" sound track, throughout the frequency range investigated, the distortion is practically independent of modulations below 100 per cent.

MILITARY TRAINING AND HISTORICAL FILMS*

F. W. HOORN**

Summary.—*Some of the problems involved in developing a program of military and civilian training films are briefly described, in addition to the manner of using the films in peace-time and war-time training. The relation between the Signal Corps and the storage of historical film in the New Archives Building at Washington, D. C., is briefly referred to.*

It is assumed that the interest of the S. M. P. E. in the subject of military use of films is based upon two aspects of the activity. If the subject has any significance, it is derived, first, from the relation of the undertaking to national defense and, second, from its possible value as a guide to the possibilities that may lie in the use of talking films for educational purposes.

This assumption is made without any implication that the army is now ready to point the way to the development of training films. Such an implication would be far from the fact. Only a very small portion of the army's resources have been or can be placed at the disposal of this activity until such time as its development can begin to show promise of dividends commensurate with the investment. It is well known that the army's resources are so scattered over a wide range of civil and military missions, that any further dilution of its strength by embarking on a grand scale upon new activities of unproved worth is not considered justifiable. Before any considerable commitments are made in the field of training films, it will probably be required that measurable results demonstrate their value.

This preface is not offered in order to evade responsibility for the many limitations of technic in the output available to date, but to present a true picture of our little organization, as a basis for an analysis of its possibilities.

In the development of any training film program there are two

* Presented at the Spring, 1933, Meeting at New York, N. Y.

** Captain, U. S. Signal Corps, Washington, D. C.

distinct phases: the building up of a library of films and the creation of an outlet by providing projection facilities. This appears to have resulted in a vicious circle in the civilian teaching field in that the lack of each has retarded the growth of the other.

In the field of military training the scope of the subject matter is not so broad, and consequently the vicious circle should be easier to break down by the production of a reasonable number of films of wide applicability. Specificially, when twenty or more sound film subjects have been produced, it will probably be justifiable to begin the program of supplying projectors.

At present the activity is in a development rather than a production stage. The laboratory is small and the personnel limited. Whether or not it will grow, and to what extent, depends upon future developments. Next year it is hoped that we shall be able to produce from twelve to sixteen reels of training film negative, if unexpected personnel cuts are not imposed. While this seems a small amount, it should be adequate as a basis for study and future planning.

Ever since the World War, the army has produced and utilized in a desultory manner, training films on a fairly wide variety of subjects. These films were, however, of the silent type, and were therefore much more limited in scope than those at present possible. Only subjects in which the picture was virtually self-explanatory could advantageously be presented. Titles as a means of explanation in an instruction film leave much to be desired. That one picture is worth a thousand words is one of those sayings whose forceful brevity often inclines one to exaggerate their applicability. Instruction in architecture might conceivably be given mainly by pictures, whereas instruction in economics or philosophy could best be presented by words. Most military subjects are such as to require both picture and words. Keeping clearly in mind that motion is the essence of good films and that verbalism is obnoxious, it is nevertheless somewhat apparent that subjects involving personnel, matériel, and their maneuver over terrain, can best be presented with the aid of verbal explanation to support the picture.

For that reason the advent of sound films gave a slight impetus to the training film idea and indicated the desirability of determining their usefulness. A start was made in acquiring a minimum of essential equipment and in training personnel. This personnel training was further handicapped by the military necessity for rotation of officers in duty and station, thereby limiting specialization.

More publicity has been given to the undertaking than is warranted by its magnitude. The idea of replacing the legendary hard-boiled drill sergeant with a phantom screen instructor seemed a fairly welcome subject for speculation by the press. One commentator hazarded the thought that the screen would not go far toward creating the "day-of-judgment atmosphere provided by these old-time drillmasters."

Actually, the field of training films is much broader than close-order drill. As far as present experience permits one to judge, it appears that its greatest value will lie in the field of tactics, especially the tactics of small units. For such a type of subject can more easily be produced and, when finished, has a wider applicability than those pertaining to the higher commands. More of the actual movements of the unit can be shown and less reliance needs be placed on animation.

In the case of large units, maps and drawings or aerial views, combined with animation devices for locating organizations and activities on the ground, will be indispensable. Actual scenes will be limited to those showing the activities of commanders and staffs, and special activities which can be viewed at sufficiently close range to make them distinct.

In all training subjects the technic of presentation must offset the well-known limitations of camera and screen as to distance and narrow angle of vision. In the drama the relative location of events is usually not as important as are the emotions and characters of the participants, while in the military films continuous orientation of the observer as to the space relations of the things he sees is usually essential.

At the beginning of our development program, it seems desirable to produce as wide a variety of subjects as possible, in order to be able to judge the susceptibility to treatment of each type. In the second stage, effort will probably be concentrated on the production of subjects for which there is the most widespread demand, inasmuch as efficiency of the method of instruction depends in large degree on the universality of the subject.

Experience is still somewhat limited as to the best method of treatment of military subjects. At the outset, only the off-stage voice type of film was contemplated. Since then, it has seemed desirable to attempt field recording for the sake of heightening the interest by the inclusion of dialog between the actors wherever it appears that the instructional matter can be so presented. A natural sound film on the subject of Communications in the Infantry Regiment has just come through the shooting stage and is awaiting cutting and editing.

This film will at least furnish information as to the feasibility of this method with our present organization. If it is satisfactory, future productions will probably be combinations of the descriptive talk and the natural sound methods. Subjects involving technic and the method of handling matériel can often be handled best by the descriptive talk or off-stage voice, while subjects based on the decisions and actions of personnel can be handled largely by natural sound with occasional off-stage voice explanations. Considerable study can be utilized devising ways of incorporating instructional matter in the speech of the actors without undue sacrifice of naturalness.

The success or failure of instructional films, whether military or civilian, will in the end depend on the instructional effectiveness which can be developed and the relative efficiency on a cost basis as compared with other methods. A few of the factors affecting instructional value have been touched upon. Actually its value can be determined only by trial and test with films produced under existing limitations. Relative efficiency on a cost basis can be estimated only by making certain broad assumptions as to the conditions under which film will be projected. Such data as are available indicate that a film of wide applicability in the military service may be shown throughout its life to a hundred thousand persons. On this basis, the cost per individual per hour of instruction should not exceed fifteen cents, and may be considerably less.

In order that the widest possible use may be made of the films in time of peace, sound projection facilities should be made available to the civilian components of the Army, namely, the Organized Reserve, the R. O. T. C., and the National Guard. For this purpose, the 16-mm. projector seems to be quite well suited. Any improvements which can be made in the way of simplicity so that the projector can be operated by any one after looking over the instructions, will be a step toward solution of the future projection problems.

Until such time as it seems advisable to supply portable projectors in considerable number, the use of sound training films will be limited to groups who can make use of projection facilities on nearby army posts or to groups in the large cities near Corps Area Headquarters where portable projectors can be made available on loan. Another method of utilizing these films for the time being is to send a mimeographed copy of the descriptive talk with the film, to be read in approximate synchronism with the picture by someone conversant with the subject. This method has been used in some instances with success but its effectiveness under average conditions has not been determined.

In the event of a major war, the training film program will probably enter a third stage, namely, the hurried production of films on basic subjects for mass instruction of men throughout the country according to uniform standards, using the latest developments of the moment. An attempt to provide a complete library in advance of such a contingency would not be warranted, for military methods change, as does everything else, and many of the films would be obsolete when needed. If and when such a need arises, the army will have to lean heavily on the industry in organizing a producing unit, capable of turning out, let us say, eight or ten reels a week.

Production of historical film lies in the past and in the future. At present only a very limited amount of footage is being produced that can in any sense be termed historical.

The termination of the World War left us with approximately six hundred thousand feet of negative made in France. This film includes action at the front and in the rest and training areas, activities at supply depots, and debarkation centers.

The quality of the film both as to photography and subject matter varies greatly. A great deal depended on the initiative and skill of the individual cameramen. In many cases the scenes are longer than necessary, and editing while shooting could have been accomplished to great advantage.

However, the A. E. F. file constitutes a valuable record that will be of increasing interest as time goes on. That every means should be taken to preserve this film, or the most valuable part of it, is self-evident. A step in this direction was taken when the advice of a technical committee was obtained in order to provide the best possible conditions in a film storage vault of the Archives Building at Washington, D. C., where it is contemplated placing this film for indefinite storage.

At the present time the World War film is used principally for loan to the American Legion and other service organizations, patriotic societies, and educational institutions. Our laboratory makes approximately a thousand loans a year to meet this demand.

In the event of another war, the organization of the photographic service should be such as to make possible a continuous record of each tactical division, with animation to show their movements and descriptive talk to supply further detail and color.

To accomplish this task would require a considerable personnel, with prior training in the various specialties, administration, direction, laboratory supervision, and technical work. A central laboratory well to the rear would do the film processing and probably animation work. A photographic company would be included among the Army troops of each Field Army. From that company would be sent out nine divisional assignment units to cover the activities of the combat divisions. If, say, four field armies were mobilized, it is estimated that the photographic personnel required would be not less than ninety officers and eight hundred men, almost all of whom would have to come from the industry.

BOOK REVIEW

Light in Motion Picture Projection (La Lumière dans la Projection Cinematographique). JACQUES MARETTE. *Gauthier-Villars Co.*, Paris, 1933.

The purpose of this book, as stated in the introduction, is to present a coherent practical explanation of the factors in projection influencing the quality of the projected motion picture. The treatment is rather elementary, but the book is valuable because it fulfills the need for a well-rounded exposition of the subject in language understandable to those engaged in practical projection.

Topics touched upon include the following: principles of vision, quality of the film image, visual appreciation of the projected image, the effect upon picture quality of screen brightness and stray light, optical properties of the screen, rear projection, light sources, the large screen, *etc.*

C. E. IVES

SOCIETY ANNOUNCEMENTS

FALL MEETING OF THE SOCIETY, EDGEWATER BEACH HOTEL, CHICAGO, ILL.

OCTOBER 16–18, INCLUSIVE

CONVENTION ARRANGEMENTS COMMITTEE

W. C. KUNZMANN, *Chairman*

J. H. KURLANDER
M. W. PALMER

LOCAL ARRANGEMENTS COMMITTEE

R. F. MITCHELL, *Chairman*

J. E. JENKINS	R. P. BURNS	O. HOLMES
H. T. COWLING	G. W. BAKER	J. E. MCAULEY
H. H. DEVRY	O. B. DEPUE	J. H. GOLDBERG
A. WARMISHAM	B. W. DEPUE	O. F. SPAHR

PROJECTION COMMITTEE

H. GRIFFIN, *Chairman*

J. E. MCAULEY	J. H. GOLDBERG
R. P. BURNS	J. FRANK, JR.

Members of Local No. 110, I. A. T. S. E.

LADIES COMMITTEE

MRS. O. B. DEPUE, *Hostess*

assisted by

MRS. R. F. MITCHELL	MRS. B. W. DEPUE	MRS. J. E. JENKINS
MRS. H. T. COWLING	MRS. H. DEVRY	MRS. A. WARMISHAM

OPENING OF CONVENTION

The Convention will convene at 12:30 P.M., Monday, October 16, in the North Room of the Edgewater Beach Hotel, opening with an informal luncheon, during which the members of the Society will be addressed by several prominent speakers. Luncheon tickets may be procured at the registration headquarters; charge, one dollar per plate. The morning preceding the luncheon will be devoted to registration, committee meetings, and various organization matters. The convention registration fee will be three dollars.

The hotel may be reached from the La Salle St. station either by taxicab ($1.50), by No. 51 bus going north on Michigan Avenue, or by elevated express train at the Howard St. station.

SESSIONS

All technical sessions and film programs will be held in the East Lounge of the hotel, where also will be located the registration headquarters. The *Berwyn* room will be provided for the Board of Governors and the technical committees. Technical sessions will be held on Monday, Tuesday, and Wednesday afternoons, and on Tuesday and Wednesday mornings. The film program, under the direction of Mr. H. DeVry and Mr. S. A. Lukes, will be held on Monday evening, and will include several recent outstanding productions, in addition to several reels of the Century of Progress World's Fair, photographed by Mr. H. T. Cowling.

BANQUET AND DANCE

The S. M. P. E. Semi-annual Banquet and Dance will be held in the Ball Room of the Edgewater Beach Hotel, Tuesday evening, October 17, at 7:30 P.M.—an evening of dancing and entertainment, with no banquet speeches. Banquet tickets should be obtained at the registration headquarters; tables reserved for eight or ten persons; tickets, four dollars each.

EXHIBIT OF NEW MOTION PICTURE APPARATUS

Arrangements are being made to hold an exhibit of newly developed motion picture apparatus, in order to acquaint the members of the Society with the newly devised tools of the industry. This exhibit will not be of the same nature as the usual trade exhibit. There will be no booths, although each exhibit will be allotted definite space, and all exhibits will be arranged in one large room. Please direct requests for space to the General Office of the Society, 33 West 42nd St., New York, N. Y., stating the number and nature of the items to be exhibited.

SPECIAL EXTENDED RATES

Excellent accommodations are assured by the management of the Edgewater Beach Hotel, and minimum rates are guaranteed. Reservations, subject to cancellation prior to the convention dates, must be made *at once*, on account of the heavy advance registration incident to the large attendance at the Century of Progress Fair. Special rates have been arranged by the hotel, which will be effective during the stay of S. M. P. E. delegates and their guests in Chicago, should they wish to visit the Fair before or after the Convention. Particular attention is called to the special railroad rates applying to trains leaving New York on Saturdays and Tuesdays; 10-day round trip charges: fare $33, lower berth $13.50; in contrast with the regular rates on other days of the week of $65.40 and $18, respectively.

CENTURY OF PROGRESS WORLD'S FAIR

Members of the Society who attend the Convention will be able to take advantage of the opportunity of visiting the Century of Progress World's Fair, now being held in Chicago, and which will close October 31. They will also be able to benefit by the special rates provided by the Edgewater Beach Hotel and the reduced railroad fares now in effect because of the Fair.

LADIES' HEADQUARTERS

A reception suite will be provided for the use of the ladies attending the Convention, and an attractive program for their entertainment is being arranged by the Ladies' Committee. Upon arriving, the ladies should register immediately at the reception room. The ladies are invited, weather permitting, to be the guests of Mr. and Mrs. H. DeVry aboard their yacht, for a cruise on Lake Michigan and a view of the beautiful waterfront of the World's Fair.

TENTATIVE PROGRAM

MONDAY, OCTOBER 16TH

The morning will be devoted to organization of the Convention, registration, meetings of committees, *etc.*

12:30 a.m. Luncheon (for members and their families and friends). Addresses by prominent speakers, to be announced later.

2:30 p.m. *East Lounge:* **Business Session.**
Opening of Convention; A. N. Goldsmith, *President.*
Report of the Secretary; J. H. Kurlander.
Report of the Treasurer; H. T. Cowling.
Report of the Convention Arrangements Committee; W. C Kunzmann, *Chairman.*
Society Business: election of Officers for 1933–34; proposals for amendment of Constitution and By-Laws. (The importance of the matters to be acted upon at this meeting makes a full voting attendance very desirable.)
Report of the Membership and Subscription Committee; E. R. Geib, *Chairman.*
Technical papers will be scheduled for this session, as time permits.

8:00 p.m. *East Lounge:* Exhibition of recent talking motion pictures, including pictures of the Century of Progress Fair, taken by H. T. Cowling.

TUESDAY, OCTOBER 17TH

9:30 a.m. *East Lounge:* **Technical Session.**
"Wide Range Recording;" by F. L. Hopper, Hollywood, Calif.
"Acoustic Requirements for Wide Range Reproduction;" by S. K. Wolf, Electrical Research Products, Inc., New York, N. Y.
"Wide Range Sound Reproduction;" by J. S. Ward and F. C. Willis, Electrical Research Products, Inc., New York, N. Y.
Report of the Historical and Museum Committee; E. Theisen, *Chairman.*
Report of the Committee on Laboratory and Exchange Practice; R. F. Nicholson, *Chairman.*
"Sixteen-Millimeter Film and Film Recording Problems;" by J. O. Baker, RCA Victor, Inc., Camden, N. J.

2:00 p.m. Group "A," *East Lounge:* **Projection Session.**
"New 35-Millimeter Portable Projector;" by H. Griffin, International Projector Corp., New York, N. Y.
"Continuous Projection in Motion Pictures;" by H. R. Menefee, Pathé News, New York, N. Y.
"Automatic Change-Over Device;" by A. Pritchard, Coronado, Calif.

"The Control Frequency Principle;" by J. E. Jenkins, Jenkins & Adair, Chicago, Ill.

2:00 p.m. Group "B," **General Session.**

"Acoustic Materials;" by H. M. Baker, U. S. Gypsum Co., Chicago, Ill.

"Some Suggestions on Motion Picture Laboratory Practice;" by D. E. Hyndman and H. E. White, Eastman Kodak Co., New York, N. Y.

"The Photographic Disk Reproducer;" by E. D. Cook, RCA Victor Co., Camden, N. J.

"Recent Improvements in the Bell & Howell Automatic Printer;" by R. F. Mitchell and A. S. Howell, Bell & Howell Co., Chicago, Ill.

"The Rotambulator, a New Type of Camera Stand;" by J. A. Dubray, Bell & Howell Co., Chicago, Ill.

7:30 p.m. *Ball Room:* **Convention Banquet.**

Dancing, Motion Pictures, and Entertainment.

WEDNESDAY, OCTOBER 18TH

9:30 a.m. *East Lounge:* **General Session.**

"Film Noise in Sound-on-Film Reproduction;" by H. C. Silent, Electrical Research Products, Inc., Hollywood, Calif.

Report of the Standards and Nomenclature Committee; M. C. Batsel, *Chariman.*

"Educational Use of Sound Pictures" (with demonstration); by H. B. Lemon, University of Chicago, Chicago, Ill.

Report of the Projection Practice Committee; H. Rubin, *Chairman.*

2:00 p.m. Group "A," *East Lounge:* **Illumination Session.**

"A Non-Rotating D-C. High-Intensity Arc;" by A. C. Downes, National Carbon Co., Cleveland, Ohio.

"Alternating-Current Arc Equipment;" by J. E. Robin, Palisades, N. J.

"A New Type of Carbon Arc Broadside Lamp for Use in Motion Picture Production;" by Peter Mole, Mole-Richardson, Inc., Hollywood, Calif.

"Economies of Projection Lamps;" by E. W. Beggs, Westinghouse Lamp Co., Bloomfield, N. J.

2:00 p.m. Group "B," **General Session.**

"The New DeVry Camera;" by H. A. DeVry, Chicago, Ill.

"Home Talkie Movies;" by C. F. Jenkins, Washington, D. C.

"Effect of Film Shrinkage on Sound Film Printing;" by J. Crabtree, Bell Telephone Laboratories, New York, N. Y.

"Manufacturing Problems in Sound Picture Equipment;" by H. E. Decamp, Western Electric Co., Chicago, Ill.

"Some Applications of Sound Reproducing Equipment at the Century of Progress Exposition;" by E. P. Kennedy, Electrical Research Products, Inc., Chicago, Ill.

ADJOURNMENT OF THE CONVENTION

NOTE: The Society of Motion Picture Engineers will not be responsible for statements made by authors. It should be understood that this program is *tentative*, and that the order of presentation of the papers is subject to change by the Papers Committee.

Convention Committee,
W. C. KUNZMANN, *Chairman*

Papers Committee,
O. M. GLUNT, *Chairman*

STANDARDS COMMITTEE

An informal meeting of the group of the Standards Committee engaged in preparing and collecting data on sprocket dimensions was held at the General Office on September 12. Drawings and charts submitted by Mr. H. Griffin were studied preparatory to submitting them to the Standards Committee as a whole at its next meeting, which is to be held on September 27.

A complete revision of the S. M. P. E. Standards booklet has been prepared for submission to the Society at the approaching convention in Chicago, October 16 to 18. The Committee is also communicating with the British Kinematograph Society of London in regard to deciding upon the dimensions of a standard film core.

PROJECTION PRACTICE COMMITTEE

At a meeting held at New York, N. Y., September 19, the preliminary arrangement of the semi-annual report, to be presented at the Chicago Convention, was decided upon, the tentative draft to be acted upon at the next meeting on October 4. The subjects of the report will include an exposition of the elementary systems of sound projection, projection routine and maintenance, and precautionary measures for avoidance of trouble in projection.

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SYLVAN HARRIS, EDITOR

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DIRECTIONAL EFFECTS IN SOUND FILM PROCESSING—II*

J. CRABTREE AND J. H. WADDELL**

Summary.—*This paper represents a continuation of work previously reported (J. Soc. Mot. Pict. Eng., XVIII, No. 2, February, 1932, p. 207) concerning distortion of the photographic image resulting from directional currents of developer generated by movement of the film in film processing machines. Simpler methods of breaking up the directional currents than those previously described have been examined. Characteristic curves from "directional pairs" of sensitometric strips, and "densograms" of uniform exposures have been used for purposes of comparison.*

Application of developer in the form of fine jets impinging upon the emulsion surface at frequent intervals has been found largely to eliminate directional effects. Violent agitation of the body of developer in the developing bath by injection of air gave good results, but was inferior to the jet system. Propelling the film on edge in a tray type machine offered no advantage over the horizontal film position. It is shown that under conditions found to be good from the standpoint of directional effects, distortions due to "Eberhardt effect" are present.

In an earlier paper by J. Crabtree,[1] of the same title, it was shown that in continuous film processing machines the unidirectional movement of the film generates a current of developer relative to it and opposite in direction. This current causes the photographic density at any point of the film to be affected by that preceding it, gives rise to various distortions of sensitometric exposures, and introduces distortion into the sound record. It was shown that this current is very persistent but can be broken up by use of a multiple squeegee device. It is obvious that any system of developer circulation efficient enough to suppress the directional current will prevent these effects.

Subsequent examination of sensitometric and flash exposures developed in the machines used in industrial laboratories showed that this directional effect is present in all commercial film processing machines in various degrees, depending upon the type of machine and the manner of developer circulation; being pronounced in negative development of positive film to low gammas and less in positive

* Presented at the Spring, 1933, Meeting at New York, N. Y.

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

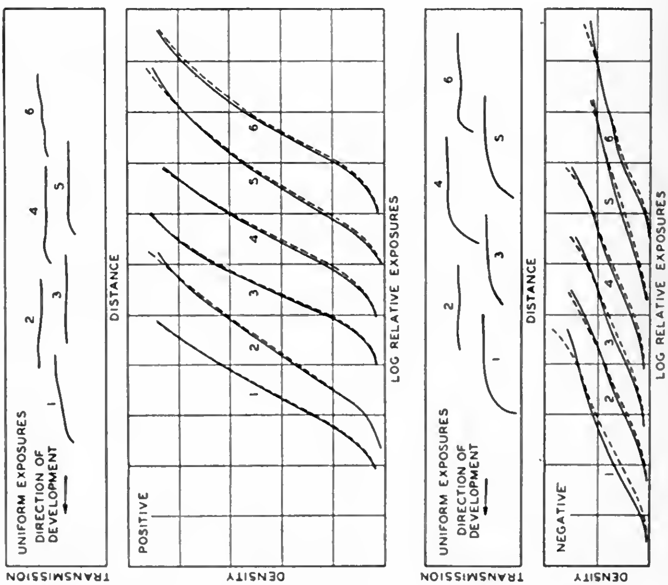

FIG. 1(*a*).

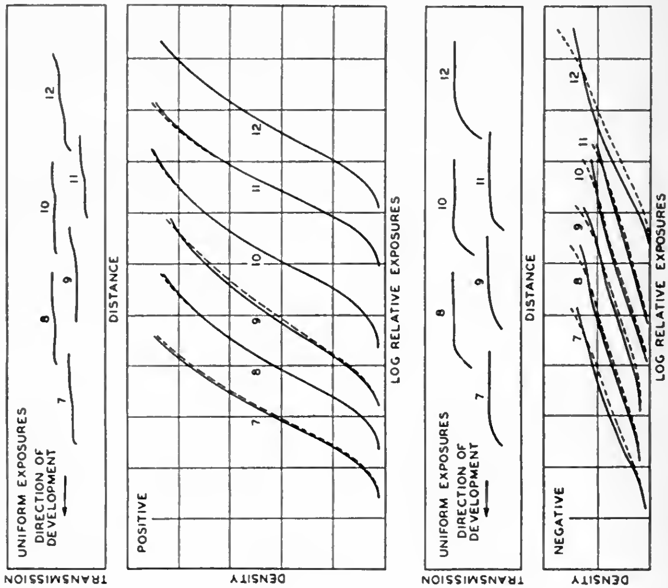

FIG. 1(*b*).

FIGS. 1 (*a*) and 1 (*b*). Directional effect exhibited by film processing machines in twelve different laboratories.

development, as would be expected from conclusions arrived at in the paper referred to above.

Fig. 1 summarizes data obtained from such an examination. It shows H&D characteristic curves derived from "direction pairs"* of sensitometric exposures for both negative and positive development in twelve different laboratories. The degree of separation between these curves gives an indication of the extent of the "directional effect."

In addition to the sensitometric exposures, lengths of film were processed which had received exposures to light over a longitudinal distance of twelve inches, across the entire width of the film. These exposures were made in a printing frame under conditions known to give uniformity of exposure. After processing, a "densogram" of each strip was made on a recording densitometer, the scanning being done at the normal location of the sound track. This results in a graph in which values of light transmission appear as ordinates and longitudinal distances along the film appear as abscissas. If development is uniform, the light transmission will be constant and the graph is a horizontal line. When directional currents exist, the leading end of the exposure will attain a higher density than the following portions and the graph of transmission will show a rising characteristic, the degree of slope and the length of the curved portion being measures of the degree of non-uniformity of the development.

In Fig. 1 the graphs of the flash exposures are shown above the corresponding H&D characteristic curves. Those curves having the same numeral are from the same laboratory. Eleven commercial laboratories are represented, the twelfth (No. 2) being the Sound Picture Laboratory of Bell Telephone Laboratories, Inc.

It is evident from the graphs that in all the laboratories for which data are available directional effects are pronounced in negative development.

The modifications of the sound record which result from these effects are not easy to determine. An attempt was made, by harmonic analyses of microphotometric traces of the developed record, to measure the distortion produced by development of a 100-cycle record under conditions known to produce directional effects. The results were not entirely satisfactory and do not warrant conclusions, and lack of time has since prevented their repetition.

* That is, two identical sensitometric exposures are processed, one with the "toe" end, the other with "shoulder" end, leading through the developer.

Another development defect arising from insufficient developer circulation results from the surge of developer through the film perforations, causing local turbulence around such perforations and occasioning an increase in the degree of development adjacent to these points. This may give rise to a variation in density of the sound track corresponding to the frequency of the perforations. A microphotometric trace of three frames of a 5000-cycle record having such defect in a marked degree is shown in Fig. 2.

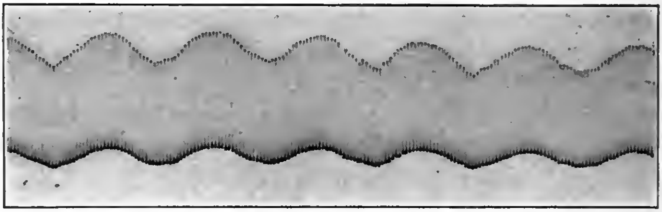

FIG. 2. Sprocket hole modulation due to development defects.

It is obvious that an entirely satisfactory development of a sound film record can not be attained unless the circulation of developing solution at the emulsion surface of the film is sufficient to overcome the effects mentioned. An attempt was therefore made to determine what might be an effective means of attaining the degree of circulation essential to this requirement. This doubtless depends to a considerable degree on the type of machine involved. While only one type—the Erbograph, a horizontal tray type—was available at the Sound Picture Laboratory for the experiments, it was hoped that certain principles could be arrived at covering conditions in general.

Rapid interchange of developer at the surface of the film may be accomplished by:

(1) Continual wiping of the emulsion surface by squeegee, brush, or by jet of developer;

(2) Sufficiently violent agitation of the mass of developer; by:

- (*a*) rapid inflow and outflow,
- (*b*) agitation by blades or paddles,
- (*c*) agitation by injection of air.

It was felt that squeegees and brushes should be avoided, if possible, as representing potential causes of scratches, and additional parts requiring servicing. It was also felt that avoidance of agitation by moving mechanical parts should be sought.

Agitation by the bubbling of air might be considered undesirable on account of the increased rate of oxidation of the developing reagents induced thereby. Although this is undoubtedly the case with highly alkaline positive developers, the aeration induced by the bubbling of air would probably in some laboratories not greatly exceed that normally suffered due to entrainment of air by the developer pump circulating systems. In any event, the depletion of developer ingredients from aeration is a fraction of that due to the developing of the image.

In the metol-hydroquinone developers of low alkalinity (borax developers), in general use for negative development, aeration actually increases the developing power of the bath for a time. This has been shown to be due to the oxidation of the hydroquinone sulfite to the sodium salt of hydroquinone monosulfonate, liberating sodium hydroxide, which increases the alkalinity of the bath and therefore increases its developing power. The exhaustion of the bath by development of the image is accordingly partially offset by this increase of developing power, and it would seem possible that in a bath intended for comparatively short life, as negative baths usually are, the composition could be arranged so as to balance to some degree the effect of aeration against that of exhaustion, and thus attain a fairly constant developing power.

It is felt, therefore, that bubbling of air as a means of securing thorough agitation of developer is a practical possibility and perhaps worthy of further study.

The most promising means of circulation and agitation was considered to be by jets. By allowing the developer to enter the developing tank as a multiplicity of jets under a suitable head, a most efficient agitation can be secured. By making the jets of developer impinge on the emulsion surface of the film, which is submerged in the body of the developer solution, they serve the additional purpose of multiple squeegees. The developer tank may, however, be left empty, the film being suspended in air and the developer applied to the emulsion surface by the jet system, which results in a very rapid change of developer at the film surface. Aeration is, of course, marked in this latter case.

One Hollywood laboratory employs a machine of very ingenious design in which the film travels in a horizontal direction but with the emulsion plane vertical, *i. e.*, film on edge. Although this arrangement is made for purely mechanical reasons it was thought that gravity would assist in the removal of development reaction products more readily than in the arrangement where the film surface lies in a horizontal plane. It was thought worth while to study this plan.

The following ten conditions were compared in the Erbograph machine at the Sound Picture Laboratory* from the standpoint of perfection in results from development:

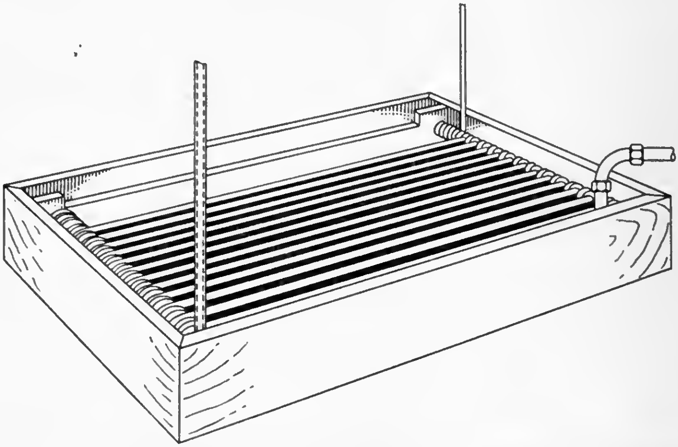

FIG. 3. Erbograph machine; developing trays, showing inlet pipe and overflow weir.

Condition 1.—No circulation of developer other than that generated by the motion of the film: film lying in a horizontal plane.

Condition 2.—Developer inlet by single pipe at one corner, outflow over wire along one side (Fig. 3): film lying in a horizontal plane.

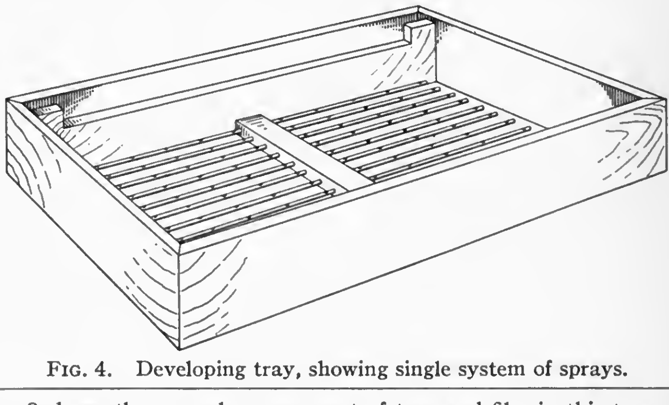

FIG. 4. Developing tray, showing single system of sprays.

* Fig. 3 shows the normal arrangement of tray and film in this type of continuous processing machine.

Condition 3.—As in (*2*), but film on edge.

Condition 4.—Developer inlet as a series of jets issuing from holes $^1/_{32}$ inch in diameter in a series of pipes secured to the bottom of tray (see Fig. 4 for arrangement). Film and jets submerged; film horizontal; jets in line. Rate of circulation 9 gallons per minute.

Condition 5.—Developer inlet as double set of jets; one set at bottom of tray with jets directed upward as in (*4*) and a second similar set suspended above the tray and directed downward on the top strands of the film (Fig. 5). Film submerged. Total rate of circulation 16 gallons per minute.

Condition 6.—As in (*5*), but film on edge.

Condition 7.—As in (*5*), but film suspended in air, *i. e.*, developer return by pump arranged to keep the tray always empty.

Condition 8.—As in (*2*), but air bubbled through the developer from the system of pipes shown in Fig. 4: film horizontal. Air consumption not determined, but in quantity sufficient to cause as violent ebullition as possible without spilling the developer over the tray sides.

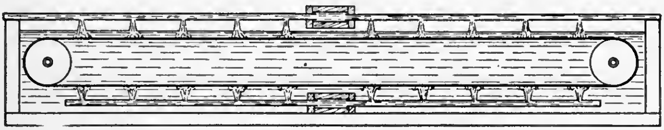

FIG. 5. Developing tray elevation, showing double system of sprays.

Condition 9.—As in (*8*), but film on edge.

Condition 10.—As in (*5*), but jets staggered so as to distribute the points of contact of jet with film effectively over the whole width of the emulsion surface.

Test exposures for comparing development efficiency may be of several types, but in these experiments consisted of:

(*a*) A series of "direction pairs" of sensitometric strips on E. K. positive film, covering various widths of track from full film width to sound track width in the region of the sound track. Of these, the results from the full and sound track width exposures are plotted for both negative and positive development in Figs. 6 to 15.

(*b*) A series of uniform exposures, twelve inches long and occupying the whole width of the E. K. positive film. After development, these exposures were scanned along the entire length of the image in the region of the sound track as described earlier in connection with Fig. 1, and also scanned transversely from one row of perforations to the other in several selected places.

The data for both negative and positive development—in *D76* and *D16* developers, respectively—are given in Figs. 6 to 15. Directional effects are shown in almost equal degree for both positive and negative development, because the positive gammas were so chosen as to lie on the steep portion of the time-gamma curve, thus

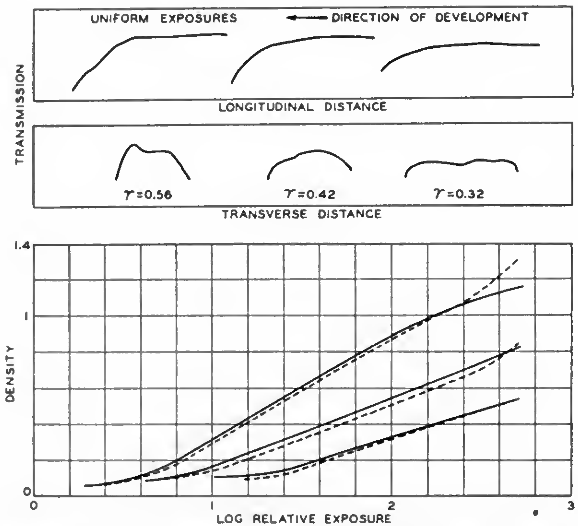

FIG. 6 (*a*). Condition 1, negative—no circulating system; film flat.

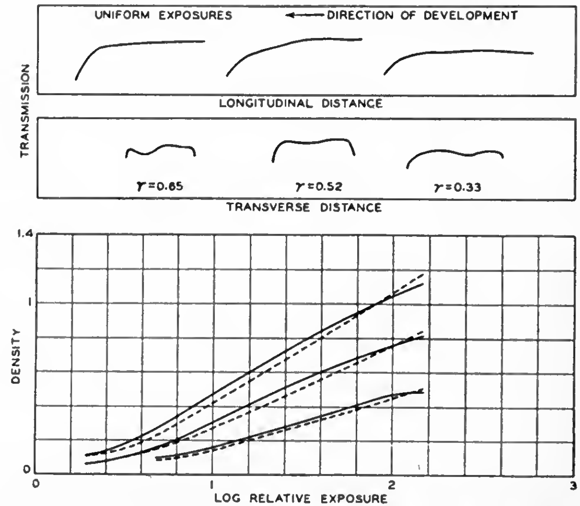

FIG. 7 (*a*). Condition 2, negative—circulating system as in Fig. 3; film flat.

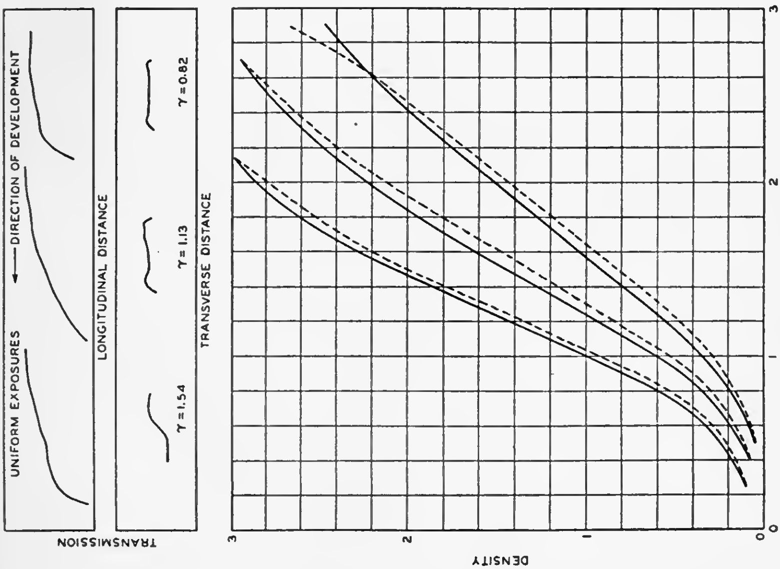

FIG. 6 (*b*). Condition 1, positive—no circulating system; film flat.

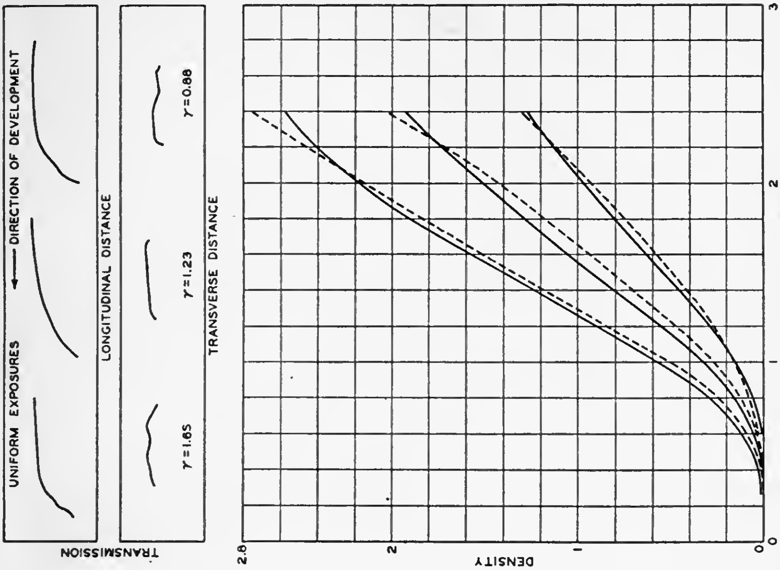

FIG. 7 (*b*). Condition 2, positive—circulating system as in Fig. 3; film flat.

facilitating discrimination between the respective performances of the different conditions tested.

Perfect development will show no difference between direction pairs of sensitometric strips, and the "densograms" of the uniform exposures will be straight lines both for the longitudinal and transverse scannings. The fact that in no case were these results fully attained indicates how difficult it is to secure perfect development by the use of the modern motion picture developing machine.

A careful analysis of the records reveals the fact that condition *10* (Fig. 15) gave definitely the best results from the standpoints indicated above. In this case, jets of developer six inches apart impinge on the surface of the submerged film during its entire travel in the developer bath, and these jets are carefully staggered to insure that the whole width of the film is impinged upon.

Condition *5* (Fig. 10) presents exactly the same set-up except that in this case the jets were in line with the longitudinal axis of the film. This caused a greater degree of development in the center than toward the edges, as shown by the transverse scannings of both negative and positive.

Reducing the number of jets to one bank (condition *4*, Fig. 9) gave an obviously inferior result, although this was a very decided improvement on the system originally provided for in these machines (condition *2*, Fig. 7). Condition *4* (Fig. 9) also represents about the average condition prevailing in the film processing industry. Note particularly in condition *2* (Fig. 7) the extremely unsatisfactory way in which the uniform exposures were developed. This effect is even more pronounced in condition *1* (Fig. 6) where no circulation was provided.

When the double-bank jet system was used with the film on edge (condition *6*, Fig. 11), the results were not nearly so satisfactory as with the film horizontal. In this case the jets passed mostly between the strands of film. Since the general developer circulation was identical with that in condition *5* (Fig. 10), it is obvious that for the best results the jets must impinge on the emulsion surface; that is, they must act as a wiper or squeegee, breaking up the directional current existing at the face of the film as did the squeegee device described at the beginning of this paper.

No particular advantage over condition *5* (Fig. 10) and certainly not over condition *10* (Fig. 15) is attained by removing the body of liquid in the tray (condition *7*, Fig. 12). This is probably the result of a tendency of the developer to drain along the sagging loops of film. With tight strands, preferably on edge, this method should give good results, although the necessary mechanical arrangement would be cumbersome. Since excellent results were obtained by condition *10* (Fig. 15), method *7* was not developed further in view of the added aeration produced by this system.

The violent agitation produced by bubbling air in conditions *8* (Fig. 13) and *9* (Fig. 14) gave fairly good results, better in the case where the film is flat (condition *8*) and where the bubbles, or the current of liquid carried in front of the bubble, strike the emulsion surface, than where the film was on edge with the current of solution and bubbles passing between. Although a very decided improvement was secured by the use of air over the regular system, it was distinctly inferior to the double developer jet system (condition *10*, Fig. 15). Nevertheless, the use of air jets would be useful in those cases where for design reasons the developer jets are not convenient.

The running of the film on edge through the developer bath in the regular system (condition *3*) produces no improvement over running it in a horizontal plane (condition *2*), indicating that under these conditions gravity is of little importance in determining the course of the reaction products of development.

From these results can be drawn the following conclusions:

(1) To break up the directional current in a motion picture developing machine of the Erbograph type at linear film speeds of 20 to 100 feet per minute, it is necessary that the surface of the film be "wiped" at frequent intervals by some method—either by squeegee, brush, or by a jet of developer. A jet system is described herein which is simple to install, has no moving parts and is very effective.

(2) Where such a system as the above is impossible of application, good results can be obtained by violent agitation of the mass of developer by injected air (or other gas, preferably inert).

(3) Arrangement of the film so as to enlist the aid of gravity in removal of the reaction products from the developing image is of little or no benefit with film moving at the speeds investigated.

It is necessary to point out that while the complete interchange of developer at the surface of the emulsion will prevent the local effects referred to, it does not follow that perfect development of the photographic image will thus be attained. There still remain certain effects which result from the diffusion of the developer within the emulsion layer itself. Most prominent among these effects is the well-known "Eberhardt effect" which refers to the depression of

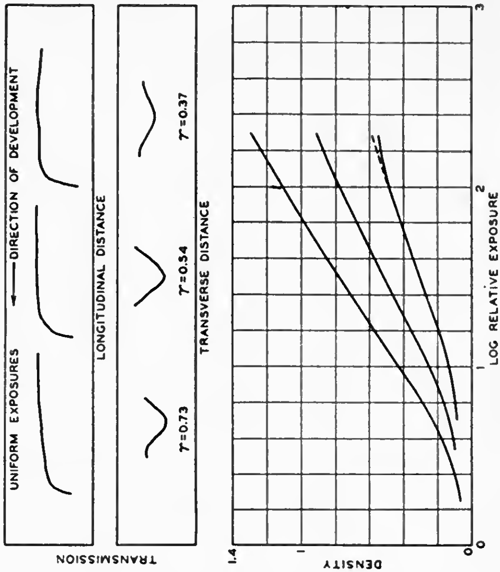

FIG. 9 (*a*). Condition 4, negative—circulating system as in Fig. 4; film flat and submerged.

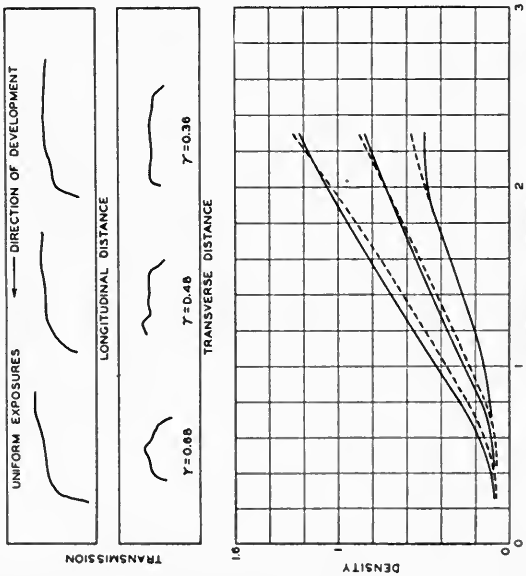

FIG. 8 (*a*). Condition 3, negative—circulating system as in Fig. 3; film on edge.

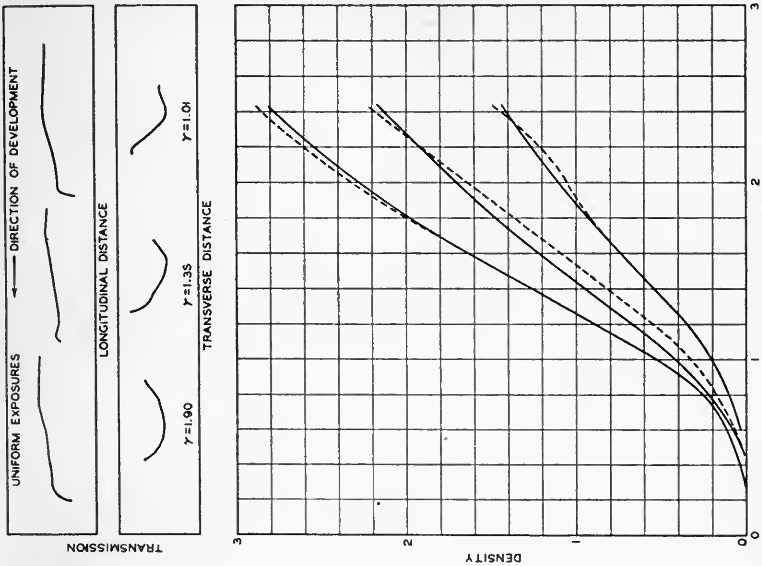

FIG. 9 (*b*). Condition 4, positive—circulating system as in Fig. 4; film flat and submerged.

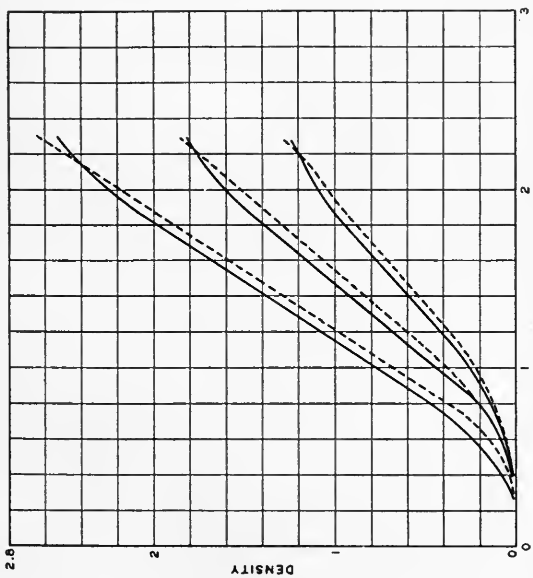

FIG. 8 (*b*). Condition 3, positive—circulating system as in Fig. 3; film on edge.

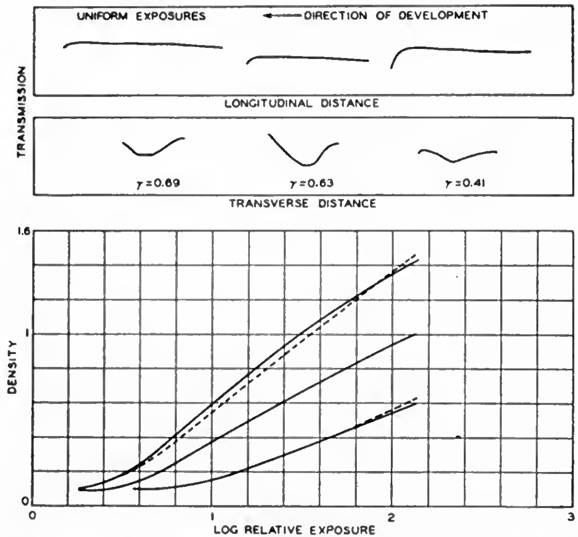

FIG. 10 (*a*). Condition 5, negative—circulating system as in Fig. 5; film flat and submerged.

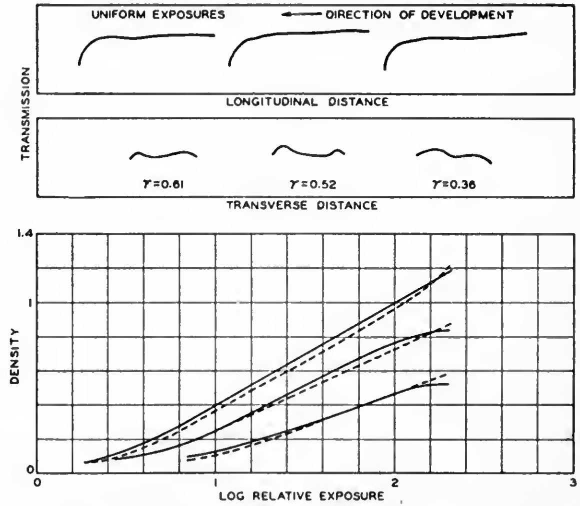

FIG. 11 (*a*). Condition 6, negative—circulating system as in Fig. 5; film on edge and submerged.

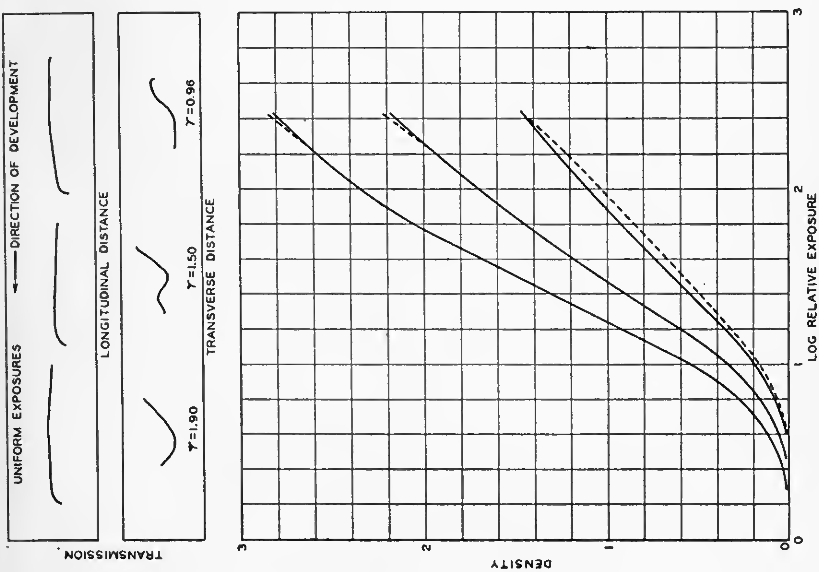

FIG. 10 (*b*). Condition 5, positive—circulating system as in Fig. 5; film flat and submerged.

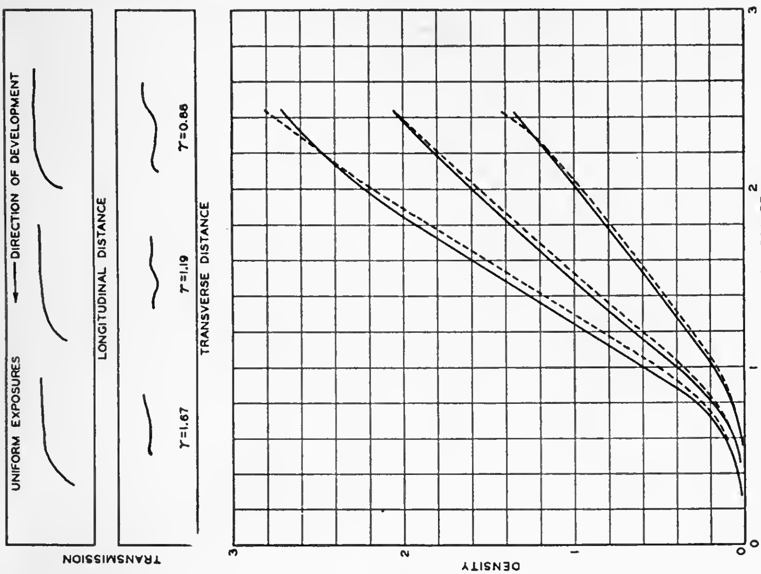

FIG. 11 (*b*). Condition 6, positive—circulating system as in Fig. 5; film on edge and submerged.

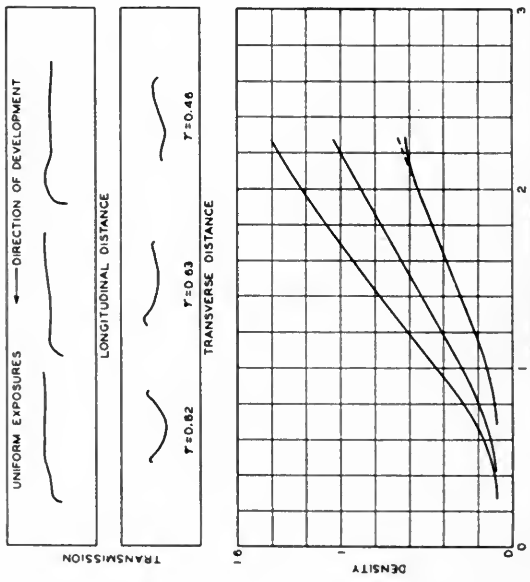

FIG. 12 (*a*). Condition 7, negative—circulating system as in Fig. 5; tray kept empty.

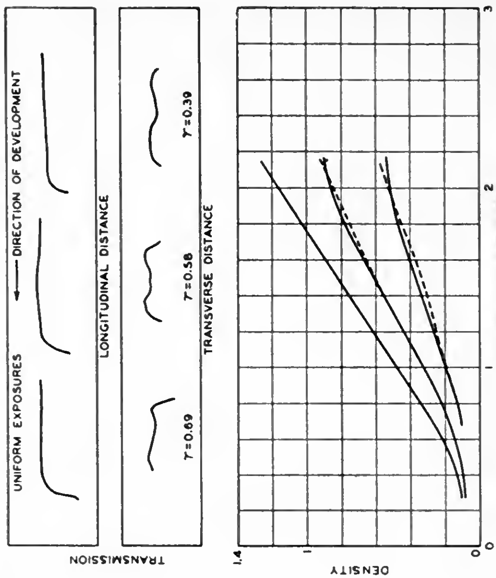

FIG. 13 (*a*). Condition 8, negative—agitation by air, film flat.

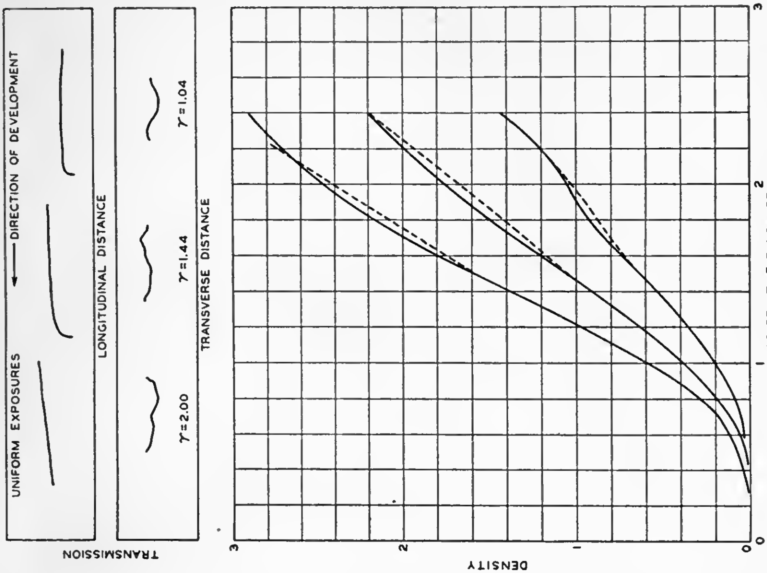

FIG. 13 (*b*). Condition 8, positive—agitation by air, film flat.

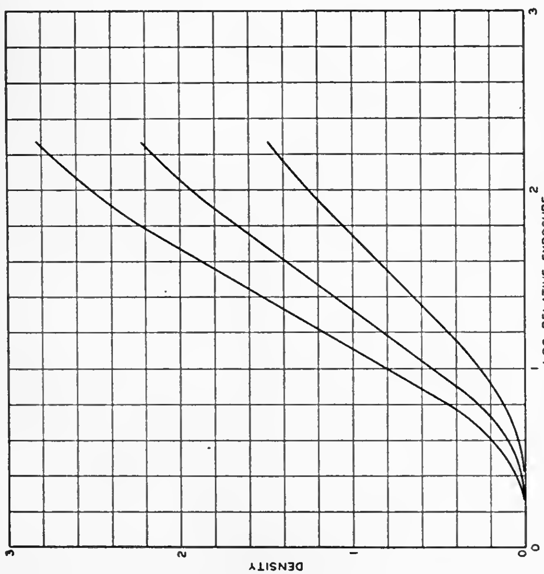

FIG. 12 (*b*). Condition 7, positive—circulating system as in Fig. 5; tray kept empty.

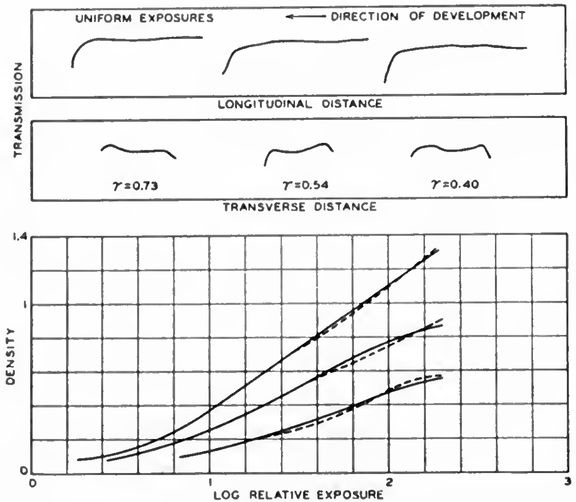

FIG. 14 (*a*). Condition 9, negative—agitation by air, film on edge.

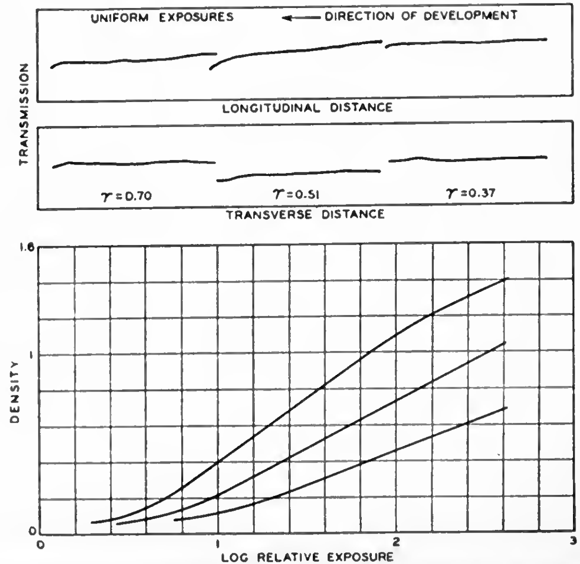

FIG. 15 (*a*). Condition 10, negative—circulating system as in Fig. 5; jets staggered; film flat.

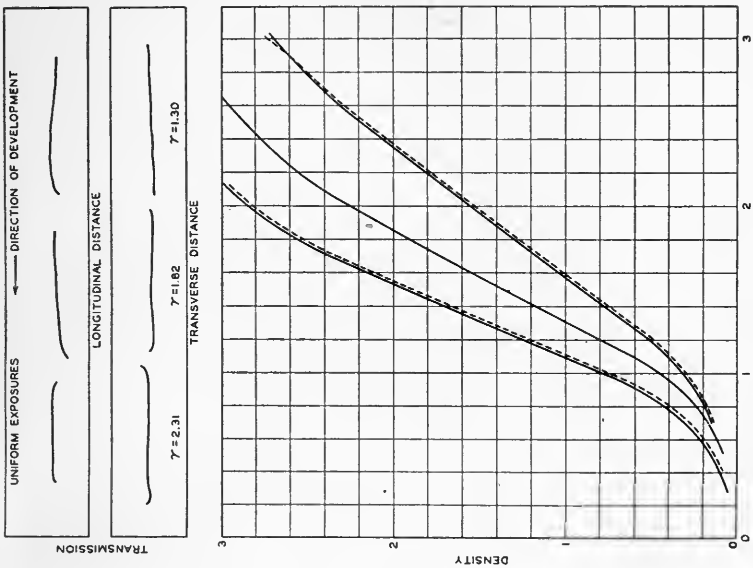

FIG. 15 (*b*). Condition 10, positive—circulating system as in Fig. 5; jets staggered; film flat.

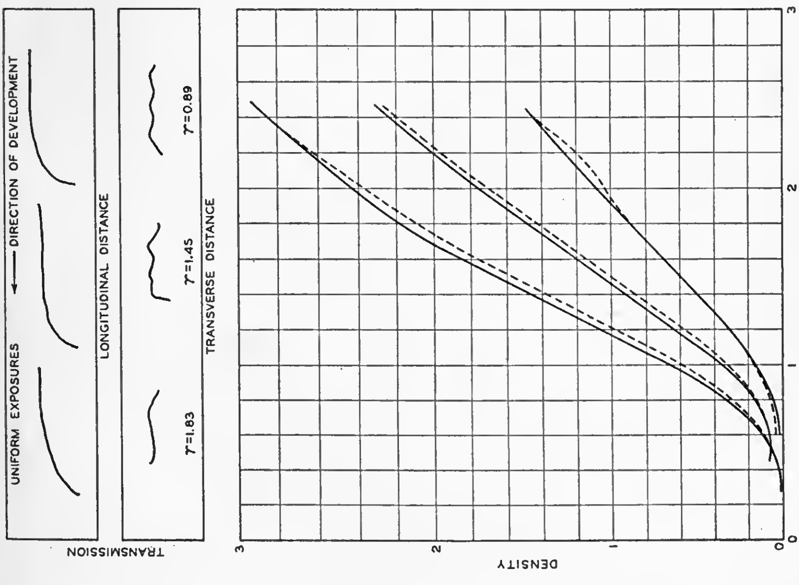

FIG. 14 (*b*). Condition 9, positive—agitation by air, film on edge.

density at the border between a light exposure and a heavier exposure due to diffusion of reaction products outward from the latter into the former when development is checked before the region of gamma infinity is reached.

Consider, for example, a square-topped light wave exposure. In Fig. 16, *abcd* represents a latent image produced by a peak exposure

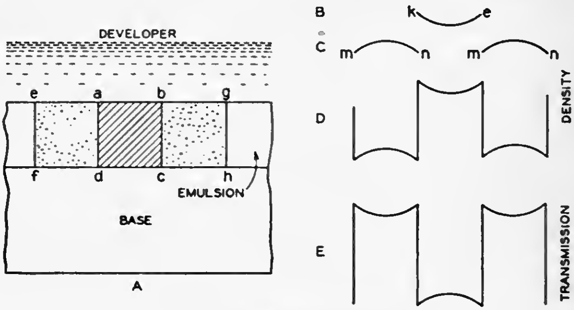

FIG. 16. Eberhardt effect.

of such a wave, and *eadf* and *bghc* those produced by the lesser exposure of the troughs. When immersed in developer, the emulsion absorbs an amount of liquid depending on its composition and temperature, swelling by so doing (in *D76* to about 400 per cent). The emulsion layer is now a spongy network of cells retaining both the light-sensitive material and the developer. As development proceeds within this cellular structure, the developer reagents are depleted and reaction products are formed. A difference in composition, and therefore of specific gravity, osmotic pressure, *etc.*, now exists between the developer in *abcd*, the developer in the bath, and also in the regions *eadf* and *bghc*, since less change has occurred here. Interchange of new and exhausted developer therefore ensues by diffusion at the surface plane *ab* and at the boundary planes *ad* and *bc*. This is not an instantaneous procedure, and it follows that at any moment during active development, the developing power of the developer in the emulsion layer will be less in the center of the heavy exposure than at its edges. It follows again from this that the resultant density of the uniform exposure will be greater at the edges than at the center, assuming that development has not been allowed to reach the region of gamma infinity where, of course, the center portions will receive full development.

The graph of density for the developed image *abcd* will appear as in *kl* at *B* (Fig. 16). In the area of lighter exposure, *eadf*, the developing power will have been consistently higher in the center than near the boundary plane *ad*, since depleted developer emerging from *abcd* will reduce the developing power in this latter region. The resulting density will appear as in *mn* or *m'n'* at *C* (Fig. 16). The shape of the developed density wave will then be as shown at *D* and the wave of light transmission as shown at *E*. Moreover, since the average density of the heavy image will be less than it should be, the amplitude of the wave envelope will be less than complete development would give, though it will be offset to some degree by the density depression of the edges of the lighter exposure.

These phenomena actually occur in practice, as is seen from Fig.

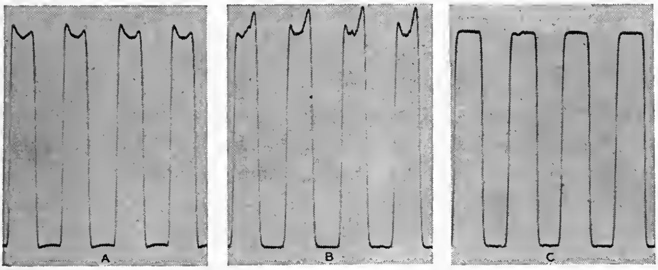

FIG. 17. Eberhardt effect; (*a*) negative, gamma 0.6; (*b*) print from (*a*), gamma 2.0; (*c*) negative, gamma 2.0.

17, which shows a microphotometric trace of a square-topped wave of 1000 cycles made by exposure to positive film through a line grating test object and machine developed to gamma 0.6 under condition *10* in the above tests. This is a graph of transmission comparable to *E* in Fig. 16, and its resemblance thereto is readily apparent. The variation in transmission of the dense portion of the wave (bottom of figure) is not very pronounced in the graph; but this is by reason of the geometry of the graph, the percentage transmission being low in this region. A print from this negative on positive film, developed to regular print gamma (Fig. *17b*), brings out the shape of this denser region of the negative, since in this case the transmission peak of the print corresponds to the trough of the negative wave shape.

The basic cause of such an effect in the negative as that discussed is that the image is formed within high gamma material developed to a low gamma. It is the checking of development during this active stage that is the cause of the local distortions. If the image is developed to an approximate gamma infinity, as in a sound print, the Eberhardt effect does not occur. Fig. *17c* shows a similar exposure to that producing Fig. *17a* but developed in *D16* to gamma 2.0. Here both trough and peak are flat; that is, the wave is without distortion other than that produced by image spread due to emulsion turbidity.

It is apparent that the over-all effect of the Eberhardt phenomenon in a wave-shape such as that shown will depend to a considerable degree on dimensional considerations. With an emulsion layer 0.001 inch thick swelling in the developer to 4 mils, a section of a 1000-cycle print recorded at normal speed would show the dark and light regions as rectangles 18 mils long and 4 mils thick. Developer diffusion from the surface downward would dominate, and the general result of the Eberhardt effect would be relatively small. At 4000 cycles, an approximately square cross-section would be seen where lateral diffusion in the emulsion would dominate and the Eberhardt effect be more pronounced, and the frequency characteristic of the record thus distorted. The Eberhardt effect, together with the directional effects above described, will doubtless explain certain observed peculiarities of frequency characteristics of sound records derived from negatives processed in different laboratories.

The Eberhardt effect will probably be less severe in the record from a sine wave of exposure than the flat-topped wave described, since the changes in density are gradual. Such exposures are now being considered from this standpoint.

Since the Eberhardt effect is directly related to emulsion thickness, its degree would probably be reduced by decreasing the thickness of the sensitive layer. It is known that reducing the emulsion thickness improves the resolving power of the film; therefore a decrease in this dimension of the emulsion layer of stand.rd positive film would lead to improvement in the fidelity of the sound record.

The Eberhardt effect has been discussed rather fully to forestall an impression that the adoption of the particular methods of development described in this memorandum will solve all problems associated with the development of the sound negative and print.

REFERENCE

[1] CRABTREE, J.: "Directional Effects in Continuous Film Processing," *J. Soc. Mot. Pict. Eng.*, **XVIII** (Feb., 1932), No. 2, p. 207.

DISCUSSION

MR. R. C. HUBBARD: What effect has the rate at which the film passes through the bath on the directional effect?

MR. J. CRABTREE: I neglected to mention that. That was the reason why the series of time-gamma curves was given in each illustration. There are three gammas, representing three different machine speeds. Judging from these curves there seems to be no definite relation between the degree of directional distortion and the speed of film propulsion over the range covered.

MR. J. I. CRABTREE: I should think if a flapping motion were imparted to the film by an increase of speed, enough agitation would be produced to improve the condition.

Most machines at the present time are of the vertical type and it is a question whether these principles apply to that type of machine. In the case where the film travels slowly, vertically, we have found that it is necessary to agitate the developer. We have had the most success by blowing nitrogen into the developer. Nitrogen is relatively expensive, but we have had some success with air, depending upon the type of developer. We have made quite an extensive study of the effect of aerating various developers on their photographic properties. One interesting observation is that with the developers containing hydroquinone, an exhausted developer is revived considerably by aeration; due to the fact that caustic soda is liberated in the chemical reaction. That is, the reaction between oxidized developer, sodium sulfite, and air, gives probably hydroquinone sulfonate plus caustic soda. In the reaction, therefore, the aeration offsets to some extent the diminution in developing activity caused by the loss of developing agent through exhaustion. These remarks apply only to developers that contain hydroquinone, and do not apply to developers containing only metol.

MR. J. CRABTREE: In the text I have suggested that it might be possible so to balance the composition of the developer and the degree of aeration as to maintain an approximately constant developing power. As regards the flapping, I don't know. There is very little such motion. I think it would be dangerous from a breakage standpoint.

MR. COFFMAN: Did you find at any time that an occasional upturn of the shoulder, which is characteristic of the directional effect of which you speak, also occurs when the motion is in the opposite direction?

MR. J. CRABTREE: Yes.

MR. COFFMAN: Occasionally we find a sensitometric strip that shows that characteristic upturn, for no apparent reason whatever.

MR. J. CRABTREE: I have no explanation of that so far.

MR. COFFMAN: On the *11b* sensitometer we occasionally find that one side of a strip will show an upturn whereas the other sides turn down; the two sides of the strip, obviously, have gone through the bath in the same direction.

MR. J. CRABTREE: I am sure it is something in the mechanics of the thing that we have not run down yet.

ANALYSIS OF SOUND QUALITY WITH THE VARIABLE DENSITY RECORDING METHOD FROM SENSITOMETRIC DATA*

R. SCHMIDT AND A. KUESTER**

Summary—*The manner in which quality controlling factors for reproduced sound can be derived from the photographic characteristics of variable density sound records is described. Density curves and transmission values serve to calculate and express in quantitative terms: loudness, volume range, noise, and distortion, for a given degree of electrical amplification. Normal and noiseless sound recording are discussed and described from the photographic point of view. The photographic process is described in sensitometric terms, and it is shown how the tolerances within which it has to be carried can be determined and controlled.*

The quality of sound reproduction in motion picture theaters is described only in more or less vague terms. It may be called faithful, hollow, rough, harsh, *etc.*, but the commonly used terms of criticism do not refer to defects in proportional or quantitative figures. It is desirable in sound film technic to have means for giving numerical values which could characterize the quality or defects of reproduced sound.

Disregarding the electrical equipment which is of importance when considering the quality of recording or reproducing, this paper will try to describe the influence of the photographic process and to analyze the elements which together control the quality of sound reproduction. The term quality can be resolved into the following elements:

(1) Volume (maximum loudness).
(2) Range of volume.
(3) Frequency range.
(4) Non-linear distortions.

Important factors of the photographic process that control these quality controlling elements are:

(1) Intensity and range of negative exposure.
(2) Sound negative film properties and development.

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* Presented at the Spring, 1933, Meeting at New York, N. Y.

** I. G. Farbenindustrie, Agfa Film Fabrik, Wolfen, Germany.

(3) Positive exposure.
(4) Sound positive film properties and development.

Fig. 1 shows which of the four elements are influenced by these photographic factors. It is the purpose of this paper:

(1) To determine quantitatively the influence of changes in the photographic process on the four quality controlling elements.

(2) To establish the degree of tolerance in the photographic process in order to direct and control it in a practical way.

Influence of Photographic Conditions on the Quality of Reproduction

	Intensity of negative exposure	Range of negative exposure	Neg. Film	Neg. Dev.	Pos. Exposure	Pos. Film	Pos. Dev.
Sound Volume					+	+	+
Range of Volume		+	+	+		+	+
Frequency Range			+			+	
Non-linear Distortion	+	+	+	+	+	+	+

FIG. 1. Chart showing which of the four elements of sound quality are influenced by the various photographic factors.

Although all the controlling elements refer to the ultimate acoustic output, it will be shown that we can deduce the numerical values for them from the sensitometric data of sound negative and positive film, except for the frequency range. The latter can not be determined by merely sensitometric methods. It has been dealt with previously[1] and will only be referred to in this paper.

The proper interpretation of the well-known photographic density and transmission curves will therefore serve to characterize the quality of the reproduced sound.

I. CONTROLLING ELEMENTS WHICH CHARACTERIZE REPRODUCTION, AND THEIR DEDUCTION FROM SENSITOMETRIC DATA

(1) *Maximum tone volume* (*loudness*).—Loudness is a physiological term and refers to an acoustic intensity. This intensity can be measured; it is proportional to the square of the acoustic pressure.

A definition has been given in the European literature for a standard acoustic intensity as a physical unit. For loudness, however, it has been found sufficient to characterize it by proportional figures:

$$L = 10 \log \frac{I_1}{I_0} = 10 \log \frac{p_1^2}{p_2^2} = 20 \log \frac{p_1}{p_2}$$

The sensation of loudness on the human ear has been found to vary with the frequency of the sound for the same physical intensity. Fig. 2 shows curves of equal loudness plotted against frequency and acoustic pressure. From the diagram it can be seen that:

$$\left.\begin{array}{l} 1 \ \frac{\text{dyne}}{\text{cm}^2} \text{ at 1000 cycles has a loudness of 70 db.} \\ 0.1 \ \frac{\text{dyne}}{\text{cm}^2} \text{ at 1000 cycles has a loudness of 50 db.} \end{array}\right\} \text{Diff. 20 db.}$$

$$\left.\begin{array}{l} 1 \ \frac{\text{dyne}}{\text{cm}^2} \text{ at 125 cycles has a loudness of 60 db.} \\ 0.1 \ \frac{\text{dyne}}{\text{cm}^2} \text{ at 125 cycles has a loudness of 30 db.} \end{array}\right\} \text{Diff. 30 db.}$$

These figures show that the loudness at low frequencies decreases more rapidly than the loudness at higher frequencies when the total volume of reproduced sound is lowered.

The volume obtained with a definite amplification depends on the transmission range of the sound record. It can be considered an ideal record if the minimum density be 0, the maximum transmission 1, and the maximum density ∞, minimum transmission 0. Such a recording has a transmission range of 1, and would give the greatest possible loudness.

If the volume control of the amplifier is set so that the sound record with $\Delta T = 1.0$ gives a loudness of 70 decibels, it is possible to calculate the loudness of each sound record of 1000 cycles for lower transmissions. A transmission of 0.45 compared with a transmission of 1.0 gives a loudness which is

$$20 \times \log \frac{\text{I}}{0.45} = 7 \text{ db. lower}$$

(2) *Volume range and noise.*—It has been shown that the maximum loudness of the sound record with a definite amplification is controlled by the transmission range ΔT. The minimum loudness obtainable with this same record without change of volume control

on the amplifier is limited by the ground noise. Recordings below the noise level will be masked by the noise. The lowest audible sound above the noise level depends on various factors, and also on individuals. For practical purposes the volume range of reproduced sound can be given as the difference between the maximum loudness and the noise level.

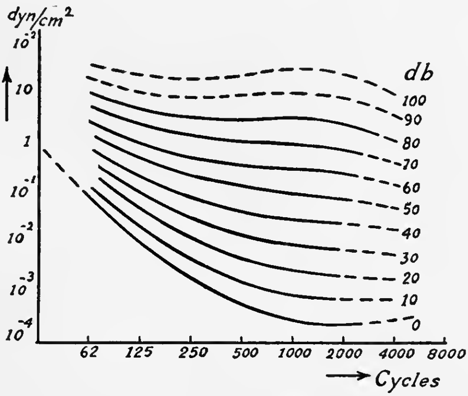


FIG. 2. Curves of equal loudness plotted against frequency and acoustic pressure.

The desirable volume range for the reproduction is about 70 db. In order to increase the range of a sound record, it is necessary to increase the maximum loudness or to reduce the noise. The latter has been done successfully, and will be explained from the photographic point of view later in this paper.

Noise caused by the sound record must be attributed to fluctuations in density or transmission, which may be caused by mechanical or optical unevenness of the sound record, such as dust, scratches, *etc.* To a certain extent the graininess and physical properties of the emulsion will cause a similar effect. The variation in density which causes the noise is about $\pm$ 0.01 from the unmodulated.

The determination of the volume range from sensitometric data can be done as follows:

Max. dens. of sound record, $d_{max.}$ = 1.25; Min. transm. $t_{min.}$ = 0.056
Min. dens. of sound record, $d_{min.}$ = 0.18; Max. transm. $t_{max.}$ = 0.661

Transmission range ΔT = 0.605

Unmodulated density of sound record $du = 0.45$

Max. dens. of noise level $dn_{max.} = 0.46$; Min. transm. $tn_{min.} = 0.347$
Min. dens. of noise level $dn_{min.} = 0.44$; Max. transm. $tn_{max.} = 0.361$

Transmission range of noise record $\Delta Tn = 0.014$

$$\text{Volume range } L = 20 \log \frac{0.605}{0.014} = 33 \text{ db.}$$

(3) *Frequency range.*—This is one of the controlling factors of the quality of reproduction. As it can not be dealt with in sensitometric data, it will not be described in this paper.

(4) *Non-linear distortions.*—It is essential that a faithful sound reproduction contain the same frequencies as the original sound. If the reproduced sound contains additional frequencies, these must be attributed to non-linear distortion, which is caused by non-linear response of some part within the sound recording or reproduction process. In this case, a sine wave on the recording end would be reproduced as a different and distorted wave on the reproducing end. As a rule, it is possible to analyze such a distorted wave and determine its components (Fig. 3). A wave of 250 cycles may thus be composed of a group of sine waves of 250, 500, 750, 1000 cycles, *etc.*

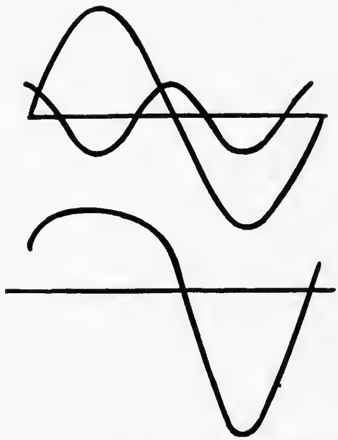


FIG. 3. A 250-cycle wave analyzed into sine waves off requency 250 and 500.

It depends on the character of the response of the non-linear parts of the system, as to which of these higher frequencies will be reproduced. The proportion of the amplitudes of the higher frequencies and the original frequencies is being used to give quantitative figures for non-linear distortion.

$$\text{Per cent distortion} = \frac{\sqrt{\Sigma p_n^2}}{p}$$

Non-linear distortion will cause harshness, and a variation of the timbre. A large percentage of non-linear distortion of a single frequency will create only harmonic overtones which do not influence the quality. In practice, however, when various frequencies are recorded and reproduced, it is possible that the overtones create an inharmonic relation which may cause objectionable effects.

The variable factors of the photographic process are: exposure and development of the sound negative, printing light, development of the sound positive, control of the transmission of the sound track, and the modulations of the light from the exciting lamp. From the transmission curve non-linear distortion can be detected.

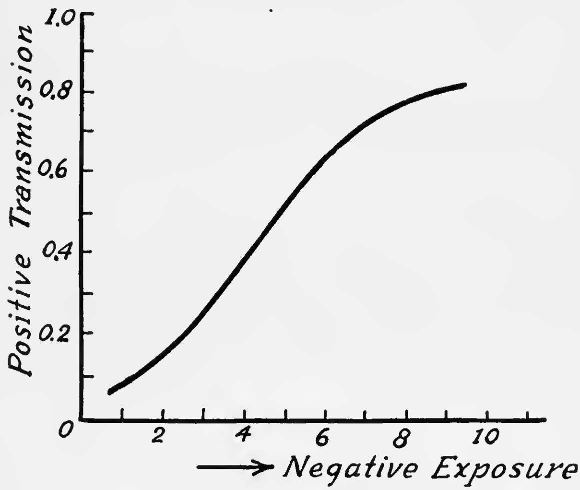


FIG. 4. Light intensity of recording lamp *vs.* light energy transmitted by sound track.

Fig. 4 shows the light intensity from the recording lamp which exposes the film, plotted against the light energy transmitted by the sound track, falling on the photoelectric cell. If this curve is a straight line, non-linear distortion will be avoided; if it is not a straight line, it is possible to draw the curve for the distorted frequency, as shown in Fig. 5.

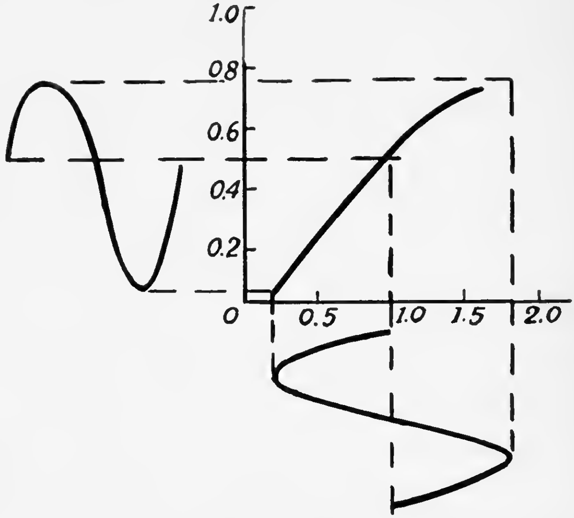


FIG. 5. The sine wave, below, projected to the non-linear transmission curve, produces the distorted sine wave at the left.

Fig. 5 shows a sine wave, a non-linear transmission curve for the sound track, and the resulting distorted wave of the sound reproduction. This distorted curve can be analyzed and resolved into higher frequencies by calculation or geometric construction (Fourier's Analysis or various types of analyzers). Fig. 6 shows Mader's analyzer.

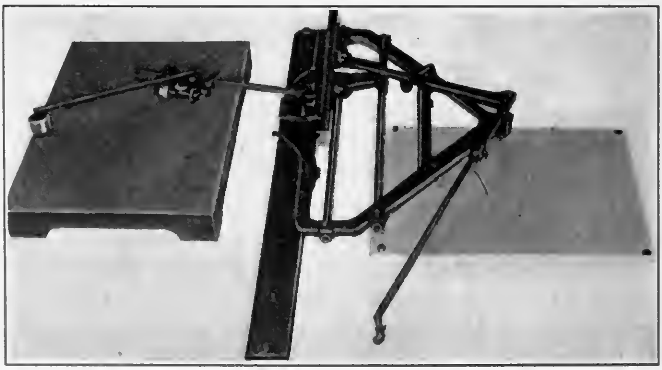


FIG. 6. Mader's wave analyzer.

II. THE PHOTOGRAPHIC PROCESS

There are some factors affecting the quality of sound reproduction which depend solely on the quality of the recording material; for instance, resolving power or color sensitivity. In this paper we are interested only in those factors which we can vary and which can be adjusted during the photographic process. Those are:

(1) Density curve and unmodulated density of the sound negative.
(2) Density curve and unmodulated density of the sound positive.
(3) Density curve of the sound record. } The over-all photographic characteristics.
(4) Transmission curve. }

Fig. 7 shows the curve of the sound negative film, *N*; the curve of the sound positive film, *P*; the curve of the sound record, *R*; and the transmission curve of the sound record.

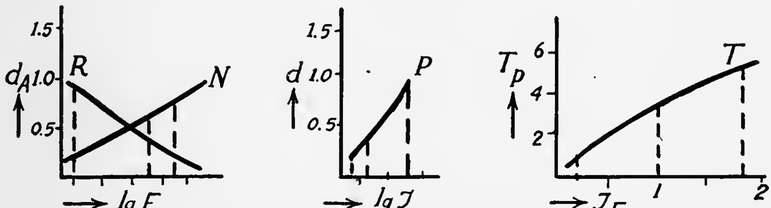


FIG. 7. Curves of density of negative, *N*, positive, *P*, and over-all, *R*; and transmission curve of sound record, *T*.

Only those parts of the curves which are actually used for the recording are shown in the diagram. The transmission curve gives directly the data which are required to determine the various factors which control the sound reproduction and which have been described in the previous paragraph. The curves *N*, *P*, and *R* refer to the recording, developing, and printing processes. It will be shown later how the tolerances for these processes can be determined from those curves.

The control of the photographic process in preparing photographic sound records is done by sensitometric means. It is necessary that development and exposure of the sensitometric strips correspond as closely as possible to practical conditions. As the exposure for the sound negative is about $^1/_{25,000}$ second and that of the sound positive about $^1/_{30}$ second, the corresponding sensitometric strips should be given a similar time of exposure. The curve of the sound record *R* can be obtained by direct printing of the sound negative sensitometric strip or it can be derived from the positive sensitometric strip *P*. It is necessary to analyze and examine only those parts of the curves which are actually used in recording and reproduction. For this purpose the exposure range of the recording light must be known and the working conditions must be adjusted accordingly. If the modulations are not linearly related to the fluctuations of the electrical current from the microphone, the over-all transmission exposure curve must be brought into a non-linear shape, so as to produce an over-all linear result. This is shown in Fig. 8.

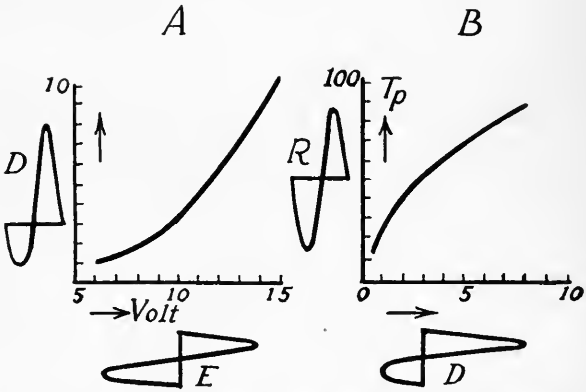


FIG. 8. *A:* non-linear response; *B:* correction of non-linear response by means of a non-linear transmission curve.

In order to determine the tolerances within which the photographic process should be carried out, the unmodulated density or the density curve of the sound negative may be varied between limits which are wider than would be met in the commercial laboratories. By means of the transmission-exposure relationship, volume range and distortion may be traced and compared. It can then be decided whether or not they are tolerable for faithful reproduction. It can also be easily understood that the straight-line portion of the sensitometric curve is the best suited and allows the widest tolerance.

In order to have the widest possible volume range, it has been found necessary, and also possible, to lower the noise level of the sound reproduction. Noise becomes more noticeable and disturbing as the sound volume decreases. It is less objectionable at a high volume. Therefore, it is not necessary to eliminate noise completely, but only to reduce it in proportion to the volume. Photographic and sensitometric data can serve to explain in what way and to what extent this may be achieved.

It has previously been shown that the ground noise is produced by a variation in density of ± 0.01 from the unmodulated. The variation in transmission for the noise record and the loudness of the noise, therefore, decreases if the unmodulated density increases. Fig. 9 shows the loudness of the noise, plotted against unmodulated densities, with the amplifiers set to give a loudness of 70 db. for a transmission of 100 per cent.

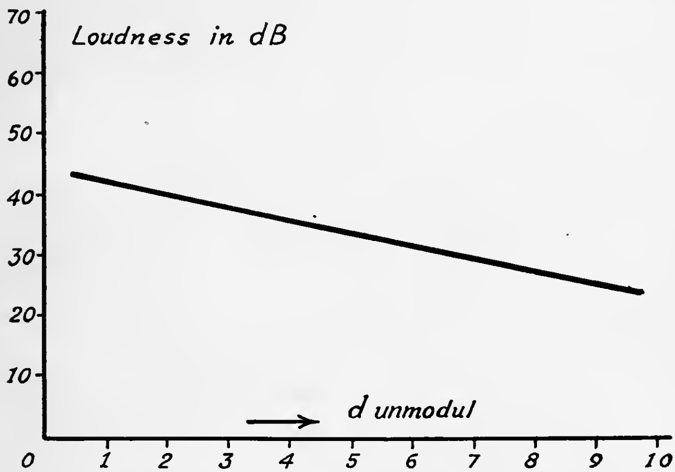


FIG. 9. Decrease of noise with increasing unmodulated density; $T = 1$, to give 70 db.

At an unmodulated density of 0.3 the noise will be recorded with a density from 0.29 to 0.31. This corresponds to a transmission range of 0.02, the variation between 0.51 and 0.49. If the unmodulated density is increased to 1.3, the noise recording will vary between the densities 1.29 and 1.31. The corresponding variation in transmission is then 0.002, between 0.051 and 0.049. In this case an increase of the unmodulated density from 0.3 to 1.3 will reduce the variation in transmission for the noise record to $^1/_{10}$ its original value, which means that the noise level is reduced 20 log 10/1 = 20 db.

The loudness or amplitude of the sound record should not be varied with noiseless recording. It is, therefore, necessary that the transmission range for recorded sound be kept constant, while the unmodulated density is varied.

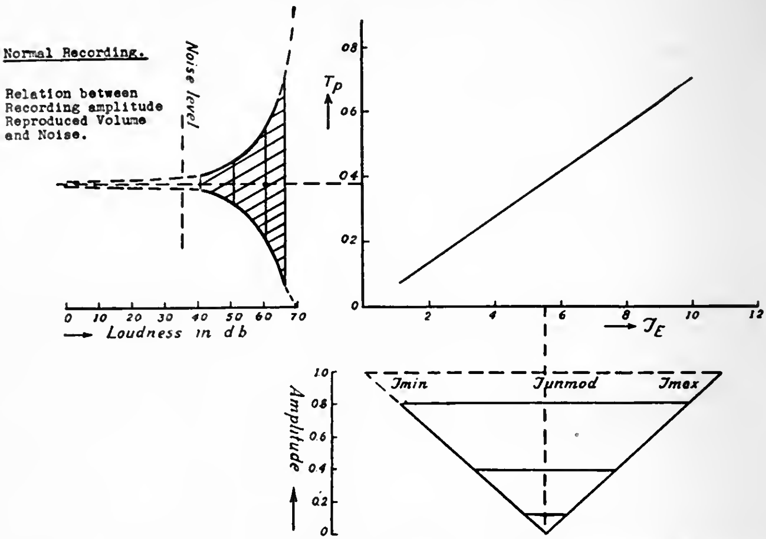


FIG. 10. Conditions for normal recording; the unmodulated exposure and noise being constant.

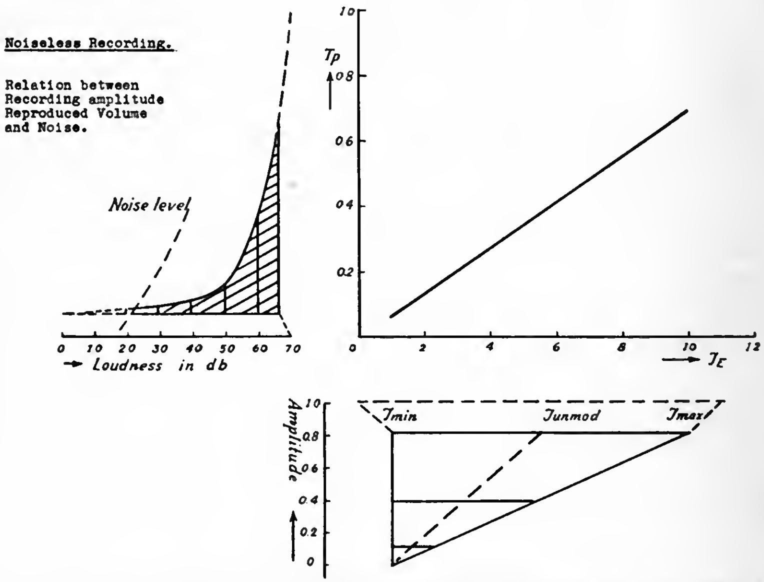


FIG. 11. Conditions for noiseless recording; the unmodulated exposure and noise decreasing with loudness. The effective volume of reproduction is greater than that in Fig. 10.

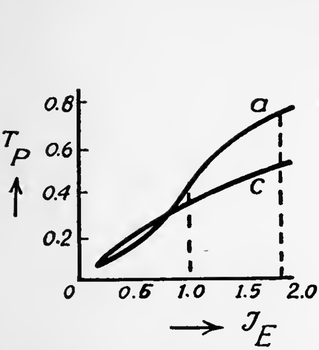


FIG. 12. Satisfactory transmission curves for normal recording: *a* gives more distortion in noiseless recording than *c*.

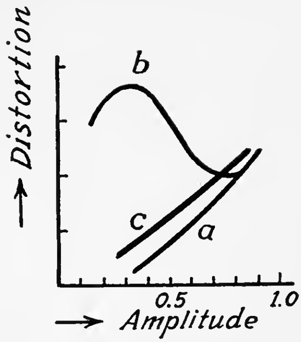


FIG. 13. Curve showing increasing distortion at higher amplitudes: *a*, for curve *a* in Fig. 12, with normal recording; *b*, for curve *a* in Fig. 12 with noiseless recording.

Fig. 10 shows the conditions for normal and Fig. 11 the conditions for noiseless recording. In Fig. 10, the unmodulated exposure is kept constant; in Fig. 11, it decreases with decreasing sound amplitude, in such a way that the minimum exposure remains constant when the

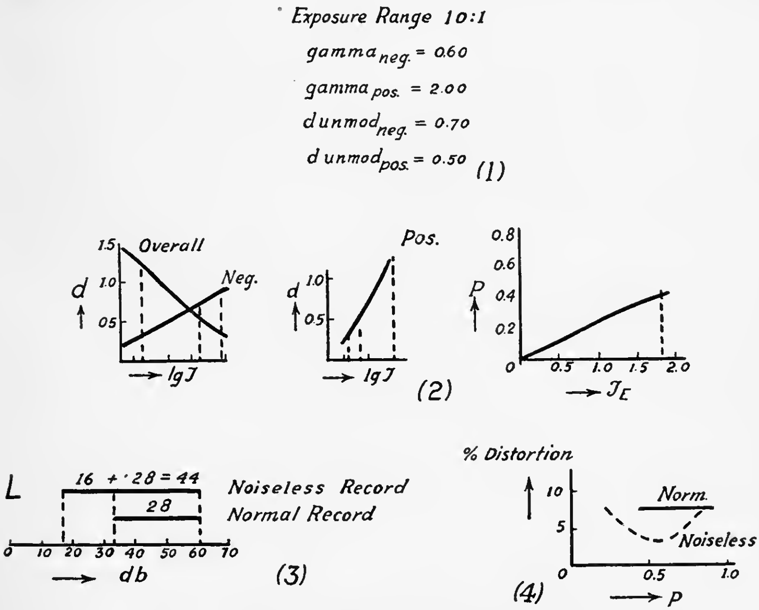


FIG. 14. Chart for analyzing photographic and sensitometric effects on character of reproduced sound.

amplitude or level varies. This is done by electrical means. It can also be seen that the noise level in Fig. 10 is constant, whereas in Fig. 11 it decreases when the loudness decreases. The effective volume range in reproduction is, therefore, greater in Fig. 11 than in Fig. 10.

The photographic process can be carried out in the same way for noiseless recording as for normal recording, if the maximum loudness is the same and the transmission curve is sufficiently linear. If, however, the transmission curve is not straight in its portion corresponding to low transmission values, recordings with low amplitudes will be greatly distorted with the noiseless recording method.

In Fig. 12 are shown two transmission curves which will give satisfactory results with normal recording. The usual volume range can be kept within the straight-line portion; distortion will therefore be very little, and noticeable only at unusually high sound levels when the curved part must be included for recording.

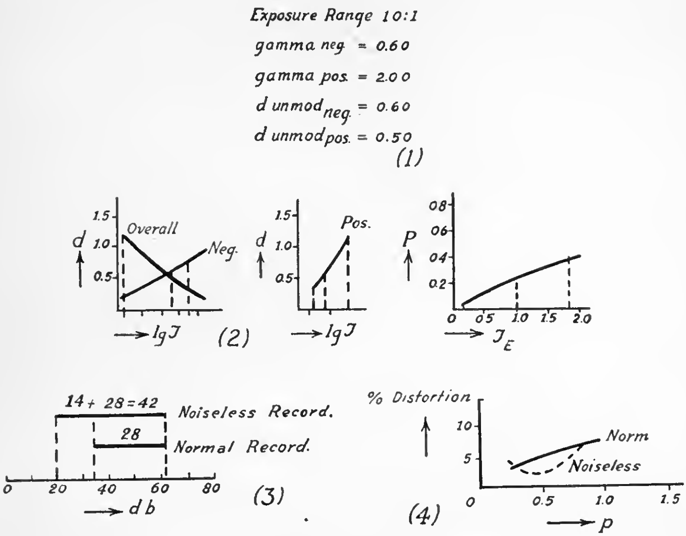
In Fig. 13, curve *a* shows the increase in distortion with higher amplitudes for curve *a* in Fig. 12 when normal recording is being used. If the same transmission curve is being used for noiseless recording, the sound record of low and medium amplitudes uses the curved portion of *a* in Fig. 12; only high amplitudes utilize the more linear portion. In this case the distortion values are very high for low amplitudes and decrease at higher amplitudes. Noiseless recording, therefore, will in this case show more distortion than normal recording (Curve *b*, Fig. 13).

If it is not possible to adjust the photographic process so as to give a straight-line transmission curve, it is necessary for noiseless recording to have it straight for low transmission values. It is less objectionable when the portion having high transmission values is not straight, as this will cause increased distortion only at the higher levels.

III. ADJUSTMENT AND CONTROL OF THE PHOTOGRAPHIC PROCESS

For an analysis of the quality of sound reproduction from sensitometric data it has been found necessary to determine:

(1) The relation of the photographic response to the recording light: An average frequency must be recorded with low amplitude and developed together with a sensitometric strip similarly exposed. The maximum and minimum density of the wave record must be read; then the exposure corresponding to those densities can be found from the sensitometric strip, the exposure of which is known. This



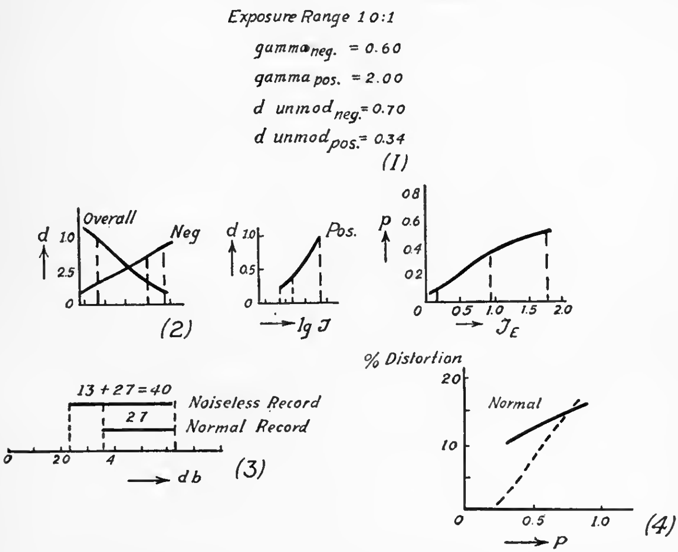


FIG. 15 (*above*). Chart for analyzing photographic and sensitometric effects on character of reproduced sound; the negative exposure has been reduced 40 per cent from the value given in Fig. 14.

FIG. 16 (*below*). Chart for analyzing photographic and sensitometric effects on character of reproduced sound; the positive exposure has been reduced 40 per cent from the value given in Fig. 15.

must be done repeatedly, increasing the amplitude to its limits. The values obtained for exposure must be plotted against the electrical current used for modulation. From the curves thus obtained the straight-line portion only should be used.

(2) The maximum exposure to which the photographic process is to be adjusted.

(3) The empirical adjustment of the photographic process: From a straight-line transmission curve with a chosen range, the corresponding density curve is drawn. From this curve, the sound positive and sound negative curves can be determined. The degree of distortion corresponding to various amplitudes of the signal and the transmission range of the recording can be analyzed with the use of those curves. If the constructed curves do not fall within the chosen transmission range, this range should be decreased until the constructed transmission curve matches closely enough the chosen curve.

If in recording, the exposure of the film is not in linear proportion to the electrical current, it is necessary to determine a transmission curve corresponding to this non-linear relation, as shown in Fig. 8.

(4) The tolerance within the photographic process: the conditions are varied within certain limits and the quality controlling factors analyzed by means of the transmission curve.

(5) The standardization of sensitometric characteristics for practical use: if the most satisfactory conditions under which the photographic process must be carried out have been determined, they can easily be controlled, as is common in laboratory practice, by (*a*) gamma and unmodulated density of the sound negative; (*b*) gamma and unmodulated density of the sound positive; (*c*) the development characteristics of the positive film.

In practice, when applied to a definite recording process and a standardized film quality, the determination of the necessary data is far more simple than would be assumed from the above description.

As an example, it will be shown how definite information about the photographic conditions and sensitometric data for characterization of sound reproduction quality can be obtained from Figs. 14, 15, and 16, each of which contains:

(1) Exposure range.
Gamma of the sound negative and sound positive.
Unmodulated density of the sound negative and the sound positive.

(2) Density curves of sound negative film, positive film, of the printed sound record and transmission curve of the sound record.

(3) Maximum loudness and volume range for normal and noiseless recording.

(4) Proportional values for non-linear distortion at various modulations with normal and noiseless recording.

In preparing charts of this kind for certain definite variations, it can easily be decided whether or not they are tolerable for the process. The conditions shown in Fig. 14 have been varied. In Fig. 15 the negative exposure has been reduced 40 per cent, and in Fig. 16 the positive exposure has been reduced 40 per cent. The charts show that the reduction of the negative exposure has little influence under the conditions characterized in Fig. 14. The reduction of the positive exposure under the same conditions, however, causes considerably more distortion, as shown in Fig. 16.

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[1] SCHMIDT, R., AND KUESTER, A.: "Untersuchungen über die Aufzeichnungsg-güte bei Tonaufnahmen (Study of High-Quality Recording of Photographic Sound Records)," II, *Agfa Veroeffentlichungen* (Agfa Publications), p. 83.

THE APERTURE ALIGNMENT EFFECT*

ELLSWORTH D. COOK**

Summary.—*The use of wide frequency-range equipment has forced the designer to consider many of the possible sources of distortion in order to determine limits for their effects. The work described in this paper was performed to ascertain the improvement provided by the new Bilateral sound track as well as to set allowable tolerances for commercial equipments. It is shown that the amount of distortion due to aperture alignment can be reduced readily to negligible amounts, particularly when the Bilateral Sound Track is used, since here both sides of the sound wave vary, thereby reducing the amplitude required for full modulation. The analysis has been limited to variable amplitude film and is restricted to a sine wave.*

The improvements introduced in recording and reproducing processes in the past few years have made it a trifle difficult to appreciate the number and importance of the individual steps by which the progress has been made. Several rather recent public demonstrations have shown that the advances have been material. It is probable that very few additions to our fund of general knowledge have been made which were not at least dimly suspected at an earlier time; but the understanding of the problems in this field, together with their importance and solutions, is on a much firmer foundation today than was heretofore the case. Admittedly, many of the improvements have been minor in themselves; but taken in the aggregate, the contribution made by them has not been inconsiderable. It has been necessary to investigate critically various possible sources of distortion to determine their importance and to ascertain a superior limit for their magnitudes.

When the Bilateral track[1] was commercialized, it was desired to determine the amount of improvement obtained for those cases where the recording and reproducing apertures did not fall at the correct angle to the direction of motion of the film. The problem of aperture alignment was recognized by several investigators rather early in the history of film recording. Perhaps one of the first authors to publish the results of his work was N. R. Stryker,[2] whose treat-

* Presented at the Spring, 1933, Meeting at New York, N. Y.

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

ment was limited to variable density film. That part of the problem will not be considered here. In variable amplitude film, the problem becomes more difficult, as far as analytical treatment is concerned. In fact, in this work, it has not been found possible to solve the problem for a sine wave by a purely analytical treatment and the general case of a complex wave has not been treated as yet.

Under the conditions of this analysis, it will be shown that misalignment of the aperture needs cause little distortion in the steady-state case except at the more extreme high frequencies; and, if commercially realizable tolerances be met, this source of distortion need not be serious in the case of a sound track of the Unilateral type, whereas if a sound track of the Bilateral type be used, it may be reduced to an altogether negligible quantity. In order to evaluate the amount of distortion produced, when the aperture does not fall

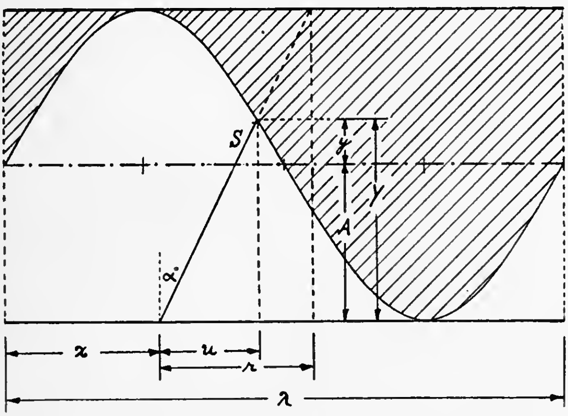

FIG. 1. Unilateral sound track, completely modulated.

at the proper angle to the direction of film travel, certain idealizing assumptions will be made.

The reproducer case will be considered under the assumptions (1) that the film moves with a constant velocity V; (2) that a perfect sine wave had been recorded on the film in such a manner that wherever light fell on the record it was uniformly and completely exposed with perfect resolution; (3) that the aperture was uniformly illuminated and infinitely fine. The importance of this latter consideration has been treated elsewhere,[3,4] and hence this analysis may be simplified by omitting any consideration of it here. The same analysis may be used when considering the recording problem.

The analysis was not carried beyond the point at which the aperture became tangent to the recorded wave-front for two reasons: first, that it is seldom necessary to consider frequencies higher than is thus permitted, and second, that the labor involved in the calculation is not an inconsiderable item.

If a sine wave of unit amplitude, and frequency $\omega/2\pi$ be recorded as a Unilateral track modulated 100 per cent, the result is shown in Fig. 1.

In that figure, linear distances along the abscissa are converted to angles as follows:

$$\beta = 2\pi \left(\frac{x}{\lambda}\right)$$

$$\gamma = 2\pi \left(\frac{u}{\lambda}\right)$$

The signal voltage developed by an ideal photoelectric cell receiving light from the aperture, will be proportional to the length S uncovered by the film record. It will be evident that the numerical work can be confined to the width Y with advantage. Consideration of Fig. 2 will show that the numerical analysis can be confined to Fig. 1 if several properly chosen values of the angle α be considered. The results can be extended later to other percentages of modulation for both the Unilateral and Bilateral sound tracks. Thus:

$$Y = A \left\{1 + \sin \frac{2\pi}{\lambda} (x + u)\right\}$$

in which

$$u = Y \tan \alpha$$

Hence:

$$S = Y \sec \alpha = A \sec \alpha \left\{ 1 + \sin \frac{2\pi}{\lambda} (x + Y \tan \alpha)\right\} \qquad (1)$$

Attempts to segregate the variables analytically in equation (*1*) have led to an expression in which the coefficients involved a series of Bessel functions of the ordinate y and a trigonometric function of the angle of aperture rotation α, but so far have failed to yield a simple Fourier Series. Recourse was, therefore, had to the laborious mechanical method of formulating the Fourier Series. This is regrettable since the method of treating a complex wave is not revealed.

In the representative wave of Fig. 1, the width Y was calculated at various points along the wave and resolved into a Fourier Series for each of a sufficient number of values of the ratio r/λ which, in itself, is determined by the angle α. The actual length of aperture S in any practical case is obviously a function of the actual width Y and the secant of the actual angle α of aperture rotation. The difference between S and Y in any practical case is quite negligible. The final result for 100 per cent modulation is:

$$S = A \sec \alpha \left[\begin{array}{l} a_0 + a_1 \sin\left(2\pi \dfrac{x}{\lambda} + \sigma_1\right) + a_2 \sin\left(4\pi \dfrac{x}{\lambda} + \sigma_2\right) \\ + a_3 \sin\left(6\pi \dfrac{x}{\lambda} + \sigma_3\right) + \ldots . \end{array} \right] \tag{2}$$

The extension of this result to any degree of modulation may be accomplished in an obvious manner by considering the sound track to be made up of three parts: an exposed region of constant width, a 100 per cent modulated region, and a clear or unexposed region,

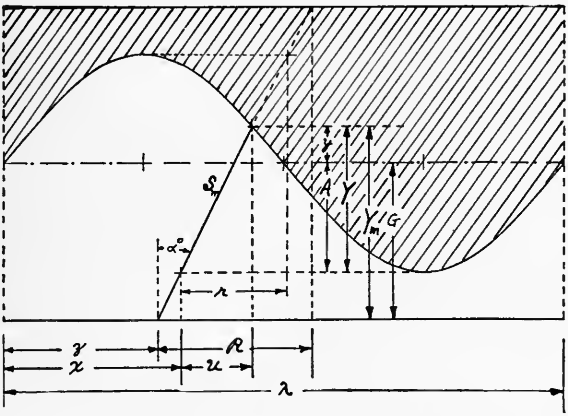

FIG. 2. Unilateral sound track.

each of which run the length of the record. In the consideration of the Unilateral sound track, the total width will be assumed to be $2G$. This will be made clear by reference to Fig. 2. It will be seen that for the case of 100 per cent modulation, $A = G$.

By definition, let

$$\beta = 2\pi \left(\frac{x}{\lambda}\right) = (\omega + \varphi)$$

where

$$\omega = 2\pi \left(\frac{z}{\lambda}\right)$$

From equation 2, Y can be written as:

$$Y = A \left[\begin{array}{l} a_0 + a_1 \sin(\omega + \varphi + \sigma_1) + a_2 \sin(2\{\omega + \varphi\} + \sigma_2) \\ + a_3 \sin(3\{\omega + \varphi\} + \sigma_3) + \ldots \end{array} \right] \quad (3)$$

Hence:

$$Y_m = [(G - A) + A\{a_0 + a_1 \sin(\omega + \varphi + \sigma_1) + \ldots\}]$$

If it be assumed that the percentage of modulation is m, then $(m) = A/G$:

$$Y_m = G[\{(1 - m) + a_0 m\} + m\{a_1 \sin(\omega + \varphi + \sigma_1) + \ldots\}] \quad (4)$$

It will be found convenient to work on a percentage basis, in which case S'_m may be written:

$$S'_m = \sec \alpha \, [\{(1 - m) + a_0 m\} + m\{a_1 \sin(\omega + \varphi + \sigma_1) + \ldots\}] \quad (5)$$

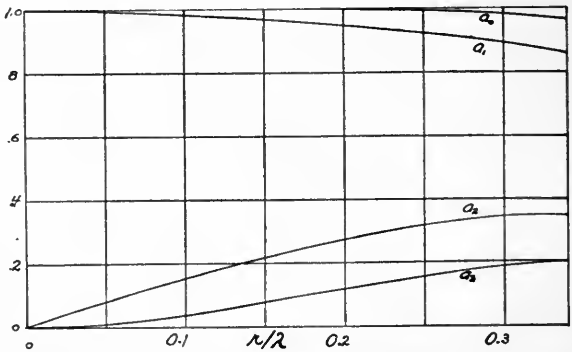

FIG. 3. Effect of rotation of reproducer aperture on fundamental and generated harmonics, for Unilateral sound track; a_0 = coefficient of average transmission; a_1 = coefficient of fundamental; a_2 = coefficient of second harmonic; a_3 = coefficient of third harmonic; $r = Rm$; m = percentage of modulation.

Equation (5) can be looked upon as an expression for the length of a stationary aperture, assumed set at an angle α to its normal position, which is cut off by a wave of percentage modulation m moving past it in a negative direction. This point of view, which describes the way in which the sound record really operates, will be found useful in work on the Bilateral sound track.

The diagrammatic representation shown in Fig. 4 is for a Bilateral track with a modulation of m per cent. Sound tracks of that type have several marked advantages over the Unilateral track shown in Fig. 2. In addition to other improvements attained, it will be found that many ill effects due to aperture rotation are materially reduced by the use of such a sound track.

Consideration of Fig. 4 will show that S_m is made up of the sum of the separate intersections of two waves, each started with a phase displacement of 180 degrees and traveling in opposite directions past a stationary aperture set at an angle α to its normal position. Although it may not be so evident, that is also true of the effective width $\mathcal{Y}_m$ of the aperture. Thus:

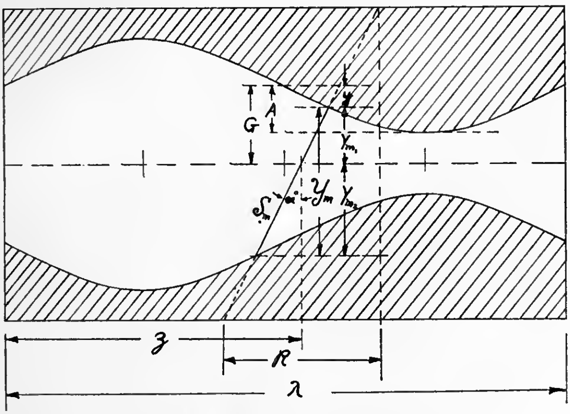

FIG. 4. Bilateral sound track.

$$\mathcal{Y}_m = (\mathcal{Y}_{m_1} + Y_{m_2})$$

It will be found desirable to express equation (4) in the following form:

$$\mathcal{Y}_{m_1} = G\left[\begin{array}{l}\{(1-m)+a_0m\} + m\left\{\begin{array}{c} b_1 \sin \omega + b_2 \sin 2\omega \\ + \dots \end{array}\right\} \\ + m\{c_1 \cos \omega + c_2 \cos 2\omega + \dots\}\end{array}\right] \quad (6)$$

Therefore

$$\mathcal{Y}_m = G\left[\begin{array}{l}2\{(1-m)+a_0m\} + m\left\{\begin{array}{c} b_1 \sin \omega + b_1 \sin (180-\omega) \\ + \dots + \dots \end{array}\right\} \\ + m\,\{c_1 \cos \omega + c_1 \cos (180-\omega) + \dots\}\end{array}\right] \quad (7)$$

Expanding the terms of equation (7) yields

$$\mathcal{Y}_m = 2G\left[\{(1-m)+a_0m\} + m\left\{\begin{array}{c} b_1 \sin \omega + c_2 \cos 2\omega \\ + b_3 \sin 3\omega + c_4 \cos 4\omega \\ + \dots \end{array}\right\}\right] \quad (8)$$

Therefore, expressing S_m on a percentage basis:

$$S_m = \sec \alpha \left[\{(1 - m) + a_0 m\} + m \begin{Bmatrix} b_1 \sin \omega + c_2 \cos 2\omega + \\ b_3 \sin 3\omega + \ldots + \ldots \end{Bmatrix} \right] \quad (9)$$

The numerical values of these coefficients for a sine wave record under the assumptions prescribed above, are given in the curves of Figs. 3 and 5.

At the risk of repetition, it is again pointed out that the means of treating complex waves is not revealed from this work. The data given by these curves do, however, allow the calculation of the frequency characteristic for the fundamental, the generated second and

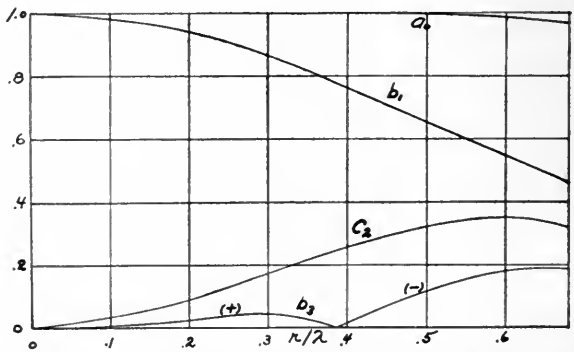

FIG. 5. Effect of rotation of reproducer aperture on fundamental and generated harmonics, for Bilateral sound track; a_0 = coefficient for average transmission; b_1 = coefficient for fundamental; c_2 = coefficient for second harmonic; b_3 = coefficient for third harmonic; $r = Rm$; m = percentage of modulation.

third harmonics, and the variation of the average transmission for the reproducer for sound tracks of either type. In passing, it may be remarked that in so far as this problem is concerned, it is fortunate that the variation in average transmission does not become significant within the commercially realizable frequency range with commercially obtainable tolerances for an angle of rotation α. It might be mentioned that variations of this factor due to other causes were shown in an earlier paper,[3] although only a superior limit to the magnitude of the change was considered. Commercial results on wide-range equipment have shown that as with many other by-products of distortion, the effect can be controlled and made inconspicuous.

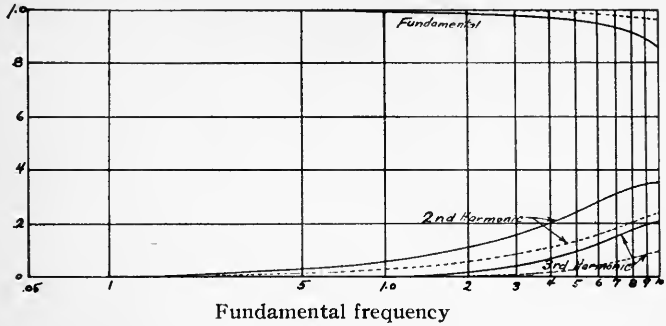

FIG. 6. Reproducer frequency characteristic, for Unilateral sound track: infinitely fine reproducer aperture; film velocity, 90 ft. per min.; track width, 0.070 in.; aperture rotation, 0.5 degree (solid curves), 0.25 degree (broken curves); modulation 100%.

In Fig. 6 the frequency characteristic of a reproducer (or with corresponding conditions, of a recorder) using a Unilateral track is shown together with the effect on the generated harmonics up to the third order. In interpreting these curves, it should be noted that the generated nth harmonic has a frequency n times that given by the abscissa. The assumptions made, in addition to those already mentioned, were a 0.070-inch sound track completely modulated, an aperture rotation of $^1/_2$ degree, and a film speed of 90 feet per minute. The dotted curves show the same conditions for an aperture rotation of $^1/_4$ degree.

Present-day commercial equipment, it should be noted, has a tolerance of $^1/_8$ degree for aperture rotation. Therefore, the rather

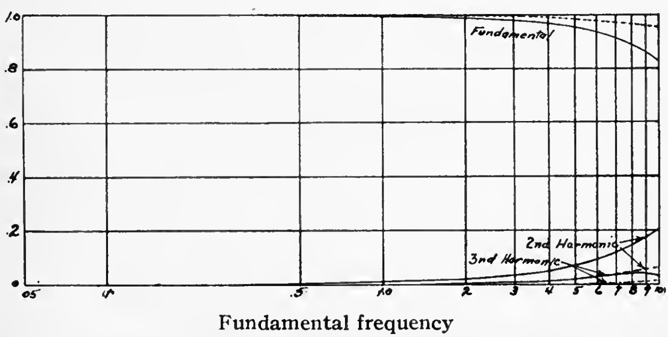

FIG. 7. Reproducer frequency characteristic for Bilateral sound track: same conditions as for Fig. 6.

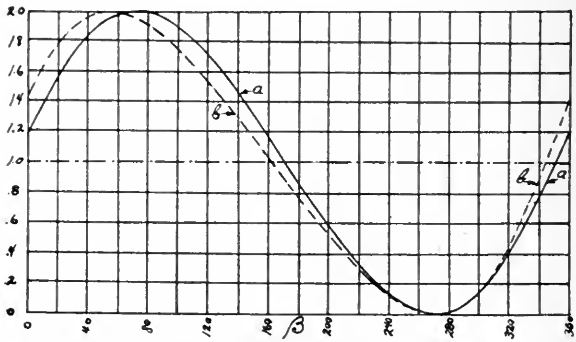

FIG. 8. Reproducer wave-shape for Unilateral sound track: infinitely fine reproducer aperture; modulation 100%; (*a*), r/λ = 0.049; (*b*), = 0.101.

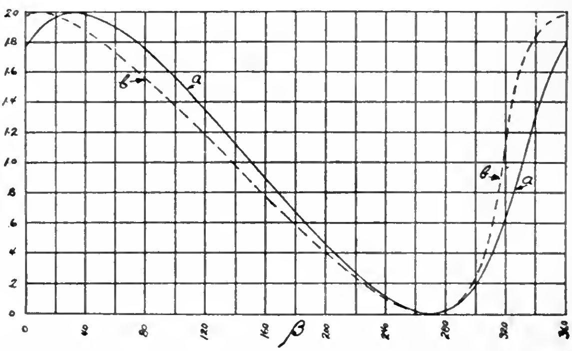

FIG. 9. Same as Fig. 8: curve (*a*), r/λ = 0.160; curve (*b*), = 0.233.

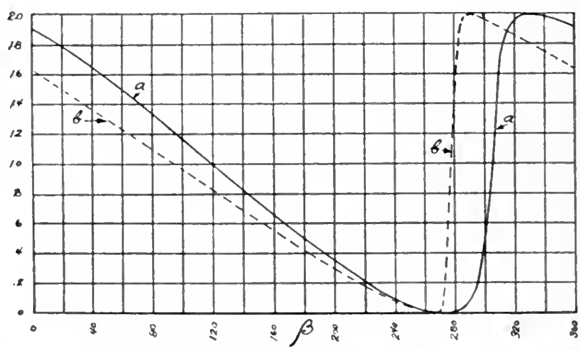

FIG. 10. Same as Fig. 8: curve (*a*), r/λ = 0.331; curve (*b*), = 0.481 (beyond tangency).

great harmonic distortions shown in this figure under the assumptions for which it was calculated, do not exist in the commercial equipment using the Unilateral sound track unless it be out of adjustment. If such distortion were to exist, the reproduction would be quite intolerable. Inspection of a protractor will show how simple it would be to set an aperture to less than the angle for which the curves were calculated. The figure, however, indicates what may be expected if one be quite careless in aligning the aperture. By comparison with the results for the new sound track, however, the improvements made in this detail may be noted.

In Fig. 7, results for the Bilateral track under similar conditions are shown. The considerable improvement is evident. The essential physical differences between the two tracks are that, whereas for the results shown in Fig. 6 for the Unilateral sound track, the aperture with $^1/_2$ degree of rotation fell parallel to the wave-front at approximately 10,000 cycles, such is not the case for the same aperture rotation in Fig. 7 for the Bilateral sound track; since here both edges of the effective sound track area vary, and consequently their individual amplitudes are reduced, assuming the same total track width and percentage of modulation.

Figs. 8 to 10, inclusive, show how, for the Unilateral track, the reproducer wave-shape (*i. e.*, variation in illumination passing to the photoelectric cell through an infinitely fine reproducer aperture), changes as the aperture rotation is increased. The curves are plotted for various values of the factor r/λ under the assumptions mentioned above. Fig. 10*b* is of special interest in that it is for the condition of the resultant wave beyond the tangent condition. The tendency toward a saw-toothed wave-shape for the Unilateral track is definitely shown. The problems introduced by such wave-shapes falling on the photoelectric cell are not essentially part of this investigation, but their existence is noted.

Figs. 11 and 12 show somewhat similar conditions for the Bilateral track, except that here the wave-shape for Fig. 12*b* corresponds to a much greater angle of aperture rotation than was the case for Fig. 10*a* for the unilateral track, since both these figures are for the condition of the aperture parallel to the recorded wave-front. It will be noticed that the wave-shape for the bilateral track differs radically from that of the Unilateral track. It is interesting to note that it is difficult to judge relative amounts of distortion by inspection of wave-shapes.

From the details of the analytical treatment, one is struck at once by the close apparent relation of this problem to that of reproducer speed variation, which is so serious because of the introduction of spurious new, and in general non-harmonic, frequencies not existent in the original record. Careful distinctions must be made here since in treating the problem of aperture alignment from this apparently

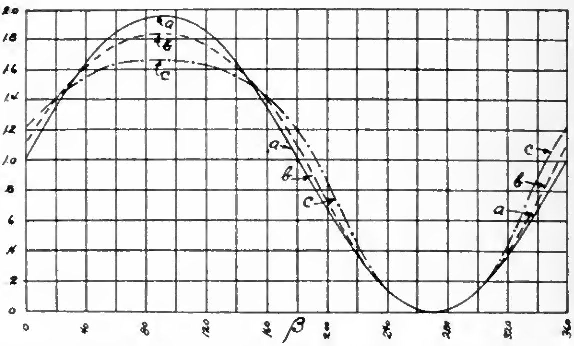

FIG. 11. Reproducer wave-shape for bilateral sound track: infinitely fine reproducer aperture; modulation 100%; curve (*a*), $r/\lambda = 0.098$; curve (*b*), $= 0.202$; curve (*c*), $= 0.320$.

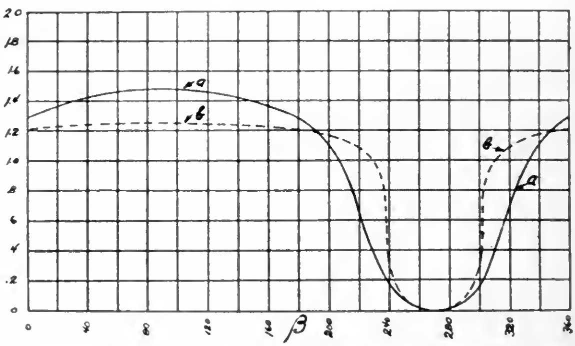

FIG. 12. Same as Fig. 11: curve (*a*), $r/\lambda = 0.466$; curve (*b*), $= 0.662$.)

analogous point of view, the "speed" variation, being dependent on the distance u or its equivalent angle $\gamma = 2\pi(u/\lambda)$ is related in frequency and extent to the recorded frequency, with the result that the "new" frequencies are now necessarily multiples of the recorded frequencies, which is not necessarily true in the problem of true film speed variation. For the Unilateral track, a fair first approximation might be obtained by assuming that the "speed" variation in the record movement produces a displacement having a sine wave of variation about an average value of phase displacement of $2\pi(G \tan \alpha)/\lambda$, as defined in Fig. 2. The amplitude of the variation would be dependent on the degree of modulation as well as on the aperture rotation, while the "frequency" would depend upon the re-

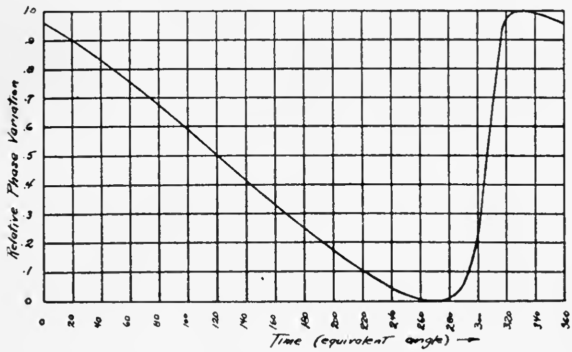

FIG. 13. Required phase variation to produce a reproducer wave-shape similar to that of Fig. 12 by variation of film velocity ($\gamma_{max.}$ = 118.52 degrees).

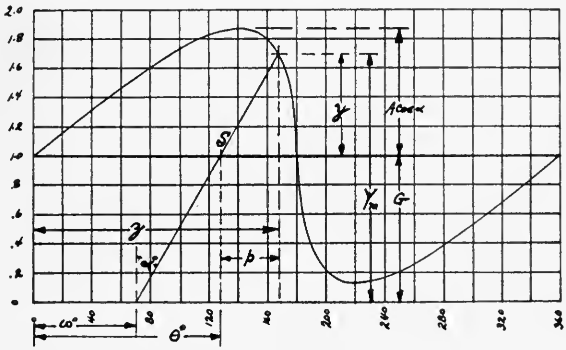

FIG. 14. Wave-shape for recorder using Unilateral sound track with aperture rotated α degrees.

corded frequency. Fig. 13 shows the equivalent phase variation γ for a 100 per cent modulated Unilateral track as a function of equivalent time under the condition r/λ = 0.331; that is, with the aperture tangent to the recorded wave-front. In the case of the Bilateral track, the discussion is more complicated.

If the recorder aperture has been rotated, the distortion may be corrected by properly aligning the reproducer aperture. Of course, no such procedure is recommended, but the fact remains that the final distortion from the reproducer due to this effect is traceable to the geometrical difference between the angles of rotation of the recorder and the reproducer apertures.

The preceding analysis, therefore, should be applicable to recording as well. From Fig. 2 for the reproducer, where the recording was a pure sine wave,

$$Y_m = G\left[1 + m \sin \frac{2\pi}{\lambda}(z + y \tan \alpha)\right]$$

Assuming in the recording process, that the length of aperture S (or light beam) varies as a pure sine wave, the conditions are as shown in Fig. 14.

In this case:

$$Y_m = G\left[1 + m \cos \alpha \sin \frac{2\pi}{\lambda}(z - y \tan \alpha)\right]$$

Here it is supposed that $m \cos \alpha$ is a new percentage of modulation, and that z is the independent variable. In extending the Unilateral recorder track analysis to include the case of the Bilateral recorder track, the same procedure used in connection with the reproducer in Fig. 4 is required. The unilateral wave is expressed as a sine and cosine series in the variable ω and the resultant wave is considered as the sum of two traveling waves moving in opposite directions past a stationary point where the variable of the first wave is ω and the variable $(180 - \omega)$ is substituted for ω to obtain the second traveling wave.

In conclusion, the helpful criticisms of Mr. E. W. Kellogg are gratefully acknowledged.

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THE MORGANA COLOR PROCESS*

J. A. DUBRAY**

Summary.—*The B & H "Morgana" process is an additive color process. Each successive picture frame is analytically photographed through a red and a blue-green filter alternately. The conventional color filter wheel has been replaced by an oscillating element that brings the proper filter into position between the lens and the film at each exposure. Regular panchromatic reversal film is used. The normal photographic speed is 24 picture frames per second though other speeds can be used.*

During projection two successive frames move forward and one backward, or in reverse, in the following order: 1–2; 1–2–3; 2–3–4; 3–4–5; etc. The result is that, although the film is running at a linear speed of 24 frames ($1^2/_3$ feet) per second, 72 frames are alternating at the aperture during the same length of time, each picture frame being projected three times on the screen. This accrued projection speed eliminates color flicker and greatly reduces color fringing. A conventional filter wheel rotating before the projection lens at a speed of 2160 rpm. synthetically produces the impression of color during projection. Photographic filters are now available for panchromatic reversal 16-mm. film for daylight or tungsten filament incandescent bulbs, selected for proper analysis of color during the photographic process in accordance with the light radiation characteristics of the source of light used.

"Morgana" is the trade-name of an additive 16-mm. color process recently announced by the Bell & Howell Company. Its basic principles are well known,[1] and have been applied more or less successfully to the cinematic reproduction of colors practically since the beginning of motion pictures. The process is fundamentally based on analyzing the object photographically into two records of wide and complementary spectral bands. One record (picture frame) selects the so-called "warm" colors, the yellows and the reds; and the other, the "cold" colors, the violet and green. This selection is obviously attained by using colored screens or filters, which absorb the unwanted colors for each picture frame, and transmit to the film those that are selected. The film must necessarily be sensitive to all the light radiations of the visible spectrum.

The result in the picture print (or film finished by the reversal process) is that the multitude of densities that concur to form the

* Presented at the Spring, 1933, Meeting at New York, N. Y.

** Bell & Howell Co., Chicago, Ill.

image and that correspond, for each successive picture frame, to the particular radiations transmitted by the selective filters, are inversely proportional to the brilliance of the hues that concur to make the object a colored one. It is quite obvious that the filters will be orange-red for transmitting the "warm" colors, and the complementary blue-green for the "cold" colors.

The fidelity of color reproduction depends mainly upon three factors:

(*1*) The color-sensitivity characteristic of the photographic emulsion.

FIG. 1. Exterior view of Filmo Morgana camera.

(*2*) The selective characteristic of the photographic and projection filters relative to the character of the source of light.

(*3*) The instrument (camera and projector) must be so constructed as to fulfill the requisites for analyzing, and subsequently synthesizing, the color radiations of the object.

It is not within the scope of this paper to discuss the first two factors, since many data are already available on these subjects. Suffice it to say, that panchromatic emulsions must, of necessity, be used; and that the filters used for photographing must be so selected as to coördinate the color-sensitivity characteristic of the film with the character of the light used for photographing. Thus, different pairs of filters must be used when photographing with a tungsten filament lamp, and when photographing in daylight. For projection, the color transmission characteristic of the filter is chosen with regard to the light radiated by tungsten filament lamps, which are used exclusively for 16-mm. projection.

It may not be amiss to mention here that since the faithfulness with which color is rendered depends upon the above-mentioned physical characteristics, and since these characteristics vary some-

FIG. 2. Front view; lens removed showing oscillating filter.

what and are difficult, if not impossible, to control with regard to the visual characteristics of the human eye, the results obtained can only approximate the true colors of the object. The approximation attained, however, is quite close, and, at any rate, very pleasing to the eye.

The designing of the camera for the Morgana process did not present any great difficulties or involve radically distinctive features except as to its portability and compactness.

Fig. 1 shows the external appearance of the Filmo Morgana camera.

It will be noticed that the cumbersome filter-carrying wheel usually attached to cameras to be used to take alternate frames through different filters, has been replaced by an oscillating filter carrier (Fig. 2). The red and the blue filters are alternately brought into position between the lens and the film by a to-and-fro motion of the carrier which takes place during the periods of shutter occultation.

The advantages of this method of alternating the filters are: compactness and correspondingly improved portability of the camera; immobility of the filter during the periods of exposure; protection of the filter against possible damage due to external causes; and the

FIG. 3. Camera head showing slot through which color filters are inserted.

facility with which the filters may be removed, permitting the camera to be used for ordinary black-and-white cinematography. Black-and-white pictures may be made with the same roll of film, since panchromatic film is used and the films are processed in the customary way.

The ease with which filters can be withdrawn or inserted in their carrier is illustrated in Fig. 3. By rotating the knurled rim of the camera head, the slot *A* is brought to the position shown in the illustration and the filter holder is easily withdrawn or inserted, as the case may be. A twist of the knob closes the slot and prevents the filter from moving out of place or stray light from entering the camera when the filter is not in position and the camera is being used for black-and-white work.

Fig. 4 illustrates the inside mechanism of the camera head, which does not differ from that of the similar model of the Filmo camera except for the cam shown at *A* which controls the oscillating motion of the filter carrier.

Since the sensation of color is attained during projection by the subjective composition of successive complementary frames, it is

FIG. 4. Camera head mechanism; *A*, the cam that actuates the filter carrier.

obvious that each frame should be identical to its complement. This is not the case, however, and the change of position of a moving object, due to the lapse of time between the taking of two successive (complementary) frames, produces the well-known effect called "fringing." This effect is, fortunately, objectionable only when the object that is photographed is moving rather rapidly across the field of view of the camera and quite close to it.

It is evident that the shorter the time between any two complementary frames the less noticeable will the fringing be. This would naturally suggest that the taking speed be increased. On the other hand, such increase of speed involves an objectionable consumption of film and limitations with regard to the exposure time. It is recommended for satisfactory results that the Morgana camera be operated at a normal speed of 24 frames per second. However, it is not compulsory to maintain this rated speed, but higher or lower speeds can be used to produce slow-motion effects or for photographing inanimate objects. The Morgana camera is therefore equipped with a control by means of which its speed can be varied from 8 to 32 picture frames per second.

FIG. 5. Morgana projector.

No limits are imposed as regards focal length of lenses and diaphragm opening, except for the necessary increase of exposure as compared with black-and-white cinematography, due to the absorption of the filters and the increase of the taking speed. This increase of exposure is, however, relatively small, as it corresponds to a factor of 4x for daylight and of 3x for Mazda illumination.

In the projector (Fig. 5) the conventional color-filter wheel has been retained for convenience of construction as well as for convenience in synchronizing the proper sector of filter with the picture frames corresponding to it.

Fig. 6 is a view of the filter wheel, showing the two color sectors. Each sector is composed of smaller sectors (two for the red and three for the blue) and transparent spacings, the color transmission characteristic and area of each sector being chosen so that the aggregate effect upon rotation will be correct for the color transmission of the taking filter and the color radiation characteristics of the projection lamp.

The most striking feature of the Morgana projector is to be found in the manner in which the motion of the film is controlled at the projector gate.

FIG. 6. Color filter wheel showing the red and blue-green sectors.

Since the pictures are taken at a normal speed of 24 frames per second, it would be necessary only to project them at that speed, care being taken that the proper filter is placed before its corresponding frame. However, taking into consideration that the final effect depends upon the ability of the eye to superimpose each pair of complementary pictures, and that the colors of the object are analyzed in terms of only two primary components, it is found that a projection speed of 24 frames per second involves physiological difficulties known as "color flicker" or "color bombardment," which are extremely disagreeable and fatiguing. It is obvious that the greater the rapidity of alternation of the two complementary colors the less noticeable the flicker will be.

In order to achieve greater projection speed the movement of the Morgana projector is so designed that each forward movement of two successive frames at the projector aperture is followed by a backward or reverse movement of one frame, so that each picture frame is projected three times instead of once. The rate of projection *at the aperture* is therefore 72 frames per second, although the linear motion of the film at the feed and take-up sprockets corre-

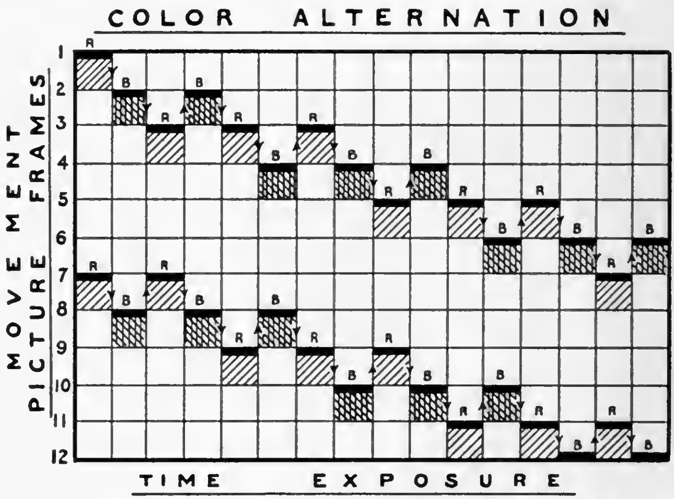

FIG. 7. Chart showing the alternation of color filters and the triple projection of each film.

sponds to a running speed of only 24 picture frames per second (7.2 inches).

Fig. 7 shows graphically the relation between film movement, time of exposure, and color. The letters *R* and *B* indicate the color of the projection filters, red and blue-green, and the arrows indicate the direction of the movement. The graph illustrates the alternation of the red and blue-green filters, and the triple projection of each frame.

The intermittent movement of the Bell & Howell regular Filmo projector is so designed that for every frame "pulled down," the single-bladed shutter revolves three times. In the Morgana projector, motion is imparted to the film for *every* revolution of the shutter, the cycle of motion being as stated above, causing a movement of two frames in the forward direction and one in the reverse direction.

Fig. 8 shows details of the Morgana projector gate with the lens and lens holder removed. At *A* is the pull-down feeding finger. At *B* is the reverse feeding finger, and at *C* is a pilot pin that engages the film perforation for each one of its motions, in order to register each frame at the projector aperture.

Fig. 9 illustrates the cams and double shuttle that control the motion of the feeding fingers and pilot pin, again designated by the letters *A*, *B*, and *C*.

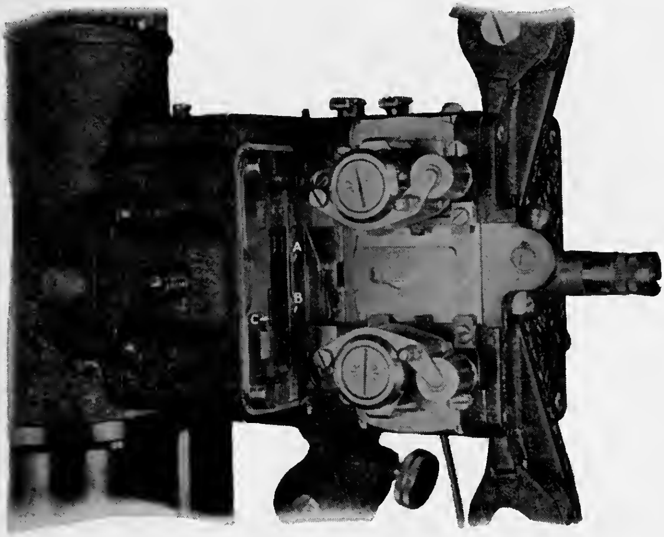

FIG. 8. Detail of projector gate and registering mechanism.

SUMMARY

The obvious objections to the Morgana process are that it is a two-color process, and that color fringing is experienced in photographing close-ups in fast motion. The Morgana process is practicable despite these objections, because of its manifold advantages.

First, and most important, it allows any lens, from a wide-angle to a telephoto, to be used on the camera; and, perhaps even more important, it allows any number of duplicates to be made, a vital necessity for industrial and educational applications.

Even though it is a two-color process, the only colors that are really lost are the deep purples, the magentas, and the rich yellows.

Flesh tones are exceptionally good, much better than heretofore obtained, to our knowledge, with any two-color process.

The backing-up phase of the projection is radically new in projection practice, and is responsible for the ability to show ordinary movement without any apparent trace of flicker or objectionable color fringing, so that for practical purposes, bearing in mind the slight limitations of the process, it is quite satisfactory for industrial and educational applications.

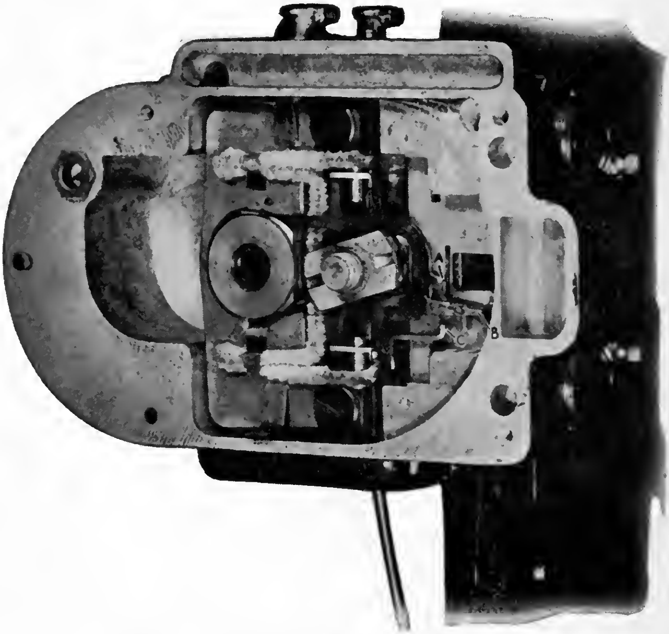

FIG. 9. Details of cam and double shutter.

An advantage of the process is the fact that considerably less light is needed for color photography, and that large color pictures can be projected quite readily. With the 400-watt lamp now widely used, an 8 × 10-ft. picture of adequate brilliance for an audience of one to three or four hundred is quite satisfactory. Some interesting work is being done with this new process, including time-lapse work with growing flowers, medical cinematography, and the like.

REFERENCE

[1] MATTHEWS, G. E.: "Processes of Photography in Natural Colors," *J. Soc. Mot. Pict. Eng.*, XVI (Feb., 1931), No. 2, p. 188. "Photography of Colored Objects," *Eastman Kodak Co.*, Rochester, N. Y.

NEW DEVELOPMENTS IN PORTABLE GAS-ELECTRIC GENERATORS FOR MOTION PICTURE LIGHTING*

PETER MOLE**

Summary.—*A newly developed gas-electric generator, recently made available to the industry, is described. There are two types, the small units having a capacity of 40 kw. and the larger ones a capacity up to 160 kw.*

The gas-electric generators described have unique features of voltage control, which is an essential requirement when generators are used in the field with incandescent lamps as a load. They have been designed to have minimum weights for their capacities and are more silent in operation than any units heretofore built.

It is the purpose of this paper to describe some developments that have been made in the past year toward producing suitable gas-electric generators for supplying current used in motion picture production on location. During the earlier years of sound motion pictures, the limitations imposed by the recording operations restricted the taking of pictures almost exclusively to sound-proofed stages. In the past two years technologic advance in recording equipment and operation has made it entirely practicable to carry on location work.

In order that the shots taken of scenes away from the studios may attain to the same high quality as those taken in the studios, it is necessary for both day and night work on location to utilize the advantages of lighting by artificial means. The supplementing of daylight with artificial illumination is designated in studio vernacular as "booster" lighting.

In most cases the current for booster lights may be supplied by generators having capacities up to 60 kw. The lighting of night scenes to a large extent parallels that of lighting stages, large values of current in this case being required. Current for location lighting may be obtained from either of two sources. Where power companies have transmission lines reasonably close to the location, those lines may be tapped and portable motor-generator sets connected to them to produce the 115-volt direct current, which is

* Presented at the Spring, 1933, Meeting at New York, N. Y.

** Mole-Richardson, Inc., Hollywood, Calif.

standard in the industry. Many desirable locations isolated from a commercial supply require the use of electric generators driven by prime movers.

Gas engine driven generators are not new to the industry. In the days of silent pictures many satisfactory plants were built, using aeronautical engines connected to direct-current generators and mounted on trucks.

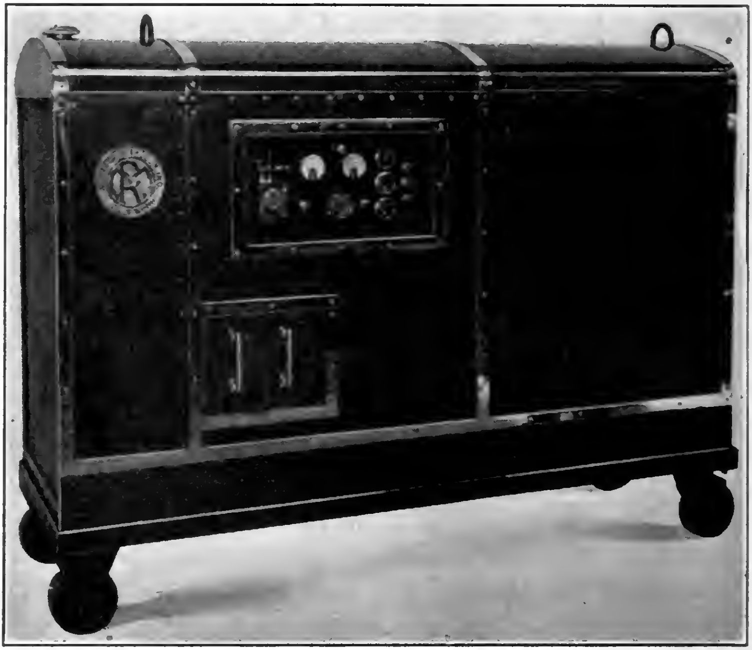

FIG. 1. 40-kw, gas-electric generator set.

The advent of sound pictures made obsolete most of the gas-electric generators of the old type. The engines heretofore used were principally war-time Liberty, Curtis, OX 5, and Hispano engines. The valve actions were always noisy, and the engines themselves in most cases had fallen into disrepair and were unreliable.

As location work was revived, the small booster lighting plants were developed, and the better types of automobile motors were found suitable. Very satisfactory plants have been built utilizing Chevrolet, Cadillac, Lincoln, and other engines that could develop sufficient power to suit the various requirements. The plant illustrated in Fig. 1 is capable of delivering 350 amperes at 125 volts as operated under motion picture conditions, and under continuous operation will deliver 250 amperes at that voltage. The essential characteristics of the booster plant are light weight, minimum size, reliability, and quietness of operation. The plant, the interior of which is shown in Fig. 2, is equipped with a Ford *V-8* engine, capable of producing 70 hp. at 3250 rpm. This motor was selected because of

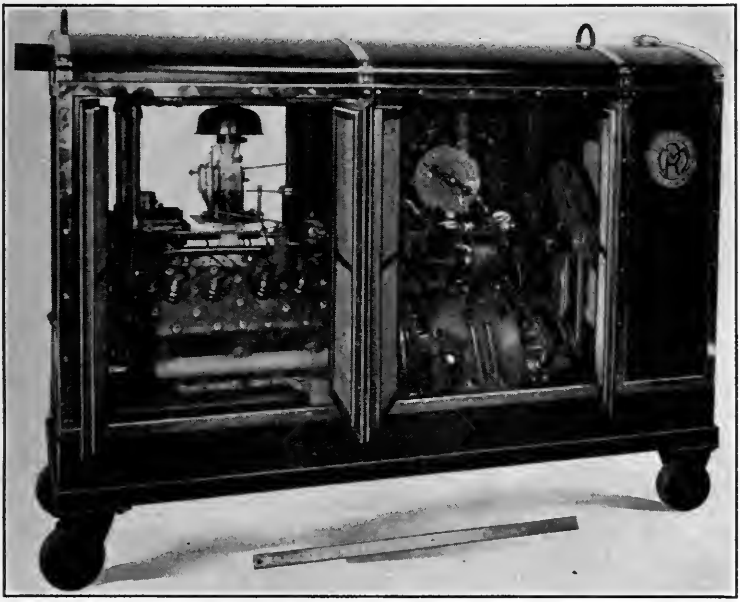

FIG. 2. Interior view, 40-kw, gas-electric generator set.

its compactness and the reliability that it has demonstrated for motor car use. It is connected to an electric generator which is specially designed to match the power output of the motor. This generator attains its rated voltage at 1200 rpm. Its armature shaft is flexibly connected to the engine crank-shaft. The frame of the generator is rigidly attached to the end bell of the generator so that the engine-generator assembly may be mounted on a three-point support. The supporting points rest on suitable rubber pads to reduce the transmission of sound. The radiator and fan are mounted on the generator end of the frame to avoid having to conduct the heat radiated by the engine and its exhaust pipes over the generator. The generator is self-ventilated, and in many hours of service has proved well adapted for the purposes for which it had been designed.

This little power plant is six feet long, two feet wide, and three feet, ten inches high, weighing only 2100 pounds, so that it may be readily transported from place to place on a truck carrying additional equipment. It is covered completely by a sheet metal housing insulated with sound-proofing material; the housing is made in sections to facilitate repairing.

The unique feature of the plant is the system of voltage control and engine governing. The use of filament lamps has made close

FIG. 3. 160-kw., gas-electric generator set.

control of the voltage very necessary, since a sudden rise of voltage, due to a reduction of the load, tends to burn out the lamps. During the nominal shooting period it is essential that the voltage be maintained constant, in order that the illumination of the units be uniformly maintained. Hand control is inadequate, because the least inattention on the part of the operator might allow wide voltage fluctuations and consequent detrimental effects.

In taking sound pictures it is essential that the generating equipment operate as silently as possible, as often the locations are in canyons and valleys, the reverberation characteristics of which make noisy equipment impracticable. Adequate muffling of the exhaust and the use of suitable sound-insulated housing in these modern plants have made it possible to operate the sets reasonably close to the sound recording equipment.

The development of high-power equipment for use on large night locations presented a more difficult problem than the designing of suitable booster equipment, because the greater power involved necessitated heavy equipment and engines of large displacement; yet, for convenience in such operations, portability must be maintained.

Fig. 3 illustrates the latest development in the larger portable gasoline generators. The plant is capable of delivering a current of

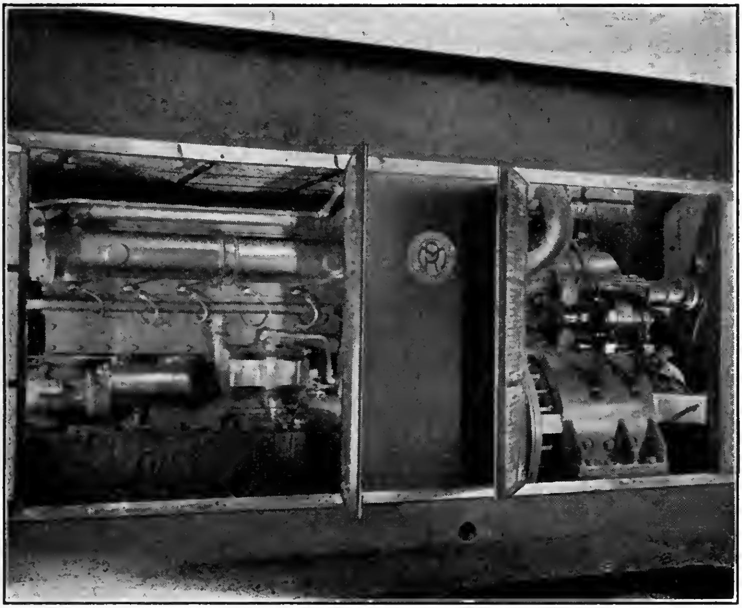

FIG. 4. Interior view, 160-kw., gas-electric generator set.

1400 amperes at 125 volts intermittently, and is capable of delivering 1000 amperes continuously. To deliver this power a gasoline motor of 270 hp. is used.

The unit shown is equipped with a Hall-Scott model *168* Invader Engine having six cylinders of $5^1/_2$-inch bore by 7-inch stroke, operating with a compression of 100 pounds. Operating on standard gasoline it delivers 270 hp. at 2100 rpm., and 248 hp. at 1800 rpm. Although probably other motors might have been used, this one was selected because a good opportunity had been afforded to observe its operation for over a year, a large number of motors of this type being used in water-taxis in Los Angeles harbor. It was also of advantage that the manufacturer's plant was located at Oakland, California, which made close contact possible when making certain changes required for the service. The engine was primarily designed for marine use, but the Hall-Scott engineers re-designed the crank case and removed the reverse gear that had been a part of the standard unit, making the engine adaptable to our requirements.

The generator in this plant was especially designed by the General Electric Company to match the power curve of the gas engine. It is very compact, weighing only 2100 pounds. The generator attains its rated voltage at 1200 rpm., and delivers 1000 amperes continuously at 1600 rpm. No difficulty has been encountered in generating 1450 amperes under the usually intermittent demands of picture production. The generator is practically flat-compounded at 1800 rpm., and performs well within the speed range noted above. The large commutator provides ample surface for brush contact. The generator is self-forced-ventilated.

The motor is mounted on a sub-frame supported on 3 points, and is connected by a flexible coupling to the generators. The job has been carefully engineered to provide accurate alignment under all operating conditions. The radiator is of the sectional type, and consists of two separate cores of six sections each, connected to headers at the top and bottom, the cores being separated by a two-inch air space; the air is circulated through the radiator by a fan of the aeronautical type, driven by a variable-speed motor supplied with current by the main generator. By varying the speed of the cooling fan, the temperature of the water may be maintained at 180°F. at the water-jacket outlet, this temperature being correct for most efficient operation.

Since the motor was designed for marine use, it was necessary to add a centrifugal pump, so as to provide the volume of water required for radiator cooling. The engine is supplied with full-force feed lubrication with oil that is filtered and cooled to 150 degrees by a water-cooled heat interchanger.

The speed of the engine is controlled by a centrifugal governor adjustable to various speeds at the controlling panel. In addition to providing normal regulation of voltage by compounding the generator, a voltage regulator has been installed. All controls are concentrated in a panel on which are mounted the ignition and auxiliary switches, a tachometer, water and oil temperature indicators, charging ammeter, hand throttle, oil-pressure gauge, generator ammeter and voltmeter, shunt field rheostat control, voltage-regulator relay, and circuit breaker operating lever.

The engine is mounted in a closed compartment, which is ventilated through louvers by the carburetor intake air. The walls of the compartment are sound-proofed with suitable insulating material; and since the engine has been carefully designed to operate quietly, sounds that would be detrimental have been reduced to a minimum, permitting operation under heavy load within 200 feet of the microphone on open locations.

Mufflers are mounted in a compartment above the engine, the exhaust manifold connecting to three mufflers of large capacity. Exhaust noises have been reduced to a point where they are not objectionable. The generator has been placed between the engine and the radiator in order that the temperature of the generator may not rise above the optimum value.

This 175-kw. set is mounted on a tandem wheel truck, which carries ample gasolene in its tanks for ten hours of operation under maximum load. With the exception of the gasoline tank the entire plant is self-contained, and may be lifted from the truck. This is an essential feature because these plants are often used on ships, in baggage cars, in scenes taken from trains, and other unusual places.

A SILENT CAMERA*

H. R. KOSSMAN**

Summary.—*After reviewing briefly some of the difficulties of excluding noise from sound cameras, a silent camera, recently developed, is described in detail. This camera makes unnecessary the use of blimps and possesses all the features necessary and desirable in modern camera construction.*

Before sound became wedded to the motion picture, the important requirements of a camera were steadiness, lightness in weight, simplicity of operation, and compactness. But with the advent of sound, camera manufacturers, as well as cameramen and sound recordists, realized that the cameras were far too noisy. The question of minimizing or possibly of eliminating the camera noise then became a major problem. In trying to eliminate the noise of the movement, some manufacturers changed the design of the intermittents. Some omitted the pressure plates or the pilot pins, or both. But it soon became apparent that those changes would not accomplish their aim. In many cases, the camera became better from the point of view of sound recording but at the expense of the quality of the picture.

Early in 1928 enterprising cameramen began to place their cameras in sound-proofed booths, which had hulls like battleships, the main difference between these cages and the battleship being that it would have been easier to manœuvre the battleship into firing position than to place the booth in line for every new shot that had to be taken. To make matters worse, sometimes two or three cameras were placed in one booth.

The sound-proofed booths caused so much discomfort that eventually some cameramen, in desperation, removed their cameras from the booths and covered them mountain high with blankets. That was supposed to represent an advance over the sound-proofed booth. One of the chief difficulties with the system was that the cameraman did not have any access to the camera. The next step was the "blimp."

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* Presented at the Spring, 1933, Meeting at New York, N. Y.

** Andre Debrie, Inc., New York, N. Y.

Although the blimp represented a vast improvement, many of the cameras had outside magazines which necessarily made the blimps tremendously large. The monster blimps built by the various studios were aptly named: they *looked* like blimps; although they could neither fly nor float. Quite the contrary, they were tremendously heavy and cumbersome. Their instability and tendency to tip over, generally at the most inopportune moment, caused the

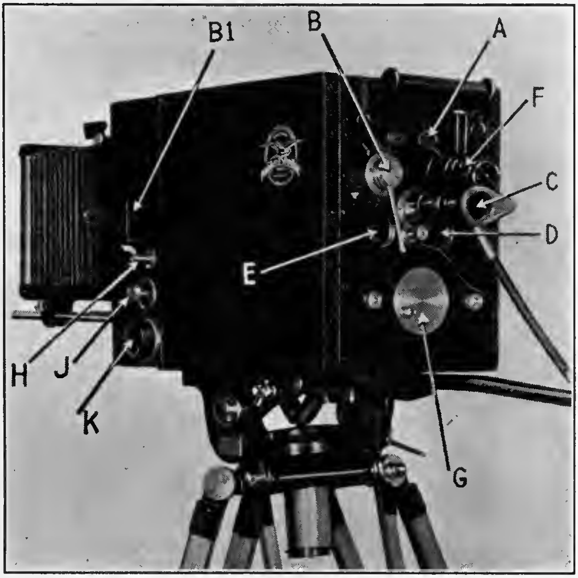

Fig. 1. Exterior view of camera; (*A*) knob for shifting ground glass, (*B*) focusing dial, (*C*) focusing tube (8*x*), (*D*) speed indicator dial, (*E*) footage and turn counter, (*F*) locket and switch with electromagnetic cut-out, (*G*) hand crank and opening for removing motor, (*H*) automatic fade and lap dissolve, (*J*) hand fade, (*K*) knob for locking case.

cameramen and the assistants no end of trouble. As quickly as a new style of blimp was built and tried, so quickly was it discarded for some reason or other. They generally violated the four cardinal requirements of a successful camera: steadiness, lightness in weight, simplicity, and compactness. It was more difficult to follow focus and to make other vital adjustments of the camera while in operation, and they were so unwieldly that it was impossible to use them for certain kinds of shots where close-ups in restricted areas are often advantageous.

The first Debrie sound camera, Parvo *T*, having 1000-foot magazines was furnished with a blimp having outside controls, which represented quite an advance on account of its unusually small weight and the ease of handling it. But a camera was visualized which would be compact, comparatively light in weight, and in which such vital parts as pilot pins and pressure plates would not have to be sacrificed in order to produce a quietly running camera.

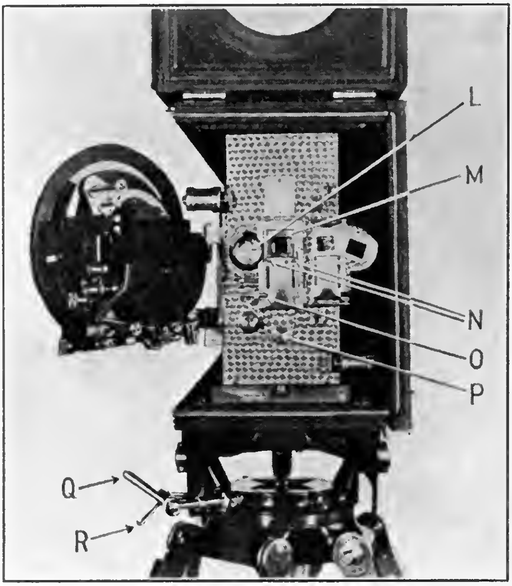

FIG. 2. Interior view of camera, front; (*L*) ground glass, (*M*) intermittent pressure plate, (*N*) registering pins, (*O*) film punch, (*P*) pivot for gate and ground glass, (*Q*) pan adjuster, (*R*) tilt adjuster.

To solve the problem an entirely different approach was made. From the start it was decided not to silence the camera, but rather to construct a *silent camera*. That meant that different raw materials would have to be used, such as lightweight metals for eliminating vibration, specially tested for their sound-carrying qualities; different gear materials; different methods of lubricating; the mounting of various important parts in rubber; gears would have to run entirely in oil; the casing would have to be independent of the camera; and the walls of the casing made of a special bakelite and rubber product.

In the camera so developed, the movement has a pull-down of 18 degrees; the pilot pins are direct acting; and the intermittent pressure plates are made of rubber composition. This last feature is of utmost importance, because of the increasing use of panchromatic and

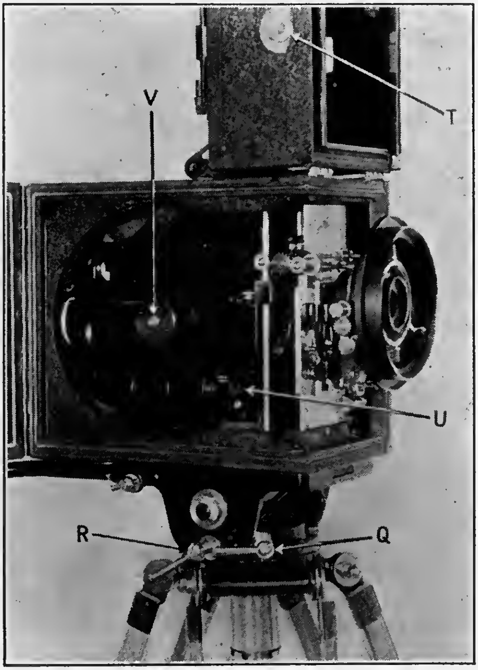

FIG. 3. Interior view of camera, left side; (*Q*) pan adjuster, (*R*) tilt adjuster, (*T*) knob for closing shutter, (*U*) oil level, (*V*) take-ups.

superpanchromatic film, the emulsion coating of which is very sensitive. The intermittent pressure plates are designed to avoid scratching the film in the aperture, by relieving the pressure on the film when it is in motion.

The shutter opening is 150 degrees with 7 openings ranging from 20 to 150 degrees. The camera is equipped with an automatic dissolve mechanism, which operates over 72 frames, the camera being stopped automatically by the operation of an electrical contact at the end of the fade. A hand fade is also provided, so that the length of the fade can be made to suit any condition. The focusing scale is at the back of the camera, and is made to suit lenses of various focal lengths. This is accomplished by changing the angle of the focusing helix of the various lens sleeves. Focusing is done directly on the film, or on ground glass, with the focusing tube at the back of the camera.

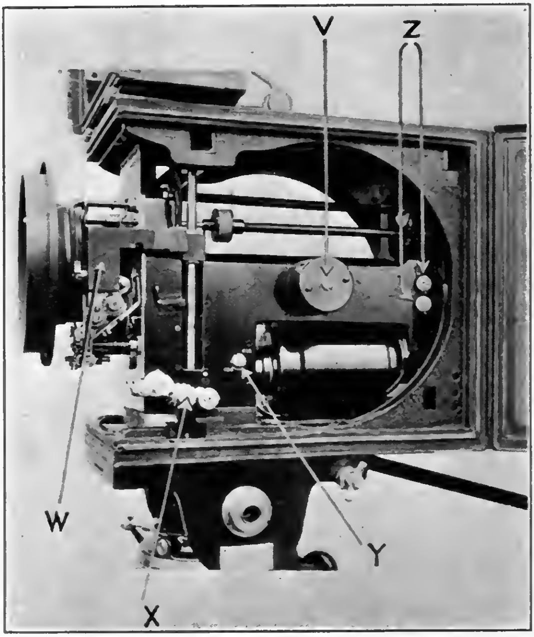

FIG. 4. Interior view of camera, right side; (*V*) take-ups, (*W*) switch for automatic fade, (*X*) automatic switch for anti-buckling device, (*Y*) gear shift for motors of 1500 or 2400 rpm., (*Z*) knobs for setting footage and turn counters to zero.

Besides the focusing scale and the focusing tube, the footage and image counter as well as the speedometer and the main switch are located at the back of the camera. The latter is of the electromagnetic type, and is integral with the plug for connection to the power supply. In order to reverse the motor the female plug is turned around. The plug is plainly marked so that no mistakes are possible. The switch is connected to an anti-buckling contact, located on the lower sprocket, and the electrical cut-out contact of the automatic fade. The anti-buckling contact causes the switch to cut out when the film is subjected to the slightest amount of tension, or when the film has run out.

The motor is mounted in the interior of the camera. It is a 3-phase, a-c., 220-volt motor, $^1/_{25}$ hp.; motors of other types can be used. Special attention has been given to the casing and mounting of the Super Parvo. The casing is made of layers of bakelite, rubber, and felt, so as to be sound-proof. The frame of the camera is mounted on rubber blocks so as to prevent vibrations from reaching the casing. The gears, as well as the intermittent movement, are entirely enclosed and run in oil. Three oil-cups take care of all the lubrication of the camera.

The front of the casing is closed with a sheet of optical glass, the frame of which carries the rods for an outside extension to accommodate the sun bellows, iris, and other front attachments.

The camera measures 19 by 14 by 10 inches, which is about one-third the size of a representative blimp. The weight is about 80 pounds, including the motor and magazines. A 1000-foot magazine is located on each side of the camera.

A special friction type tripod is used, which weighs 25 pounds. The tripod head has a *V*-shaped slide, in which the camera slides and locks automatically. Perfect balance is assured by a new type of hydraulic balancer.

A TRIPLEX MOVIOLA FOR EDITING RE-RECORDING*

J. O. AALBERG**

Summary.—A multiple sound head moviola, designed for lessening the time required to synchronize and check effects tracks, is described. It consists of one standard viewing machine and three sound reproducers coupled together by flexible shafts and clutches.

The illusion of realism in sound motion pictures is continually being enhanced by the addition of suitable sound effects. Also many producers are adding musical accompaniment to portions of their productions in the attempt to add to the picture's entertainment qualities. These modifications are accomplished by re-recording. Next in importance to the selection of realistic effects and appropriate music is the synchronizing of those effects with the corresponding action. When from three to ten tracks must be synchronized correctly to a frame, the time and expense involved become appreciable.

To quicken the task of synchronizing and checking effects tracks, a multiple sound head moviola, shown in Fig. 1, was assembled. It consists of one standard viewing machine and three sound reproducers coupled to each other through flexible shafts and clutches. Additional sound heads might be added to meet special requirements. A quarter horse-power induction motor drives the sound head next to the viewing head, allowing use of the sound head alone or with the viewing head when only one track is being worked. As more tracks are to be worked, the additional sound heads are coupled together. Provision is made for running split film, as shown in Fig. 2. The sound head may be adjusted for 35-mm. film by sliding one flange of each of the rollers toward the right and removing the detachable rail from the center of the film slide. A pocket for storing the rail is provided on the supporting frame of each sound head. The amplifier is of conventional design, employing two *247* pentodes in its output stage to feed a dynamic speaker which, for convenience, is mounted

* Presented at the Spring, 1933, Meeting at New York, N. Y.

** RKO Studios, Hollywood, Calif.

(a) (b)

FIG. 1. Triplex moviola: (a) front view; (b) rear view.

FIG. 2. Close-up of sound head.

on the machine. Complete alternating-current operation of the amplifier is provided, including polarizing potentials for the photoelectric cells and energy for the exciter lamps. The housing that forms the base of the sound heads contains the amplifier and transformers. The outputs of the sound heads are directly connected to the amplifier, and the individual levels are adjusted by varying the brightness of the exciting lamps. These controls are shown at the left in Fig. 1*a*. A volume control is provided for adjusting the combined levels. The assembly runs either forward or backward, enabling one to go back a short distance to re-check a sequence without re-winding and re-threading. Lacking all the complications and the mass of selsyn or interlocking motors commonly used to synchronize a number of sound heads, this device stops and starts quickly, a very desirable feature when tracks must be moved a frame at a time and checked until found correctly synchronized. The entire machine occupies a floor space of only two feet by four feet, and is mounted on casters to facilitate moving it from room to room.

The need for such a device became apparent during the assembling of effects tracks for the Radio picture, *King Kong*. After some experience, it was possible for the film editors to mix their sound tracks on this machine and make all necessary checks without running in a projection room, as had formerly been the procedure. The triplex moviola was built for the RKO Studios by the Moviola Company of Hollywood.

BOOK REVIEW

A New System of Cinematography in Relief (Due Nuovi Systemi di Cinematografia in Rilievo). Dott. Ing. Guido Jellinek. *Liberia Editrice Politecnica*, Milan, 1932. In this monograph, which is hailed on the cover as "a revolution in the technic of the cinema," two proposed systems of projection in relief are discussed, and some crude experiments in support of the theories developed are described. The two "new" systems are, first, photographing the object by films in a series of different planes and, second, the use of a lenticular screen of the Lippmann type. The discussion and the experimental apparatus pictured serve to emphasize the fact that solutions of the problem along those lines run to great complexity of machinery and extreme refinement of apparatus adjustment. It is not clear that the author has carried his studies or his experiments far enough actually to establish the validity of his methods, even if they could be made practicable. Thus it is not clear how a series of images in different planes are to be prevented from blanketing each other; and in his proposed utilization of the Lippmann principle the author does not appear to realize that the images as obtained would be pseudoscopic instead of stereoscopic.

H. E. Ives

Society Announcements

CHICAGO CONVENTION, OCTOBER 16–18, 1933

The semi-annual Convention of the Society was held at Chicago, Ill., October 16–18, with headquarters at the Edgewater Beach Hotel. The success of the meeting was due in large measure to the efforts of Mr. W. C. Kunzmann, chairman of the Convention Arrangements Committee; Mr. O. M. Glunt, chairman of the Papers Committee, and his associates; and to the following individuals and firms:

Mr. H. Griffin, of the International Projector Corp., for providing and installing the projection equipment; Electrical Research Products, Inc., for supplying the sound reproducing equipment; the Bausch & Lomb Optical Co., for supplying the projection lenses and the balopticon; the Strong Electric Co., for the rectifiers; Mr. J. E. MacAuley, for the Peerless projection lamp; National Theater Supply Co., for the projection booth, reels, rewinds, *etc.;* and the Day Light Screen Co., for the projection screen. Thanks are also due to the Chicago Film Board of Trade; to Messrs. S. A. Lukes and T. Maloy, of Local No. 110, of Chicago; to Mr. J. H. Goldberg; to Messrs. W. Immerman and L. Lipstone, of Balaban & Katz, for providing the banquet entertainment and engaging the orchestra; and to Mr. B. Pearlman, of the National Theater Supply Co. Mr. and Mrs. H. DeVry very kindly entertained the ladies visiting the Convention on a cruise on their yacht, viewing the Chicago beach and the World's Fair from the lake. Films for projection on Monday and Tuesday evenings were provided through the courtesy of Metro-Goldwyn-Mayer Corp., Paramount Publix Corp., RKO Pictures, Inc., United Artists, Fox Film Co., and Mr. H. T. Cowling.

At the luncheon that opened the Convention on Monday, October 16, addresses were delivered by Mr. C. F. Strodel, executive officer of Balaban & Katz; Mr. Donald P. Bean, of the University of Chicago; Dr. Allen D. Albert, of the Century of Progress Exposition; and Mr. W. H. Strafford, of Chicago.

PROGRAM

MONDAY, OCTOBER 16

The morning was devoted to the organization of the Convention, registration, meetings of Committees, *etc.*

12:30 p.m. Luncheon (for members, their families, and friends.)
Speakers: Mr. C. F. Strodel, Executive Officer, Balaban & Katz; Mr. Donald P. Bean, University of Chicago; Dr. Allen D. Albert, Century of Progress Exposition; Mr. W. H. Strafford, of Chicago.

2:30 p.m. *East Lounge.* **Business Session.**
Opening of Convention, A. N. Goldsmith, *President.*
Report of the Secretary, J. H. Kurlander.
Report of the Treasurer, H. T. Cowling.

Report of the Convention Arrangements Committee, W. C. Kunzmann, *Chairman*.

Society Business: election of officers for 1933–34; proposals for amendment of the Constitution and By-Laws.

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

"A Brief History of the Kinetograph, the Kinetoscope, and the Kineto-phonograph," by W. K. L. Dickson, La Haule, Jersey, Channel Islands, England.

"The Control Frequency Principle," by J. E. Jenkins, Jenkins & Adair, Chicago, Ill.

8:00 p.m. *East Lounge*. Exhibition of recent motion pictures, including pictures of the Century of Progress Fair, taken by Mr. H. T. Cowling.

TUESDAY, OCTOBER 17

9:30 a.m. *East Lounge*. **Wide Range Session,** Dr. A. N. Goldsmith presiding.

"Wide Range Recording," by F. L. Hopper, Electrical Research Products, Inc., Hollywood, Calif.

"Acoustic Requirements for Wide Range Reproduction," by S. K. Wolf, Electrical Research Products, Inc., New York, N. Y.

"Wide Range Sound Reproduction," by F. C. Willis, Electrical Research Products, Inc., New York, N. Y.

Report of the Historical and Museum Committee, E. Theisen, *Chairman*.

Report of the Committee on Laboratory and Exchange Practice, R. F. Nicholson, *Chairman*.

"Some Practical Applications of Acoustics in Theaters," by G. W. Baker and M. A. Smith, U. S. Gypsum Co., Chicago, Ill.

2:00 p.m. *East Lounge*. **Photographic Session,** Mr. J. I. Crabtree presiding.

"Recent Improvements in the Bell & Howell Automatic Printer," by R. F. Mitchell and A. S. Howell, Bell & Howell Co., Chicago, Ill.

"Effect of Film Shrinkage on Sound Film Printing," by J. Crabtree, Bell Telephone Laboratories, Inc., New York, N. Y.

"Film Noise in Sound-on-Film Reproduction," by H. C. Silent, Electrical Research Products, Inc., Hollywood, Calif.

"Further Investigation of Ground Noise in Photographic Sound Records," by O. Sandvik, Eastman Kodak Co., Rochester, N. Y.

"Color Photography for Industrial and Business Films," by R. H. Ray and H. W. Cress, Ray-Bell Films, Inc., St. Paul, Minn.

"Automatic Change-Over Device," by A. Pritchard, Coronado, Calif.

7:30 p.m. *Ball Room*. **Convention Banquet.**

Dancing, motion pictures, and entertainment.

WEDNESDAY, OCTOBER 18

9:30 a.m. *East Lounge*. **General Session,** Mr. R. F. Mitchell presiding.

"The Use of Talking Pictures as an Additional Tool at the University of Chicago, by H. B. Lemon, University of Chicago.

"Sixteen-Millimeter Film and Film Recording Problems," by J. O. Baker, RCA Victor Co., Camden, N. J.

"Sprocket Dimensions for Visual and Sound Projection Equipment," by H. Griffin, International Projector Corp., New York, N. Y.

Report of the Committee on Standards and Nomenclature, M. C. Batsel, *Chairman.*

Report of the Projection Practice Committee, H. Rubin, *Chairman.*

"A New 35-Mm. Portable Projector," by H. Griffin, International Projector Corp., New York, N. Y.

"The New DeVry Sound Recording Camera," by H. DeVry, Chicago, Ill.

2:00 p.m. *East Lounge.* **General Session,** Mr. R. E. Farnham presiding.

"Manufacturing Problems Involved in the Production of Sound Picture Equipment," by H. E. DeCamp, Western Electric Co., Chicago, Ill.

"The Rotambulator—a New Type of Camera Stand," by J. A. Dubray, Bell & Howell Co., Los Angeles, Calif.

"Economics of Advertising Projector Lamps," by E. W. Beggs, Westinghouse Lamp Co., Bloomfield, N. J.

"A Non-Rotating D-C. High-Intensity Arc," by D. B. Joy and A. C. Downes, National Carbon Co., Cleveland, Ohio.

"A New Type of Carbon Arc Broadside Lamp for Use in Motion Picture Production," by P. Mole, Mole-Richardson, Inc., Hollywood, Calif.

"A New Carbon for Use in Photography," by A. C. Downes, National Carbon Co., Cleveland, Ohio.

ADJOURNMENT OF THE CONVENTION

Note: The Society of Motion Picture Engineers will not be responsible for statements made by authors.

Convention Committee,
W. C. KUNZMANN, *Chairman.*

Papers Committee,
O. M. GLUNT, *Chairman*

BOARD OF GOVERNORS

At a meeting held at the Edgewater Beach Hotel at Chicago, October 15, amendments were formulated for presentation to the Society on the following day, for effecting a general revision of the administrative policies of the Society. These included changes in dues, admission fees, subscription fees, and the appointment of five vice-presidents whose work it would be to maintain a close supervision over the various phases of the Society's activities, to coördinate the work of the various committees, and thus, in the interests of economy, to relieve the General Office of a considerable part of its labors. The proposals include also the plan to establish three grades of membership, to take the place of the two now in force. The three grades would be known as Fellow, Active, and Associate.

The amendments were voted upon by the general Society on Monday, October 16; the proposed amendments of the By-Laws being approved contingent upon the subsequent approval, by letter ballot, of the proposed amendments of the Constitution. Complete drafts of the proposals and the discussion held on them at the meeting, will be mailed to all Active members in the near future, together with a letter ballot form for voting upon them.

ELECTION OF NEW OFFICERS

The returns of the letter ballots cast recently by the Active membership, counted at the Chicago Convention, indicated the following results:

A. N. GOLDSMITH, *President.*
O. M. GLUNT, *Junior Vice-President.*
J. H. KURLANDER, *Secretary.*
T. E. SHEA, *Treasurer.*
H. GRIFFIN, *Governor.*
W. B. RAYTON, *Governor.*

The remainder of the officers and Board of Governors are as listed on the reverse of the Contents page of this issue of the JOURNAL. In addition, the Board of Governors elected Mr. H. T. Cowling to serve as governor in the place of Mr. W. C. Hubbard, recently deceased, for the remainder of his term.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

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JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

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

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A BRIEF HISTORY OF THE KINETOGRAPH, THE KINETOSCOPE AND THE KINETO-PHONOGRAPH*

W. K. LAURIE DICKSON**

In the year 1879 at the age of 19 I had read much of a Mr. Edison in America and his scientific experiments, and so wrote to him to inquire whether he would take me on his staff of experimenters (Fig. 1). His reply was not encouraging. It read as follows:

Menlo Park, N. J
March 4, 1879.

William Kennedy Laurie Dickson,
Care of Mrs. Aubin,
2 Tregunter Road. London. W.

Dear Sir,

Your favor of the 17th ult. has just been rec'd.

I cannot increase my list of employees as I have concluded to close my works for at least 2 years, as soon as I have finished experiments with the electric light.

Very truly,
T. A. Edison.

However, in spite of this, I persuaded my mother and sisters to pull up stakes, and after a stormy crossing we landed in New York and continued down to Richmond, Virginia, by the Old Dominion S. S. Line. After residing there for two years, we youngsters made for New York City early in 1881. I took my book of credentials, *etc.*, to show to Mr. Edison at his office at 65 Fifth Avenue, in case I should be lucky enough to gain an interview.

My reception was unique. "But I told you not to come, didn't I?" said Mr. Edison. I agreed, but told him I couldn't have done otherwise after reading about the work in which he was engaged. He watched my face while turning my testimonials over, until I had to remind him please to read them. He only replied, "I reckon they

* Requested and recommended for publication by the Historical Committee. Presented at the Fall, 1933, Meeting at Chicago, Ill., at which meeting Mr. Dickson was elected an Honorary Member of the Society.

** Montpelier House, Twickenham, Middlesex, England.

EDITOR'S NOTE: Mr. Dickson was born in France of Scotch parentage at Chateau St. Buc, Minihic-sur-Ranse, in 1860.

are all right; you had better take your coat off and get to work." I had won.

He then gave me a note to Mr. Charles Clark, chief mathematician, and another to Mr. W. S. Andrews, superintendent of the Goerk St. testing and experimental department of the Edison Electric Works, under whose able and kindly tutelage I secured a good knowledge of what was wanted. The following year, with Mr. Edison's approval, Mr. W. S. Andrews gave me his place while he traveled through the United States planning and erecting electric light and power stations.

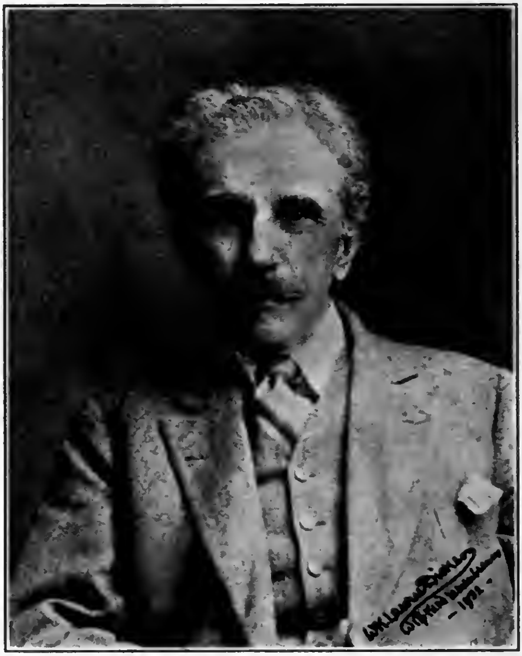
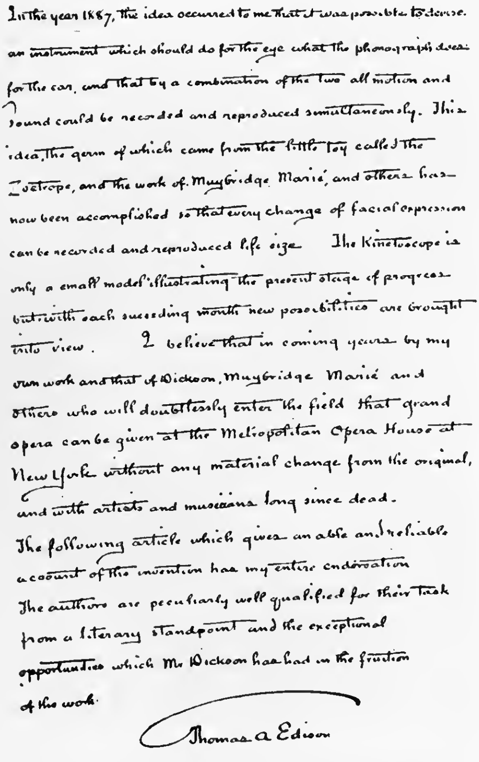


FIG. 1. William Kennedy Laurie Dickson.

My tests and experiments under Mr. Edison's direct instructions were indescribably interesting. We attempted to arrive at a fixed standardization of all electrical apparatus for home and power stations, such as type of dynamo, motors, lamps, meters, *etc.* One test or series of experiments stands out very clearly in my mind. I had the good fortune to help Mr. Edison to determine the meaning of the "Edison effect," or first concept of the famous "valve" used now in radio apparatus.

In 1885 Edison took me away from the Electric Works at Goerk St. to assist him in his private laboratory at Newark, N. J., where I was given research problems to work on. In 1887 Mr. Edison, who knew that I was keen on photography, disclosed his favorite scheme of joining his phonograph to pictures taken photographically with a device like the *Zoëtrope*.



In the year 1887, the idea occurred to me that it was possible to devise an instrument which should do for the eye what the phonograph does for the ear, and that by a combination of the two all motion and sound could be recorded and reproduced simultaneously. This idea, the germ of which came from the little toy called the Zoetrope, and the work of Muybridge Marié, and others has now been accomplished so that every change of facial expression can be recorded and reproduced life size. The Kinetoscope is only a small model illustrating the present stage of progress but with each succeeding month new possibilities are brought into view. I believe that in coming years by my own work and that of Dickson, Muybridge Marié and others who will doubtlessly enter the field that grand opera can be given at the Metropolitan Opera House at New York without any material change from the original, and with artists and musicians long since dead.

The following article which gives an able and reliable account of the invention has my entire endorsation. The authors are peculiarly well qualified for their task from a literary standpoint and the exceptional opportunities which Mr Dickson has had in the fruition of the work.

Thomas A Edison

FIG. 2. Reproduction of original letter by T. A. Edison (Courtesy *Century Magazine*).

He was then erecting his large laboratory at Orange, N. J., in which, as soon as completed, I was allowed to select two large rooms: namely, No. 5 on the 1st floor for the kinetophonograph experiments, and No. 14 above for magnetic ore separation work, analysis, *etc.*

As to animated photography, Fig. 2 is a reproduction of a letter by Mr. Edison, in his own handwriting, regarding his conception of the work he wished me to carry out for him.* This proved entirely successful in the end by giving our kinetograph the double duty of taking the films and reproducing them on a screen in the simplest possible way. If the kinetograph could take good, steady pictures it followed that the same pictures could be projected—as they eventually were—by using a smaller sprocket wheel to allow for the slight shrinkage of the film after developing and fixing.

By his order, however, projection was put aside, and our experiments were concentrated on a "money earner," the kinetoscope, which as it proved left the field open for all.

EARLY EXPERIMENTS WITH CYLINDER RECORDS

Edison's idea, as disclosed to me in 1887 at the Newark Laboratory, was to combine the phonograph cylinder or record with a similar or larger drum on the same shaft, which drum was to be covered with pin-point microphotographs which of course must synchronize with the phonograph record (Fig. 3). I pointed out to him that in the first place I knew of no medium that was sensitive enough to take microphotographs at so rapid a rate while running continuously on the same shaft.

"Well, try it; it will lead to other things," was Edison's reply. I did so soon as I got to his new laboratory, then being erected at Orange, N. J.

Before making the drum, which was to fit over the phonograph shaft, I made a small micro camera, using various objectives or lenses taken from one of my microscopes to produce the pin-head photos. In this micro camera I tried Daguerre's process on highly polished bits of silver and developed in the usual way. The subject I used was a lantern slide of Landseer's stag for all these comparative single still pictures.

The time of exposure was about three-quarters of a minute. Of course, this method was soon abandoned. Next I tried silver nitrate on wet collodion, using an exposure of 10 seconds, which was finally shortened to 5 seconds. Then I had a light drum made and produced a few spirals of pictures on a dead slow shaft. These, even with ammonia acceleration, proved a failure. So I increased the

* This letter was reproduced as a foreword to an article by the author and his sister, Antonia Dickson, which appeared in *Century Magazine*, **48** (1894), p. 206. Also published in "History of the Kinetograph, Kinetoscope, and Kinetophonograph" by the same authors; 1895, *Albert Bunn*, New York, N. Y.

size of the aluminum drum and of the pictures, and coated the drum with a bromide of silver gelatin emulsion; and would have obtained a fairly good result but for some chemical action which took place between the aluminum and the emulsion. That made me try a glass drum and a one-opening rapid shutter.

My second batch of emulsion was light struck, owing to the night-watchman's bursting in at 2 A.M., which so disgusted me that I just slotted the aluminum drum and wrapped a sheet of Carbutt's stiff sensitized celluloid over it. This proved quite satisfactory and did away with my home-made emulsion coatings. The pictures were sharp and good, and to save time in making prints or positives I turned the negative into a positive effect with bichloride of mercury. A reproduction of one of these sheets of $^1/_4$-inch pictures may be seen in the *History of the Kinetograph, etc.* (See footnote, p. 438, also Fig. 4.)

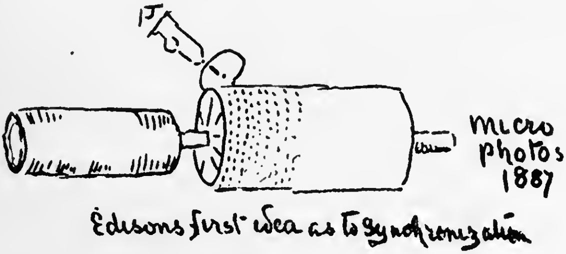
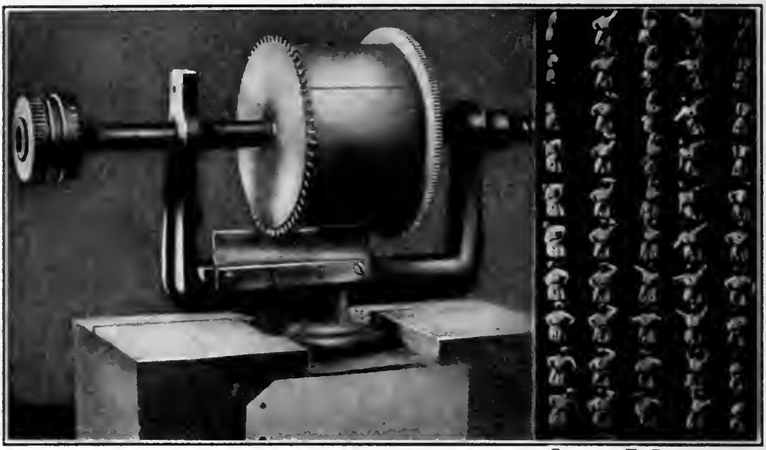


FIG. 3. Sketch of Edison's first method of synchronizing phonograph with picture records.*

To view these small pictures was another matter. If run continuously the result, of course, would be a black streak, unless seen through a slotted disk. To obtain full illumination it occurred to me to rig up a small Geissler spiral tube without a shutter.

These pictures, when viewed through a low-power microscope, were fairly good in spite of the curvature of the drum. A disk was tried next, to avoid the difficulty arising from the curved drum surface. However, for the sake of simplicity, we returned to the celluloid sheet and drum. The drum at one end had pins projecting exactly opposite each picture (Figs. 4 and 5). The pins came in contact with a stiff primary wire from an induction coil, whereas the secondary

* EDITOR'S NOTE: This sketch and several others illustrating the article were prepared by Mr. Dickson at the request of the Historical Committee. Originals are on file at the Los Angeles Museum.



Courtesy T. Ramsaye

FIG. 4. Drum for inspecting microscopic pictures on film strip shown on right.

fed the Geissler tube placed directly over or a little to one side of these pictures. Owing to the extreme rapidity of the flash of light from the Geissler tube, when compared with the movement of the drum of pictures, the images appeared to stand still and were sharply defined.

I have not mentioned some of my earlier failures, such as the use of a vertical disk which, however, being flat, got rid of the distortion of the drum. Also, I need not go into a detailed description of my glass drum illuminated intermittently from the inside by a back-and-forth straight shutter.

I was glad to get away from drums, disks, *etc.*, and a hopelessly

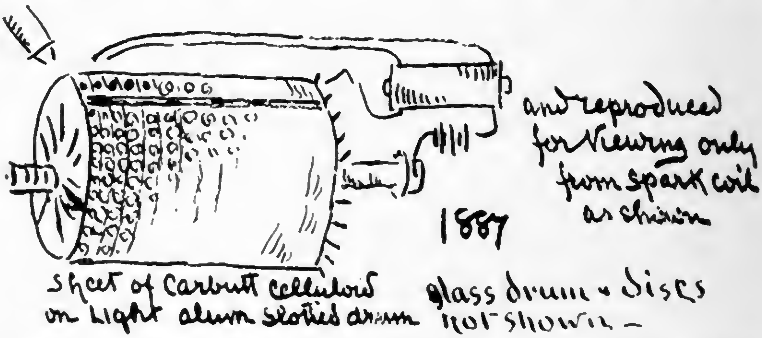


FIG. 5. Sketch of images on Carbutt film wound around drum and viewed with the aid of light from a Geissler tube.

limited number of pictures, looking forward some day to getting decent lengths or strips of film from Blair or Carbutt.

EXPERIMENTS WITH SHORT FILM STRIPS

My next attempt, after abandoning drums and the like (early 1888), was to proceed with narrow strips of Carbutt celluloid, 18 inches long, notched on the top, and impelled intermittently by a clock escapement movement (Fig. 6). A rotating shutter and a $1^1/_2$-inch focus lens were used. The pictures were $^1/_4$ inch square. This tentative test or experiment seemed to be leading me in the right direction, as will be shown. On trying to join these strips, the usual trouble was that the joints stuck in the frame or open guide, which, however, we made as springy as possible.

While wandering through our museum of showcases containing many hundreds of models of Edison's inventions, I caught sight of

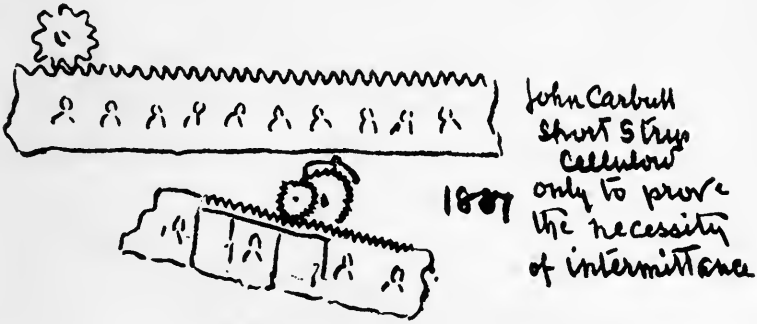


FIG. 6. Sketch of Carbutt film with notched edge.

his perforated paper automatic telegraph. By the end of a week my capable mechanic, William Heisse, had made me a perforator which made two round holes to a picture. The sprocket drive had a single row of sprockets to fit the newly punched Carbutt strips.

The escapement movement then in use was soon found to be much too slow to satisfy persistency of vision in the stopping and starting which we found imperatively necessary in the endeavor to get a quick change and a long rest. So we adopted the Maltese cross, and after some modifications found it to answer our purpose very well (Fig. 7). In less than a month we had a good working camera. This occurred in the autumn of 1888.

The pictures were taken horizontally, but were only $^1/_2$ inch in size—on Carbutt celluloid strips. Though the strips shot through the gate at a good rate, we didn't mind how often we threaded up to enjoy our success. The longest we could make was about 40 inches, or 3 joints of 14 inches each. This apparatus was finished, but neither Carbutt nor Blair could supply us with thinner or longer strips.

EASTMAN'S FILM AND ITS APPLICATION

Toward the close of the year 1888 it was rumored that the Eastman Company was experimenting on a new product for their cameras, and that it would be shown at the New York Camera Club by Mr. Geo. Eastman's representative. At the end of the meeting, which I attended, I approached the demonstrator, explained what we wanted and asked for the 2 by 4 inch sample to show to Mr. Edison. The

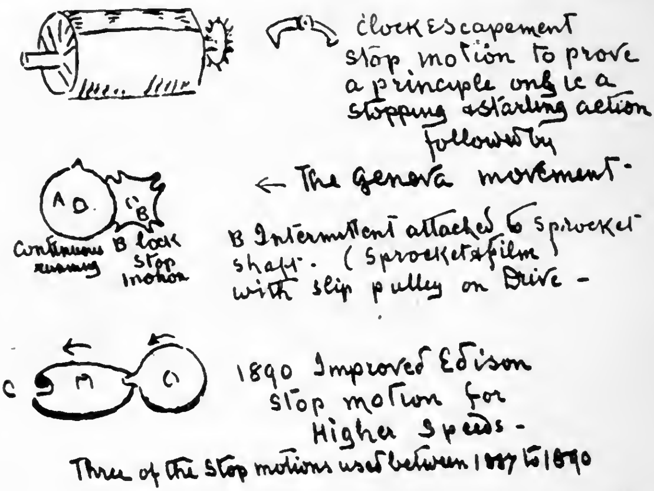


FIG. 7. Types of intermittent movements used 1887–1890.

representative quickly grasped the situation and its great possibilities, and invited me to come out to Rochester to see Mr. Eastman, which I did the next day. I knew then that we should reach our goal if the Eastman Company could supply this new product in good lengths. When I showed Mr. Edison my new find his smile was seraphic; "Good," he said, "we can now do the trick—just work like hell."

On reaching the Rochester Works, Mr. Geo. Eastman received me most courteously; and after a long talk he took my arm, guiding me through his long darkrooms while he touched on some of his ambitions. He showed considerable enthusiasm as to the new possibilities of the kinetograph requirements.

The central table was covered with long sheets of plate glass, carefully fitted together in lengths. The atmosphere was pregnant with the fumes of amyl acetate, and I was glad to get out of it. He then took me into another room and gave me many experimental samples wrapped in red and black paper for my tests; and invited me to come whenever I liked. That was the beginning of many years of friendship, strengthened by our mutual interest. Mr. Eastman was at all times ready to concede to my wishes, supporting me in my efforts to attain my great purpose for Mr. Edison.

On my return to Orange, my assistant and I were soon able to test some of these short samples of which we had a good supply, thanks to Mr. Eastman's generosity. However, we found that we should require greater sensitiveness and less coarseness. The silver grains were too apparent when magnified.

FIG. 8. Print from one of first successful Edison negatives on Eastman film (Approximate date, May, 1889).*

A few weeks elapsed before I saw Mr. Eastman again and explained our difficulties, which were remedied principally by reducing the coarseness of the silver bromide. This change proved most satisfactory. When perforating the film, however, the sprocket wheel often broke through and tore the film. I had to ask Mr. Eastman whether he could make his base tougher and less brittle, which he did.

Meanwhile we had to use this rapid negative for our positive prints; and although they lacked pluckiness, we partly overcame it by using potassium bromide in our developing bath to reduce its sensitiveness. This caused me to apply again to Mr. Eastman for a less sensitive product or emulsion similar to that used in lantern slide work, which we ultimately received.

We were, however, much troubled with "frilling," and often a gelatinous mass of pictures was left at the bottom of our developing or fixing troughs, while the base remained on the drum, a situation which we found very trying and necessitated further conferences on this matter. Mr. Eastman, however, managed to overcome this

* EDITOR'S NOTE: This scene was made apparently on film samples supplied Mr. Edison by Mr. Eastman before the Kodak product was announced publicly.

difficulty in part. An early film of a horse shoeing scene (May, 1889) shows partial frilling (Fig. 8).

About this time we received six rolls of improved negative film 50 feet long, and later some slow positive film. All these samples and experiments were made exclusively for us by Mr. Eastman, who took an ever-increasing interest in what we were doing.

To return to the work in hand, we had to devise certain essentials, such as a circular film cutter or trimmer, a perforator, a clamp with steady pins to fit the punch holes, to use in joining the films with a thin paste of the base dissolved in amyl acetate, which, I suppose, is still commonly used. Room 5 at the Edison Laboratory was used principally for our photographic experiments and mechanical work. The precision workshop was located near our room.

To take these photographs or strips, our camera or kinetograph had to be carried down to a small improvised platform placed against our ore-milling outhouse. A bright sunny-natured Greek, Sacco Albanese by name, was one of my very earliest victims, figuring mostly in the $^1/_4$-inch, and later in the $^1/_2$-inch, pictures. Draped in white, he was made to go through some weird antics. (See Fig. 4.) Some time later, early in 1890, I persuaded Mr. Fred. Ott, Edison's chief mechanic, to give me an exhibition of sneezing.

The famous firms of Bausch & Lomb and Messrs. Gundlach, of Rochester, N. Y., produced some fine lenses for the work, and I have always felt that they should be brought into this early history of the kinetograph for the perfection of their work and their patience with me and my demands. The lenses were at last standardized as $2^1/_2$-inch mean focus. With such lenses we made our second kinetograph.

Our first outside subject was the dancing and wrestling bears, which we took early in 1889 in the open yard of the Edison Laboratory, long before any studio was erected. I found these performing bears on the main street of Orange, N. J., and persuaded their Italian owners to follow me to the laboratory to have their photos taken. After a few rehearsals my assistant was ready with a pieced sample of film and the picture was soon made.

My drawer full of samples and tests was destroyed after I left America, and there remain only a few scraps of originals and reproductions and my booklet *The History of the Kinetograph, etc.* I may add also that the studio and the "Black Maria" were razed to the ground as of no historical interest, as it was deemed by my successor.

The "Horse Shoeing Scene" of May, 1889, was taken outside with an improvised background, as were other scenes taken prior to that date. (See Fig. 8.)

SYNCHRONIZATION OF THE EDISON PHONOGRAPH AND KINETOGRAPH

In the midst of this work Mr. Edison went abroad, leaving me his instructions. I accompanied him to the steamer. As the boat glided out I saw Mr. Edison leaning over the railing, his fists to his eyes to imitate the viewing of the pictures in our experimental kinetoscope. I understood the pantomine to mean that I was to have the kinetoscope completed before his return. A rough model of the instrument was constructed.

The gearing up of the kinetograph with the phonograph kept us busy day and night, experimenting until both were done in time. A smaller sprocket wheel had to be made for the row of perforations to fit the teeth better, owing to the shrinkage resulting from developing and fixing the negative film, which we had to use for all purposes.

On my return from the boat I persuaded my friend Mr. Charles Batchelor, who was in charge of the laboratory, to build an outside studio to my specifications, combining a sliding glass roof to let in the sunlight unobstructed, for photographing kinetograph subjects before a black or other suitable background.

Attached to this room, which was about 18 by 20 ft. in size, were two darkrooms—one for punching, trimming, joining the films, and printing the positives; the other for developing, fixing, washing, and "glycerining"* the films. These operations were done by using large, black, enameled drums adjustably suspended at each end when immersed in long, shallow troughs.

The films were spirally wound around these drums and the ends clamped to hold the film in place. When deemed to be thoroughly developed, the drum was carried to a similar trough to revolve in water coming from a spray over the length of the film or drum. The used water was carried away by an overflow from the trough (Fig. 9). The film was then carried to the fixing trough and back to the washing arrangement, thence to the glycerine trough, and dried before a fan while revolving on the motor-driven drum.

Method of Making Prints.—As to our method of printing negatives, I had a large 8- or 10-inch sprocketed drum made, geared to run

* A bath of glycerine and water, used to render the film more flexible.

slowly, over which the films came in contact, the unexposed film being under the negative and the pins engaging both films. A small pea-lamp and reflector were placed above the negative. A square of ground glass was interposed between the light and the film, and the light was regulated by a small slide resistance to give the right ex-

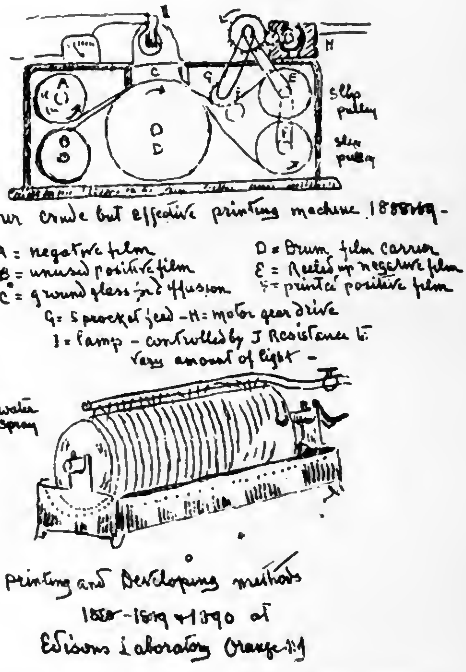


FIG. 9. Printing and developing equipment used at Edison laboratory.

posure. Two spools on each side were used, geared to pick up the negative and positive films (Fig. 9).

Above these darkrooms I had another room for projecting tests with the kinetograph and phonograph (Fig. 10). Having succeeded in devising a very simple method of doing this, I hastened to get my assistant to take a short film, using me as the subject, in combination with the phonograph, to prove that Mr. Edison was right in supposing such a thing could be done as predicted in his preamble in the *History of the Kinetophone, etc.*

Mr. Edison's return to his laboratory took place Oct. 6, 1889.* Within the hour I had him by the arm and led him to the new studio and kinetophone exhibit, on which we had been working day and night. On seeing the studio, Mr. Edison asked, "What's that building?" I explained its necessity. "Well, you've got cheek; let's see what you've got." We went in. Gradually his face lit up, the clouds of disapproval were dissipated and finally dispelled. I had

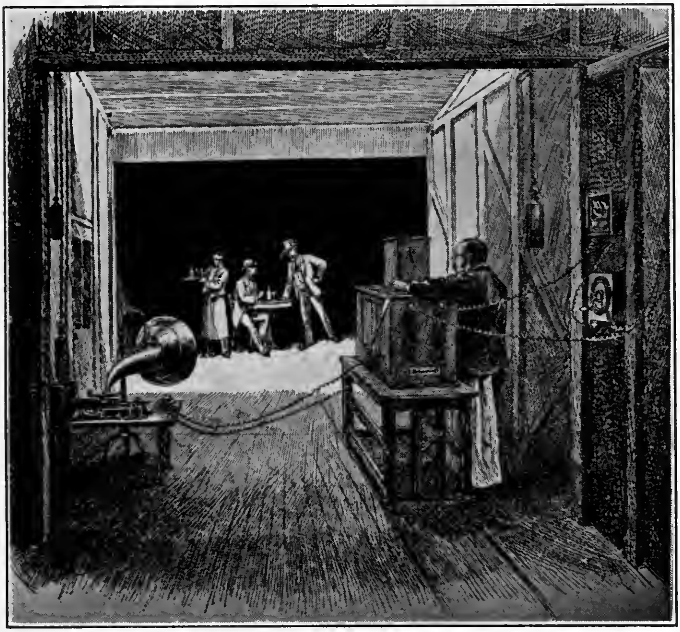


FIG. 10. Projection room (about 1894), showing phonograph attached to kinetoscope for synchronization of sound and picture. (*Century Magazine*, **18**, 207, 1894).

placed him in a chair in the upper projecting room to witness his first "talkie," or exhibit, of the kinetophone. For a wonder, the exhibition was good. No breakdown of the film occurred nor did the Zeiss arc lamp sputter. There was much rejoicing. Edison sat with

* It has been said that Mr. Edison sent me long, weekly cables and letters during his absence, to instruct me further as to what information he had gathered when in Paris from others working on these lines; which, of course, was absolutely incorrect. I wish to emphasize the fact that Mr. Edison never during his absence communicated with me either by cable or letter.

the eartubes to the phonograph. My assistant started the arc lamp and removed the metal sheet interposed between the arc and the film. The phonograph motor controlled the projecting kinetograph.

I was seen to advance and address Mr. Edison from the small 4-foot screen; small, because of the restricted size of the room. I raised my hat, smiled, and said, "Good morning, Mr. Edison, glad to see you back. Hope you like the kinetophone. To show the synchronization I will lift my hand and count up to ten." I then raised and lowered my hands as I counted to ten. There was no hitch, and a pretty steady picture. If the pictures were steady in the taking, why not in the reproduction on the screen?

A rough description of the method adopted to synchronize the two instruments may be useful. The only modification made to the

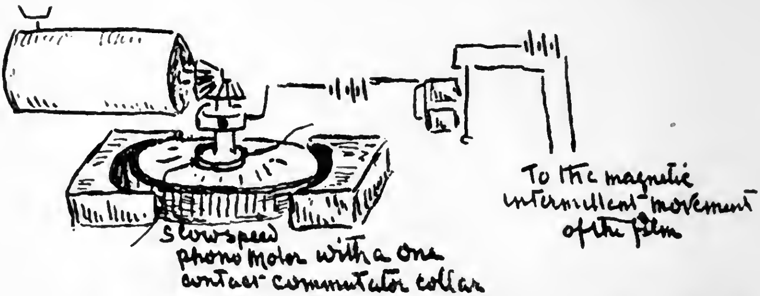


FIG. 11. Sketch of arrangement used to synchronize phonograph record and motion picture film.

kinetograph, was to place a ratchet wheel at one end of the driving shaft. Thus one end of the shaft held the sprocket wheel which engaged the perforated film, and the other end held a magnetic escapement device, which was controlled and timed through a relay and battery from an extra commutator collar on the phonograph motor shaft. The impulses electrically received through the ratchet wheel were spaced at $^1/_2$-inch intervals for each phase or picture (Fig. 11). This arrangement gave very good synchronization and was extremely simple though a little slower than when using the Geneva movement which, of course, was put temporarily out of gear for these kinetophone demonstrations.

A little later, about a year, I fancy, Mr. Edison devised an ingenious stopping and starting device, which took the place of the Maltese cross or Geneva movement for a time. A horizontal $1^1/_2$-inch disk

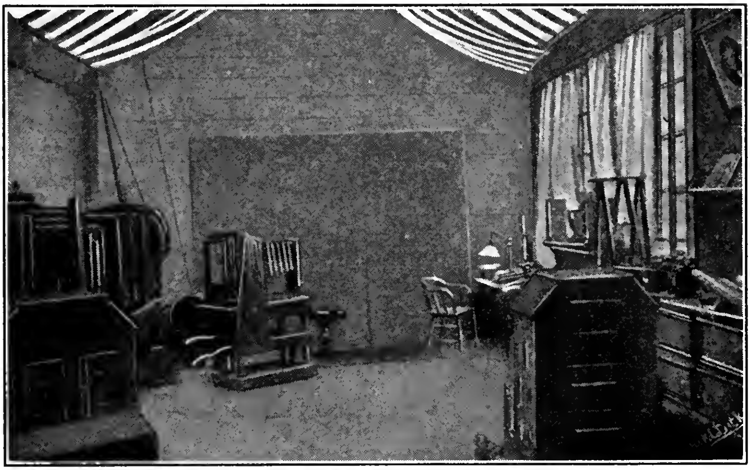


FIG. 12. Interior of first studio (1889), showing models 1 and 2 of the kinetoscope. (From *History of the Kinetoscope, etc.*, by W. K. L. Dickson and Antonia Dickson. *A. Bunn*, N. Y., 1895.)

with one slot at its edge was centered on a shaft to run continuously. A disk of similar size with a nose or pin projecting and running vertically was driven forward on a slip collar. The nose rested and slid

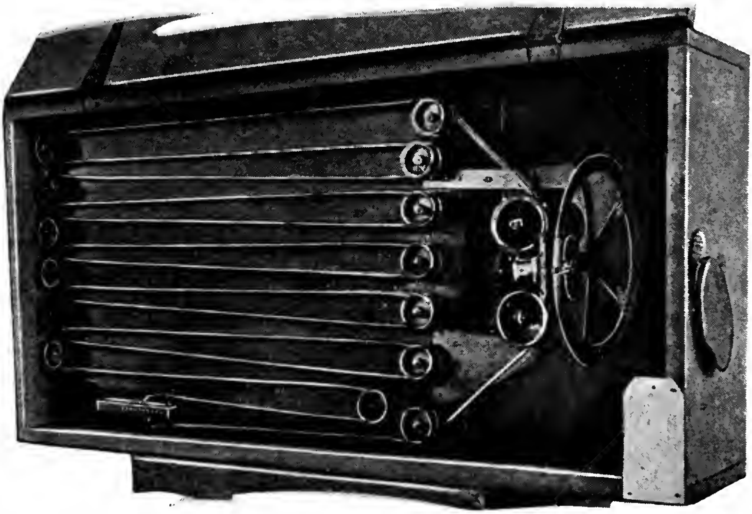


FIG. 13. Interior view of the kinetoscope (Talbot, F. A.: "Moving Pictures," *Lippincott's*, Philadelphia, Pa., 1923).

along the slotted horizontal disk; and as the vertical disk revolved, the nose or pin in the horizontal disk would fall rapidly through the slanting slot (Fig. 7). The film was therefore moved along, since it was engaged at the other end of the shaft by means of a sprocket wheel.

I waited for Mr. Edison's further approval of my model of the kinetoscope that day on his return, before going ahead with a standard model. He was quite enthusiastic, and the next day, Oct. 7, 1889,

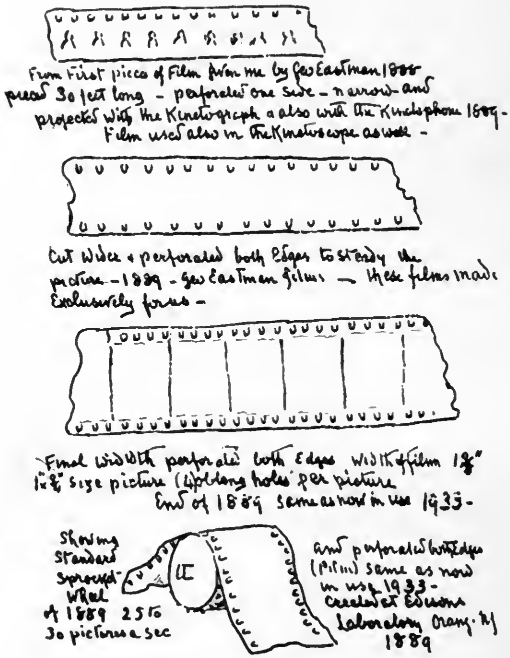


FIG. 14. Evolution of standard film width and picture size.

he brought in several visitors among them Samuel Insull, to see the "Wonderbox." A photograph of the studio interior taken a few weeks later shows both the No. 1 and 2 kinetoscope models (Fig. 12). Although this apparatus has often been described, I will venture to repeat a description.

THE FINISHED KINETOSCOPE

In the first place, the film or positive which was 47 feet long, ran continuously and not intermittently as in the kinetograph.

The kinetoscope mechanism was built up on a small platform, and consisted of an open gate through which the film ran, drawn by the sprocket wheel (Fig. 13). A 10-inch shutter revolved at high speed. The shutter was slotted in one place giving a $^3/_{16}$-inch opening to admit the light from a small electric lamp after passing through the film. The light rays from the 8-volt lamp were converged by means of a reflector, causing the rays to cross through the $^3/_{16}$-inch shutter opening to obtain a maximum of light.

The film, after leaving the gate and sprocket wheel, passed down and up over several velvet covered rollers or spools in an endless band. The last spool was weighted and controlled by a spring to take up any slack. The film used in the first model had one row of perforations. The pictures were $^1/_2$ inch in width (Figs. 14 and 15), and the shutter opening was so set as to meet a picture centrally. To increase the magnification of the image, I further devised a two-eye plano-convex lens to increase the size of the image. As this whole device was approved by Edison, I forged ahead, and soon was using a larger film perforated along both edges. The mechanism was driven by a small 8-volt motor, using storage batteries. The manufacture of this device was started in 1893 and was soon carried out in quantities for exhibitors.* Meanwhile, the projecting kinetograph remained in *status quo*, to my great regret.

FIG. 15. Print from length of early narrow width film made with kinetograph (perforations cut off when first reproduced in book form).

At the end of the year 1889, I increased the width of the picture from $^1/_2$ inch to $^3/_4$ inch, then, to 1 inch by $^3/_4$ inch high (Fig. 15). The actual width of the film was $1^3/_8$ inches to allow for the perforations now punched on both edges, 4 holes to the phase or picture, which perforations were a shade smaller than those now in use. This standardized film size of 1889 has remained, with only minor variations, unaltered to date (Fig. 16).

* The first commercial showing of this device was at the Holland Brothers Peep Show Parlour, 1155 Broadway, New York, N. Y., April 14, 1894 ("*History of the Motion Picture*," by T. Ramsaye, *Simon & Schuster*, N. Y., 1925).

The demand for films for the kinetoscopes was somewhat of a problem as the machines were being manufactured. Just at this time I was switched off to carry out some further experiments on magnetic ore-milling machinery. However, I never failed to remind Mr. Edison of his risk in not patenting all these "movie" devices. I think it was Mr. Frank L. Dyer who at last persuaded him to move in the matter, after I had talked it over with him. This, however, was not done until a year or so later, while others anticipated us by a

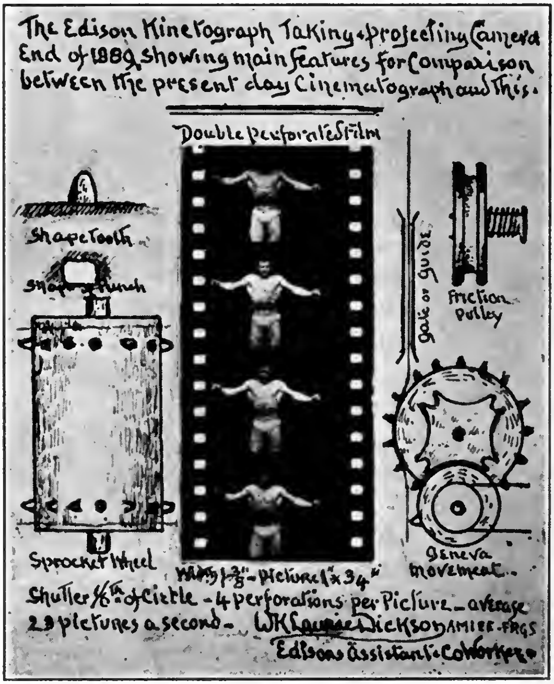


FIG. 16. Types of mechanisms and film used in the kinetograph.

patent date though we could prove priority of invention and actual working models, *etc.*

THE MAKING OF COMMERCIAL KINETOSCOPE PRINTS

On my resuming movie work (which I did off and on), I had to do my best to secure attractive subjects for the kinetoscopes. It was only at certain times of the day that I could get such pictures in the studio with its glass roof slid back, so I decided in 1891 to build another studio revolving on wheels to meet the sun at all hours, which some wag later dubbed the "Black Maria."* This had a stage at one end, backed by a tunnel to give velvety black effects, and at the other end was a darkroom fitted to change the films.

The kinetograph camera was fixed on an adjustable table which we could wheel out on rails for focusing close-ups or whole stage effects. The roof was made to fold back to admit the sun after the building had been moved around (Fig. 17). Here we took most of the pictures, although some were made at the old studio and a few in the open.

The outside pictures were taken against a long or very wide gray painted wooden wall so that when the subject moved out of the picture we would still follow it by keeping it centrally framed against an

FIG. 17. "The Black Maria" motion picture studio; designed by Dickson in 1891, completed Feb., 1892.

even, gray background, as was necessary when photographing *Duncan C. Ross' Horsemanship* or *Mounted Sword Fencing*.

The camera end of the "Black Maria" used to be swung around and such pictures taken through a small window inside the darkroom. The lighting and stage were so great an improvement, that I repeated several of the subjects I had taken earlier in the 1889 studio, such as the organ grinder and monkey, *Sandow*, and some others. I can give only an inadequate list of subjects, most of which were taken in

* Completed on Feb., 1892, at a cost of $637.67.

the "Black Maria," built in 1891–92. A partial list of subjects taken at Edison's laboratory between 1889 and 1895 follows:

Trick Dog Teddy and other Dog and trick Cats.
Madame Bertoldi, contortionist.
The Gaiety Girls.
Colonel Cody's (Buffalo Bill) Shooting Skill.
Colonel Cody and his Sioux Indians.
Sioux Ghost Dance.
Sandow in Feats of Strength.
Texan Cowboy Throwing Lassos (in the open).
Alcide Capitaine.
Mexican Knife Thrower.
Madame Armand Ary.
Fencing Bout—Experts.
John Wilson, the Tramp.
Boxing Cats.
Sheik Hadji Tahar—Summersaults, *etc.*
Walten and Slavin (long and short) comedians.
Japanese Dancers.
Chinese Opium Den Police Raid—a comic.
Milk White Flag (a play).

These subjects were taken on our full width film, having double perforations, four to a phase as used to this day, and standardized by me for Edison at the end of 1889.

In conclusion, when I left Mr. Edison's laboratory in 1895, having accomplished the problems assigned to me, I joined my friends Messrs. H. N. Marvin, E. B. Koopman, and Herman Casler* to carry out a new method of reproducing motion by means of a pack of cards, which I had devised shortly after I had left Mr. Edison. This device we called the "Mutoscope." The cards were viewed both as a peep show and as booklets given out by manufacturers for publicity purposes. A syndicate was immediately formed, and our master mechanician, Mr. Herman Casler, worked out his famous "punch as you go" taking camera.** When it was ready, I managed to secure some very stirring pictures.

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* The Biograph Co., sometimes known as K.M.C.D. (after the initial letter of the founder's names) was formed in the summer of 1896. Their first commercial showing was on Oct. 13, 1896, at Hammerstein's Olympic Music Hall, in New York.

** The Biographic camera had an intermittent movement consisting of a double mutilated, rubber-covered roller. When portions of the roller having the thicker radii came together on revolving, the film was moved forward.

Later, I secured pictures with this equipment in London, of Queen Victoria's Jubilee; in Rome, of Pope Leo XIII; and in Africa, of the Boer War. These films were exhibited in London and the United States. The pictures of the Boer War were shipped back periodically and exhibited first at the Palace Theater in London.

In conclusion, it is with considerable pleasure that I look back on these days and night sat Edison's laboratories; of strenuous work, defeat, and triumph. My friendship and close association with Edison will always remain as a happy memory shadowed by his loss. I still watch with keen interest the development of this great industry —Edison's dream materialized.

W. K. Laurie Dickson

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A SIXTEEN-MILLIMETER PORTABLE SOUND-ON-FILM PROJECTION EQUIPMENT*

C. R. HANNA,** P. L. IRWIN,† AND E. W. REYNOLDS†

Summary.—*A portable sound-on-film projection equipment using 16-mm. film is described. The film is standard with the exception that one row of sprocket holes is omitted to provide space for the sound track. The projector is only slightly larger than the average silent picture projector. A detailed description of its mechanical, electrical, and optical features is given.*

The complete equipment is mounted in three carrying cases, one for the projector, one for the amplifier, and one for the loud speaker and screen. The projector case serves also as a sound-proof housing when the equipment is in operation. The rewind, splicer, cables, spare tubes and lamps, and the films are located in the case for the loud speaker and screen. Each of the carrying cases weighs approximately 40 pounds, making the total weight of the equipment 120 pounds.

For some time there has been a need for a small projection equipment suitable for home or portable use. Until recently, efforts to obtain a relatively light equipment have been directed, for the most part, toward the disk type of machine; but because of the necessarily large size of the wax record none of these equipments has been very small. This paper describes a complete sound-on-film projection equipment, using 16-mm. film, the total weight of the equipment being 120 pounds. The apparatus to be described was developed in 1930 to meet the needs of the Westinghouse Company for educational purposes within its organization and for advertising.

The following requirements were sought in developing this apparatus: first, it should be simple, rugged, and easily operated by the average person; second, the quality of sound reproduction should be equal to that of the modern radio or electric talking machine.

THE FILM

The film is the standard 16-mm. film, with the exception that only one row of sprocket holes is employed so as to leave room for the

* Received July 1, 1933.

** Research Laboratories, Westinghouse Electric & Mfg. Co., Pittsburgh, Pa.

† Formerly with the Westinghouse Electric & Mfg. Co.

sound track on the opposite edge of the film. Fig. 1 shows an enlarged section of sound film of this type. The speed of the film is 24 frames or 7.2 inches per second, corresponding to the same number of frames or 18 inches per second in the 35-mm. film. At that reduced speed it is, of course, a great deal more difficult to obtain response at the higher frequencies, because of the reduced length of wave along the film. For example, a frequency of 5000 cycles corresponds to a wavelength of 0.0014 inch with the small film as compared to 0.0035 inch with the 35-mm. film. It has been found possible, however, with care in design and focus of the optical systems, and by providing adequate mechanical filtering for obtaining uniform film velocity, to attain very good quality of reproduction at the reduced speed.

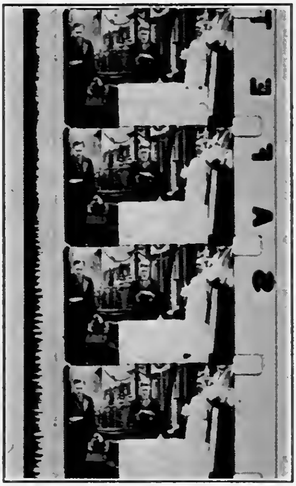

FIG. 1. 16-mm. sound film.

THE PROJECTOR

Fig. 2 is a photograph of the front side of the machine. The two reels are mounted coaxially at the top, and the three feeding sprockets are all mounted on one shaft below. The path of the film is as follows: after coming off the back reel, it passes around the sprocket (*a*, Fig. 2) nearest the center plate, and thence to the picture gate with a loop, which is skewed one position toward the observer so as to be in line with the middle feed sprocket. An intermittent claw at the bottom of the picture gate moves the film at that point, after which the film takes the form of a horizontal loop at the bottom of the machine before passing vertically upward through the sound gate. From the sound gate it passes around two rollers, one of which is connected to a free flywheel on the opposite side of the center plate. The friction between the film and the roller drives the flywheel without slippage, and thus the effective mass of the film is increased. The middle sprocket, which pulls the film at this point, is flexibly mounted on its shaft by means of a helical spring inside the sprocket. After passing it, the film takes the form of a skewed loop, shifting one position toward the observer and under the front sprocket, which is a hold-back sprocket (*b*, Fig. 2). This places the film in line with the front or take-up reel.

Such an arrangement of film feeding mechanism is very compact without, in any way, making the threading operation more difficult than it would be with sprockets and reels on separate shafts. Other advantages of the arrangement will be described later.

Fig. 3 shows the picture gate and intermittent movement. The gate has flexible steel shoes under the tension of a cantilever spring at the bottom for holding the film against the slightly curved back-

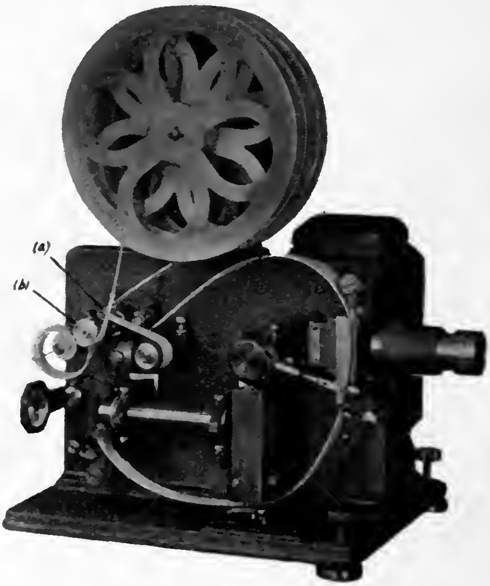

FIG. 2. View of front of projector.

plate. Such a construction causes the pressure to be uniform throughout the arc of contact between the shoes and the film and serves, also, to allow the film to be pushed forward by the intermittent claw in case the perforations do not register at the start.

The intermittent movement consists of a heart-shaped cam of novel design surrounded by a square follower. Two adjacent sides of the follower are in the form of cantilever springs, which press against the cam so as not to allow any lost motion. These cantilevers are deflected slightly outward by the cam so as to provide a spring force which is in excess of the maximum force of inertia and friction of the reciprocating parts and the film. So constructed, the intermittent operates very quietly. It is also cheap to manufacture because the tolerances of the cam may be greater than if the usual type of follower were used. The cam is designed to move the claw down in a 75-degree movement of the cam with respect to the follower. This is reduced to an actual 66-degree movement of the cam, however, because of a 9-degree clockwise movement of the rocker and follower opposite in direction to the counter-clockwise

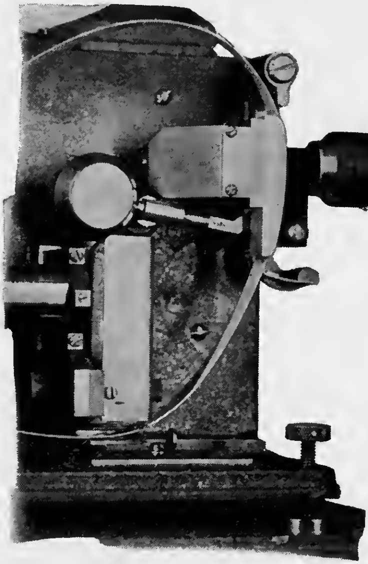

FIG. 3. Picture gate and intermittent movement.

cam movement. The placing of the rocker between the cam and the claw is responsible for the opposed rotation. It results also in another advantage: namely, that the radius of curvature of the orbit of the claw may be made any desired value. For example, if the rocker is midway between the center of the cam and the claw, the orbit of the claw will be a straight line for a considerable distance. In the design of this machine, the rocker is placed one-third the distance between the center of the cam and the claw with the result that the curvature of the claw orbit approximates the curvature of the picture gate.

A two-blade shutter is mounted behind the center plate on the same shaft as the cam. The angle of the blades is 75 degrees, so as to occult the light completely during movement of the film. Fig. 4 is a schematic diagram of the picture optical system. Condenser C_1 focuses an enlarged image of the filament of lamp L at the lens C_2, which in turn focuses the evenly illuminated surface of C_1 on the film F after reflection from the mirror M. The condenser C_3 re-images the enlarged filament image at a point midway between the two lenses of the objective O. The shutter S is placed close to C_1, which is a conjugate focus of the film in approximately a 1 to 1 ratio. This allows complete shutting-off of the useful illumination with a shutter

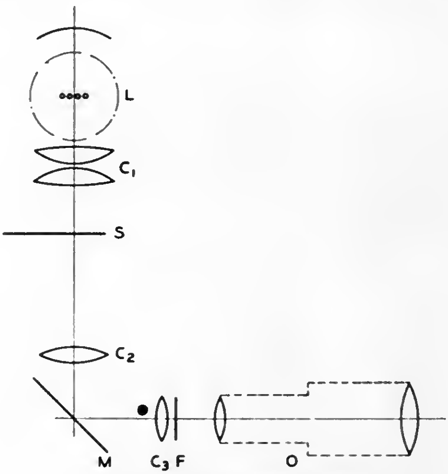

FIG. 4. Picture optical system.

movement no greater than the height of one frame, namely, 0.3 inch. This type of system was necessary because of the fact that there is a fairly great distance between the lamp and the film. Aside from the loss of light at the mirror and at the surfaces of the two extra lenses in the condenser system, this arrangement has as great an optical efficiency as any short optical system.

Fig. 5 is a close-up photograph of the sound optical system and sound gate. A heavy filament 10-volt, $7^1/_2$-amp. lamp is used for the source so as to allow it to be operated on a 60-cycle line without objectionable hum. A small condenser lens immediately in front of the lamp illuminates a slit, which is reduced in a 4 to 1 ratio by the objective at the left end of the optical system barrel. The image at the film is 0.0005 by 0.050 inch. Convenient arrangements for orienting the slit and for adjusting the image focus are provided.

Fig. 5 also shows in detail the mechanical filtering system for maintaining a uniform velocity of the film past the light image. The sound gate is similar to the picture gate, but has a smaller radius of curvature so as to hold in perfect focus the unsupported sound track at the edge of the film. The use of flexible shoes under tension for pressing the film against the curved back-plate is of greater importance here than in the picture gate, because such construction provides very smooth friction, with the result that the filtering system may be of smaller dimensions than would otherwise be the case.

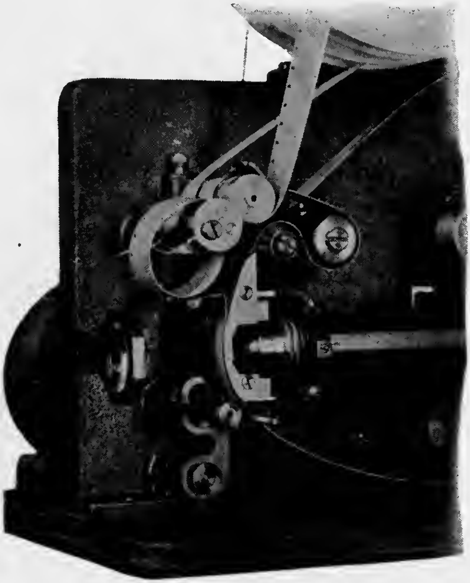

FIG. 5. Sound gate and optical system.

This friction provides tension on the film of sufficient magnitude to cause adequate driving friction between the film and the flywheel roller without the use of pressure rollers for holding the film against the flywheel roller. The avoidance of pressure rollers is very important, because they would produce torque pulsations which only a much larger flywheel could resist. As was stated at the beginning, the center sprocket which pulls the film at this point of the film path is resiliently connected to its shaft. The purpose of the flexible mounting is twofold: first, if there are any irregularities in the speed of the shaft, they will be readily absorbed by the spring; second, if the sprocket teeth do not exactly fit the perforations of the film because of shrinkage, the sprocket, because of its flexibility and its small inertia compared to that of the flywheel, may readily adjust its motion to that of the uniformly moving film. Thus the sprocket moves with a steady motion, plus a pulsating motion of exactly the right character to transmit substantially uniform motion to the film; in other words, the flexible mounting of the sprocket prevents shaft and sprocket tooth pulsations from reaching the film.

As in all other filtering systems made of springs and inertia members, it is necessary that the system be damped to prevent oscillation.

FIG. 6. Rear view of projector.

For that purpose, a lubricated leather brake is placed inside the sprocket so as to provide viscous damping for relative movements between the sprocket and its shaft. The purpose of the front or hold-back sprocket in the system is to form a film loop for isolating the spring sprocket from any pulsations which might be transmitted through the film by the take-up reel.

With this combination of refinements, it is possible to maintain extremely constant film speed with the use of a flywheel only 5 inches in diameter and 1 inch in thickness. The uniformity of speed is such that with good piano records, for example, there is no noticeable "twang" or "fuzzing" of high notes during reproduction.

Fig. 6 shows the rear of the machine. The motor is a single-phase, 110-volt, 60-cycle induction type with an external resistance for obtaining split-phase in the stator. Its pinion drives the large double idler gear, whose bearing is the outside of the bronze bushing through which the flywheel shaft passes. The gear on the sprocket shaft meshes with the smaller of the two gears of this double idler, and rotates at 180 rpm. The intermittent gear meshes with the larger gear of the idler and rotates at 1440 rpm. A spring take-up belt passes around a small pulley which is integral with the idler gear. Although the flywheel appears to be gear driven, it will be remembered that it is free-floating in its bearing, and driven only by the friction of the film as the latter passes around the roller on the opposite side of the assembly.

In this construction it will be seen that there are but five gears in all, and that the motor is mounted upon the base, where its vibration will cause the least harm. Lubrication is effected through oiler wicks on the sprocket shaft, flywheel shaft, and the intermittent shaft; and through oiler holes on the motor, rocker arm shaft, and the rocker arm slide. The intermittent cam and the spring sprocket damper are packed with vaseline and require only infrequent attention.

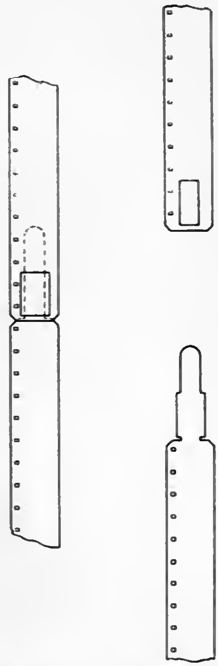

Fig. 7. Film splice for self-threading.

Although no provisions are made for film guides and loop formers, an arrangement for automatically threading the machine is provided for those who do not care to thread by hand. Fig. 7 shows a form of film splice, which is made by a special punching on the trailing end of one film and the leader of the next, so that a film already in the machine may be used to lead through a subsequent film. To make convenient use of this splicing arrangement an automatic stop is provided, so as to halt the machine at the instant the end of the film leaves the loaded reel.

Fig. 8 illustrates the electric circuit for starting and stopping the machine manually, and also the arrangement for automatically stopping the machine in the manner described. A friction brake mounted on the back reel provides the proper amount of torque for holding together a pair of relay contacts so long as the reel is rotating. In the diagram this pair of contacts is marked *Holding Switch on Reel.* The instant the reel stops, the contacts open and the machine shuts down. A new reel may then be inserted on the shaft and its leader attached to the trailing end of the preceding film. After being led through the machine, the splice is unhooked and the film is attached by hand to an empty reel placed at the front. At the end of a performance, a short strip of film is led into the machine and left there for threading the first film of a subsequent showing.

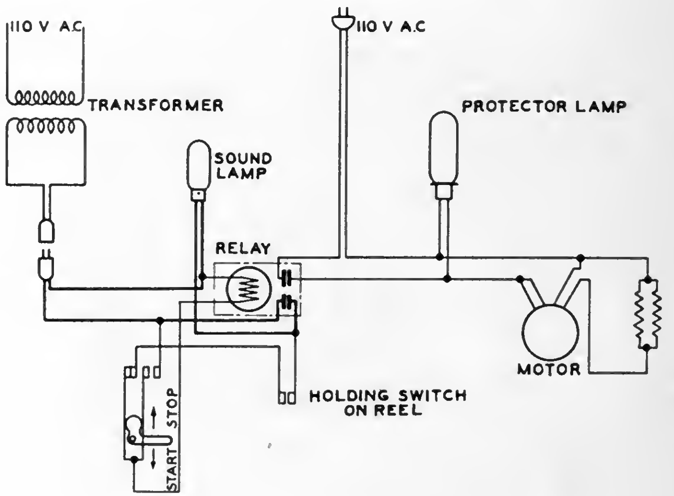

FIG. 8. Control circuit.

It will be seen from the circuit diagram that both motor and picture lamps are turned on at the same time, this arrangement obviating the necessity of a fire shutter.

THE COMPLETE EQUIPMENT

Fig. 9 is a photograph of the projector mounted in a sound-proof carrying case. A chimney at the top of the lamp house and ventilating holes in the side of the case provide adequate cooling for continuous operation without a fan. The chimney is lined with sound absorbent material to reduce noise transmission. When the complete equipment is set up for operation, the amplifier case is rigidly fastened to the back of the projector case so that the photo-cell will be in line with the sound optical system for any angle of tilt of the equipment. The light passes through holes in the two carrying cases, the photo-cell being mounted on the amplifier. The latter is operated by any 110-volt, 60-cycle supply, no batteries being used at all.

The screen is 15 by 20 inches, but for large audiences a separate roll screen 3 by 4 feet is used. The case in which the loud speaker and the small screen are mounted has a removable back with rewind and splicer mounted upon it. In the same case are provisions for

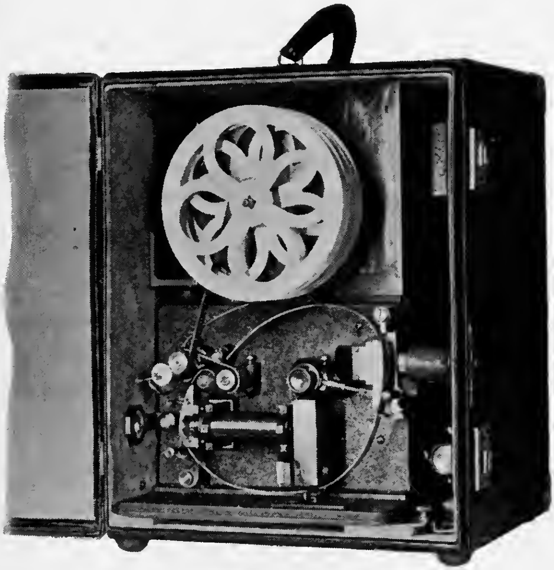

FIG. 9. The projector in sound-proof carrying case.

carrying eight 400-foot reels of film, spare tubes and lamps, and the cables.

Acknowledgment is made to K. A. Oplinger and C. N. Batsel for their work in developing recording apparatus and for making the films, to S. Sentipal for the design of many features of the projector, to E. H. Greibach who worked with one of the authors on the design of the mechanical filtering system, and to K. A. Oplinger and W. O. Osbon for working out the convenient portable arrangement of the several components of the equipment.

A LIGHT-WEIGHT SINGLE-FILM RECORDING SYSTEM FOR NEWSREELS AND TRAVELOGUES*

C. R. SAWYER**

Summary.—*A portable sound recording system is described, which weighs less than 100 pounds, is easily operated, and produces high-quality results when used in combination with a single-film recording camera.*

Since the beginning of sound recording for motion pictures, it has been recognized that the equipment for newsreel work should differ in many respects from that which would be the most satisfactory for studio recording. However, the urgency of producing such equipment made it advisable to adopt the available apparatus, with as little modification as practicable. So in most cases lightness was sacrificed to reliability of operation.

While at that time it was quite possible to picture the conditions which would be encountered in the studio, those in the newsreel field were more difficult to anticipate. Therefore, it was felt advisable to allow reasonable factors of safety in including apparatus which might be needed. This was done largely because the newsreel man is frequently much more distant from his base than is the sound man in a studio or on location. With the knowledge gained from actual field experience and with the development of such new apparatus as the permanent magnet light valve[1] and the moving coil microphone,[2] it was now feasible to improve the Western Electric Newsreel equipments radically from the standpoints of weight, size of equipment, ease of operation, and quality of recording. In describing this new equipment in some detail, the improvements made and the reasons for them will be pointed out.

Power Supply and Motor Drive.—The first point to be considered is that of the power supply, since heretofore it has been the controlling factor in the weight of equipments. To permit greater flexibility

* Presented at the Spring, 1933, Meeting at New York, N. Y.

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

in operation, it is almost compulsory that batteries be used for the power whether it be for the amplifier supply or for the motor drive of the camera.

The use of a single film for both sound and picture negatives is a logical practice to follow. Only the one motor for the camera is required, instead of the two required by the double-film system: namely, one for the recording machine and one for the camera. In addition, the motors for an interlocking system are larger and less efficient. The additional battery required makes the total motor battery weight of the double-film system probably three times as great as that for single-film. It must be recognized that the speed control is not as constant as with regulating apparatus, but experience has shown that for speech and for most newsreel pick-ups of music the regulation that can be obtained with a single motor of proper design is satisfactory.

While for the same power output 110-volt motors may be slightly lighter than 12-volt motors, a 110-volt battery of the size required for this power drive would weigh very much more than the corresponding 12-volt battery. No particular gain in battery weight, however, would result in reducing the voltage to the ordinary 6-volt automobile battery; therefore a 12-volt airplane type storage battery was selected for the motor and sound lamp supply.

Microphone.—The introduction of the moving coil microphone has made possible the elimination of the transmitter amplifier, with a resultant reduction in weight. This gain would be partially thrown away were it necessary to mix the outputs of two microphones. However, it has been found that in newsreel work it is practically never necessary to "mix," since the background sounds picked up in the single microphone are usually too loud rather than too weak. The conditions encountered in sound newsreel work are usually such as to make the mixing of sound from two or more microphones extremely inconvenient. Several newsreel sound men have stated that they have all they can do to operate one microphone well, without attempting to "mix" two microphones.

In travelogue work where sounds, particularly of descriptive lectures, may have to be introduced, it is usually advisable to "dub" these at the studio by re-recording, rather than to record them in the field. This does not mean, however, that cases do not occur where an additional microphone, located at a different point from the principal one, would be desirable. The equipment is therefore planned for the use of either of two microphones which may be selected by a switching key located at the amplifier.

Amplifier Assembly.—We may now consider the amplifier assembly to which the input and output cords are connected. The earlier shortcomings of this type of apparatus have been overcome by using new light-weight transformers developed at the Bell Telephone Laboratories, by the use of tubes having relatively low power demands, and by carefully designing the circuit from the battery supply standpoint. As a result, it is possible to include the amplifier and all its batteries in one case weighing less than 35 pounds, and still leave room for the storage and transportation of connecting cords, monitoring headphones, and a microphone. This enables the sound man

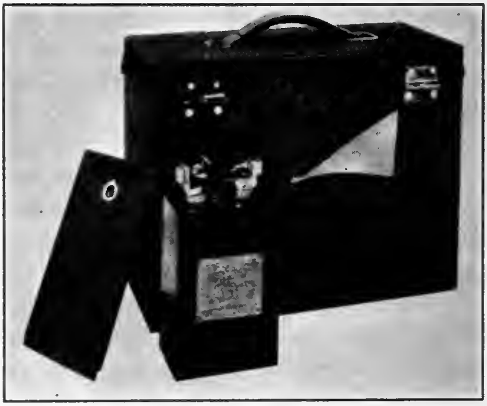

FIG. 1. Amplifier assembly (rear view).

to carry this one light case to a remote location and have all the necessary apparatus readily available for his pick-up work. The taking of a talking newsreel picture can be started almost immediately upon arrival at the scene of an important news event, which might be lost if there were delays in setting up for operation.

The amplifier assembly consists essentially of four parts, not counting the cover. The first is the outside case, which has a separate compartment for the *A*-battery opening at the back of the case (Fig. 1). When the cover of the case is raised (Fig. 2) there are seen, from left to right, the *B*-battery unit which contains six $22^1/_2$-volt batteries, the amplifier unit, and the control unit. This assembly is 15 inches long, 12 inches high, and $6^5/_8$ inches wide.

Amplifier Unit.—For convenience, the amplifier unit, weighing 10 pounds, may be removed from the main case and placed upon any convenient support or carried on the arm. For this purpose, the amplifier is connected to the batteries in the case by a 10-foot plug-ended cord, one of the plugs connecting to a jack in the back of the amplifier and the other to a jack in the control unit. The microphones are connected to two special clamping jacks mounted on the face of the amplifier unit. Between these two jacks is a small switch

FIG. 2. Amplifier assembly showing cover raised.

which determines and indicates which microphone is connected to the input of the amplifier.

On the face of the amplifier are also mounted the volume-indicator meter, a volume-indicator dial switch, a volume-control dial, and a jack into which may be inserted the plug of the headset used for monitoring. Access to the five vacuum tubes used in this amplifier is obtained by opening half of the hinged face-panel; access to the remaining equipment in the amplifier and to the *C*-batteries required by it, may be obtained by unscrewing the four screws holding the outside case in place.

Filament current for the five *264-A* vacuum tubes used in the amplifier is derived from a single 2-volt storage cell or two dry cells. The current to these filaments, which are connected in parallel, is controlled by a single rheostat in the control unit. The amplifier has a frequency-gain characteristic which is flat within ± 2 db. from 40 to 10,000 cycles, the gain is approximately 95 db., and the maximum single-frequency output approximately 10 db. with respect to six milliwatts. This output is sufficient for the operation of the permanent-magnet light valve used in this system, and the gain is ample for practical newsreel work. For newsreel operation, it is usually desirable to droop the response below 200 cycles per second by means of a simple network mounted inside the amplifier.

Control Unit.—In the control unit is a single meter with a switch and resistances so arranged that the sound lamp current, the amplifier filament current, and the amplifier plate voltage may be read separately. The battery supply to the amplifier passes through this control unit, and rheostats are provided for regulating the filament and lamp currents. There is also placed in this unit a low-pass filter, which reduces the high-frequency currents fed to the light valve, thereby reducing the probability of overloading the valve.

Camera Battery Case.—The current for the sound lamp in the modulator unit is provided by the 12-volt battery used for the camera motor drive. However, for convenience of adjustment, the regulating rheostat for the lamp current is placed in the control unit, the necessary leads being brought back to this unit from the motor battery case. Because of this connection, it is also convenient to carry the audio-frequency leads through this battery case. The complete weight of this battery case is 48 pounds and its dimensions are $13^1/_2$ by $6^5/_8$ by 12 inches. One special 10-ft. cord transmits speech, lamp, and motor currents from the battery case to the camera assembly.

Modulator Unit.—A proportionate reduction in weight has been made at the modulator unit by use of the permanent magnet light valve and by the substitution of a new small sound lamp. Based on these two improvements, a complete redesign of the modulator unit (Fig. 3) was made, with the result that the modulator unit and sound gate, with their mounting plate, now weigh less than 4 pounds. The mounting plate slides into the back of the camera and can be readily removed when not in use. Electrical connections to the modulator unit are made by means of four pin plugs which slip into corresponding jacks on the camera. It is assumed that the sound camera will be provided with a small terminal plate which will also mount the drive-motor rheostat and possibly a lamp switch, although the lamp is also controlled by a switch at the amplifier.

The cover of the modulator unit is held in place by a single thumb-nut, which is permanently attached to it so that it will not be misplaced when the cover is removed. This thumb-nut functions with a screw fastened to a bracket that also helps to protect the sound lamp. The essential parts of the unit itself are condenser and objective lenses, light valve, and the lamp, which is mounted upon a separate

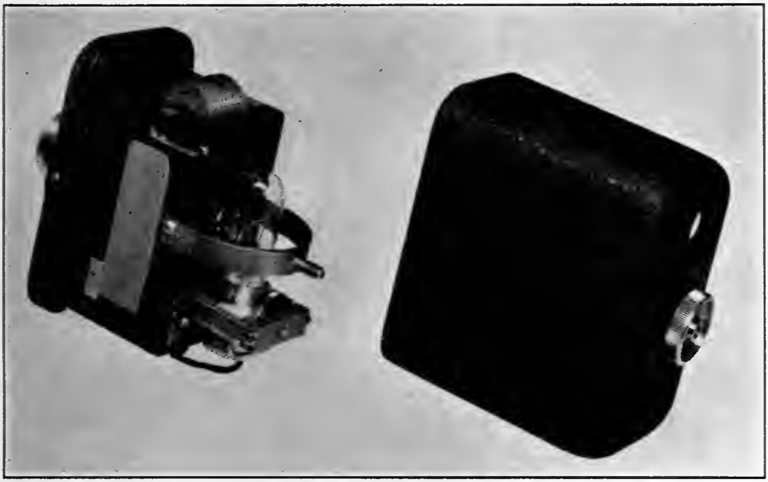

FIG. 3. Modulator unit with cover removed.

removable bracket. Two motions suffice to remove this lamp and bracket, and two more will put in an extra bracket with a prefocused lamp. This makes it possible to change the sound lamp within a half-minute in case of an accidental burnout during a take. The light valve is of the permanent magnet type, with the ribbons permanently clamped once they are tuned. This light valve can be removed and replaced readily, being held in place by a spring latch with a locking cam to prevent accidental opening. It will be noted that in this modulator unit there are no screw connections. This, it is expected, will practically eliminate loose connections in this important part of the circuit.

The operating period of a set of dry batteries or a charge of the storage batteries may be of interest. The 2-volt storage battery and the 135-volt *B*-batteries which are included in the amplifier assembly weigh five pounds each. These power sources total ten pounds in weight, and will operate the amplifier for 13 hours. This will permit the recording of about 35,000 feet of film which, for a newsreel man, is approximately a month's work. The 12-volt storage battery, which furnishes power for the sound lamp and the camera driving motor, has

FIG. 4. Light-weight single-film recording system, complete with sound camera.

sufficient capacity to operate approximately $2^1/_2$ hours, which will permit the recording of about 12,000 feet of film. For normal newsreel operation it needs to be recharged only two or three times a month.

The normal sound recording part of the equipment will then consist of a microphone and its tripod, the complete amplifier assembly, the motor battery case with camera cord, the modulator unit, the monitoring headset, and two connecting cords, one from the microphone to the amplifier and the other from the amplifier to the battery case.

The total weight of this equipment is less than one hundred pounds. Even when the camera and its tripod are added (Fig. 4), there should be no difficulty in transporting the system by hand or as personal baggage by train, automobile, or even by mule-back.

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A NON-INTERMITTENT HIGH-SPEED 16-MM. CAMERA*

F. E. TUTTLE**

Summary.—*A rather simple form of non-intermittent 16-mm. camera that seems to be especially well suited for high-speed motion-picture photography has been developed. Film under tension is pulled continuously by a sprocket across a gate that has an aperture enlarged in the vertical dimension. The image is displaced optically to follow the film by means of a uniformly rotating plane parallel plate of glass located between the lens and the film. Framing is accomplished by small uniformly rotating blades, the edges of which follow the frame lines of the picture down as the film moves.*

The camera can be run at speeds as high as 2500 pictures a second. Two forms of the camera have been developed for use with the precision timing clock, one designed for race timing by the Kirby system, having an operating speed of 120 frames per second, the other using a camera with a maximum speed of 2500 frames per second.

For some time technicians have realized that there are fruitful advantages to be gained in the study of motion, if only some practical method were available for revealing to the eye motions that occur too rapidly to be seen under normal conditions. Probably the first instrument to be used for the purpose was the stroboscope which, however, was limited mainly to the study of recurring phenomena. With the development of sources of intermittent light of great intensity for illuminating the subject in a manner similar to that of the stroboscope, high-speed photography has become possible. However, equipment for such photography has not been made available to many people interested. Moreover, a mechanism for driving the film past an aperture, similar to that used in the camera under discussion, is required.

A number of high-speed cameras of the continuous motion type have been constructed, a few of which operated successfully; the remainder either enjoyed short-lived success or failed utterly. Unfortunately, they were all too costly or too bulky for general laboratory use. The fundamental principles of some of them were discussed in a previous paper.[1]

* Presented at the Spring, 1933, Meeting at New York, N. Y.

** Development Department, Eastman Kodak Company.

Of all the methods of optically displacing an image, the one that apparently lends itself to the design of a continuous camera is the method using the rotating plane parallel glass plate. This plate, rotating uniformly, shifts the image to follow the film for short intervals remarkably well. This method is used in the high-speed camera described here.

Fig. 1 shows the essential parts of the camera. The plane parallel glass plate *A* rotates about a center perpendicular to the plane of the paper. Light from the lens *G*, passing through this plate, is displaced

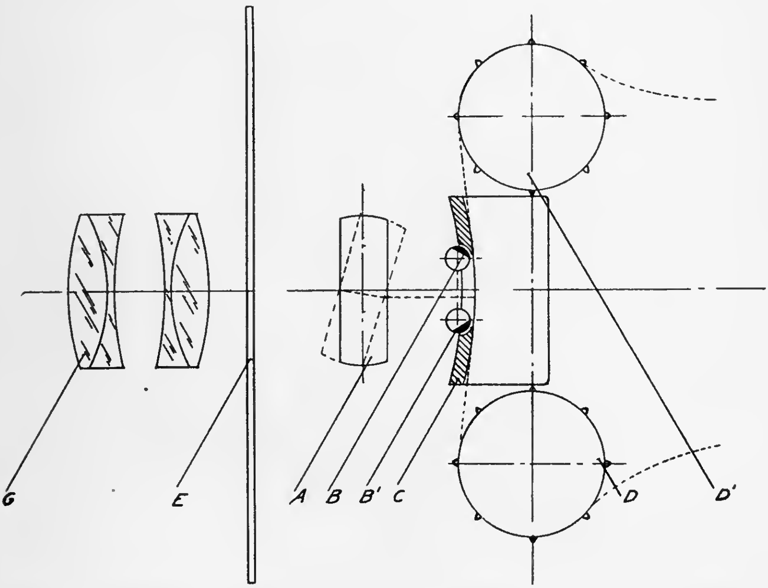

FIG. 1. Schematic arrangement of the high-speed, non-intermittent camera.

almost linearly for a part of a revolution of the plate. The disk shutter *E* then cuts off the light until the opposite face of the plate is in position to give the necessary approximation of linear displacement of the image for satisfactory definition. The film in the gate *C* moves continuously past an aperture, at a rate equal to that of the image displacement during the open period of the shutter. The height of the aperture is slightly greater than that of a film frame. The film is pulled over the gate by the lower sprocket *D*, and is held taut by the spring-mounted sprocket *D'*. *B* and *B'* are special framing devices which cause the frame line to follow the film during the exposure period. All moving parts in the camera rotate at a constant speed. The parts operate at speeds up to approximately 250 to 300 pictures per second. For higher speeds, as great

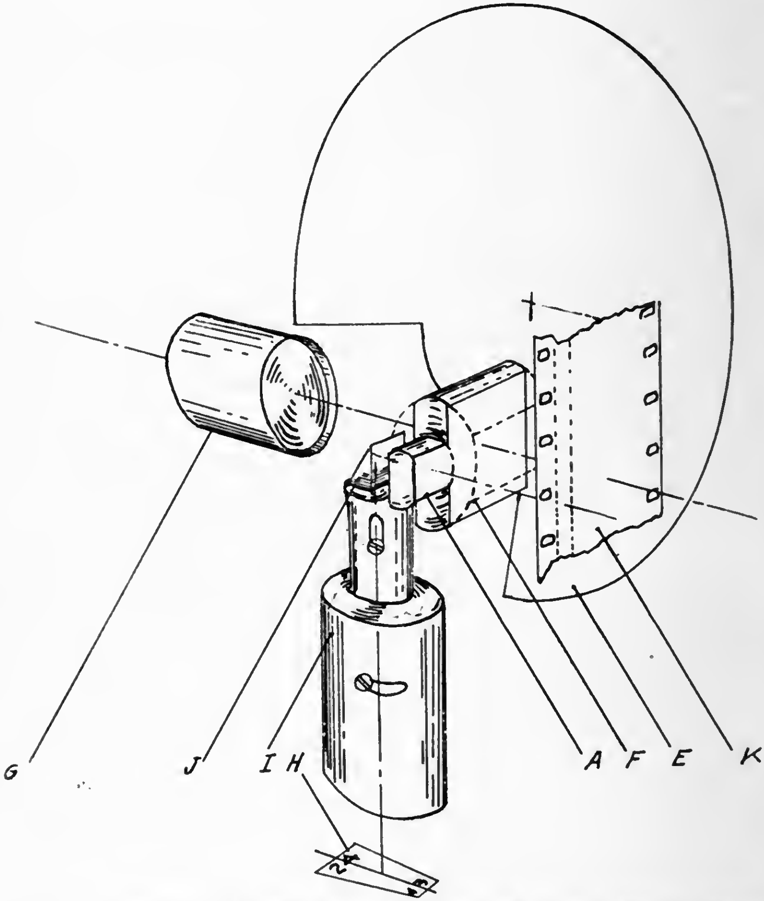

FIG. 2. Showing the manner of using the camera with the Western Electric clock system of splitting seconds.

as 2500 pictures per second, the rotating framing blades B and B' are replaced by stationary framers with only a slight loss in framing, and the disk shutter E by a barrel shutter F (Fig. 2) of low inertia and with little tendency toward distortion. The rotating parts are limited, then, to the barrel and a glass plate, the two sprockets, and gears necessary for driving those parts. It has been found that the majority of high-speed camera subjects are self-framing or may be made so by controlling the illumination; or, may be framed at the subject itself.

The field of usefulness of the high-speed camera is increased greatly when used in conjection with a very accurate clock developed by the Western Electric Company. The Kirby "two-eye" method[2] employed records simultaneously on each picture the image of the clock dials and the exposure of the subject. Fig. 2 shows how the image of the clock dials *H*, directly below the camera, passes through the clock lens tube *I*, is reflected at right angles by the prism *J*, and passes through a small section of the glass plate *A* where it is displaced to follow the film *K*. The smallest division on the clock dial is two one-thousandths of a second, making it possible to read it to one one-thousandth part of a second.

Our own use of the two speed-types of high-speed camera has shown them to be of great service in studying mechanical problems and has convinced us that they are powerful tools in making visible any form of motion. Many subjects of popular trend have also been photographed, with very interesting and instructive results.

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THE CINÉ-KODAK SPECIAL*

J. STOIBER, O. WITTEL, AND F. E. TUTTLE**

Summary.—*The new 16-mm. Ciné-Kodak Special and a new tripod made by the Eastman Kodak Co. are described. Features of the camera include a dissolve shutter, a turret which carries any two of a series of interchangeable lenses, a reflex focusing finder, a spring motor with long uniform run characteristics, controlled speed from 8 to 64 frames per second, interchangeable film chambers having capacities of 100 and 200 feet, single-exposure trip, single-frame-per-turn and eight-frame-per-turn hand crank or motor drive shafts, and masks for double exposure and effect photography. The tripod has twist lock legs, and a smoothly operating panoraming and tilting head.*

Ten years ago the Eastman Kodak Company placed on the market the first 16-mm. motion picture camera. At that time the problem was to make the taking of home motion pictures certain and simple. Several sub-standard film cameras had been introduced before, but none had proved very satisfactory because of the user's difficulty in obtaining consistently good results. The controlled film reversal process made relatively certain the achievement of uniformly good photographic quality, and, when coupled with elementary taking equipment, promoted in the public the feeling that the taking of home movies was easily within its ability.

Continued improvement in emulsions and in the reversal process, together with the advent of Kodacolor, has attracted increasing numbers of workers in various fields. Engineers, research laboratory technicians, surgeons, biologists, sales organizations, amateur cinema clubs, and the like, have all found application for 16-mm. pictures.

Contact with these workers directly and through observations of processed film has shown that the serious worker is not only desirous of, but is ready for, more elaborate picture-taking equipment. Compilation of these observations has resulted in the design of the Ciné-Kodak Special, a 16-mm. motion picture camera which is capable of producing any of the results desired.

* Presented at the Spring, 1933, Meeting at New York, N. Y.

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

The Ciné-Kodak Special is built in two units. One unit contains the spring motor operating mechanism and controls; the other consists of either the 100-foot or the 200-foot capacity film chamber. Removing the film chamber from the motor unit and replacing it with another film chamber containing a different type of film or a different length of roll is a very simple task which requires but a few seconds. It is unnecessary to remove the camera from the tripod to accomplish this change-over. During the operation, not a single frame of film is fogged because of a shield which must cover the gate aperture before the chamber can be removed. In order to prevent the loss of film, the camera drive mechanism is locked until the aperture shield on the

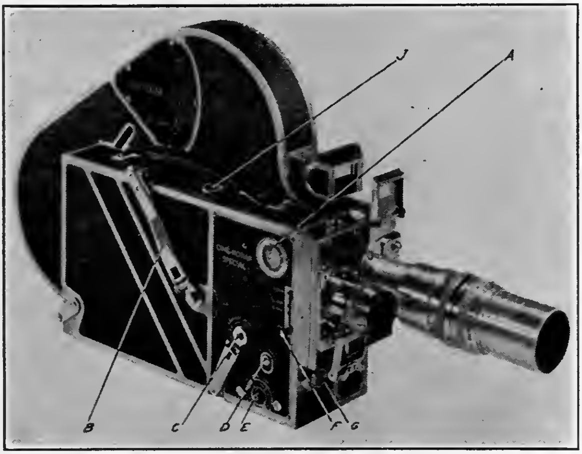

FIG. 1. Ciné-Kodak Special with 200-ft. film chamber.

new chamber has been opened. Each film chamber is equipped with a film footage indicator which shows the amount of unexposed film.

Fig. 1 shows the camera with the 200-foot film chamber and the operating control panel at the side of the spring motor unit. By means of the frame speed control A, the camera speed can be varied from eight frames to sixty-four frames per second, when driven by the spring motor. B is the spring motor crank. The camera runs forty feet of film at one spring winding. A warning bell signals when the spring is nearly tight and again when it is nearly run down. C is an eight-frame hand crank or electric motor drive shaft. If it is desired to run more than forty feet of film without interruption, an over-running clutch releases the spring drive and permits the operator to use this small hand crank after the spring motor has run down. With the speed control set, the governor furnishes a very nice brake for hand cranking. With this hand crank the film can be wound backwards in the camera for making double exposure shots, overlap dissolves, *etc.* *D* is a single-frame trip. With the spring motor wound up, the operator can make continuously as many as fifteen hundred single-frame exposures for animation work. One frame is exposed with each revolution of the single-frame hand crank shaft *E*, which also may be

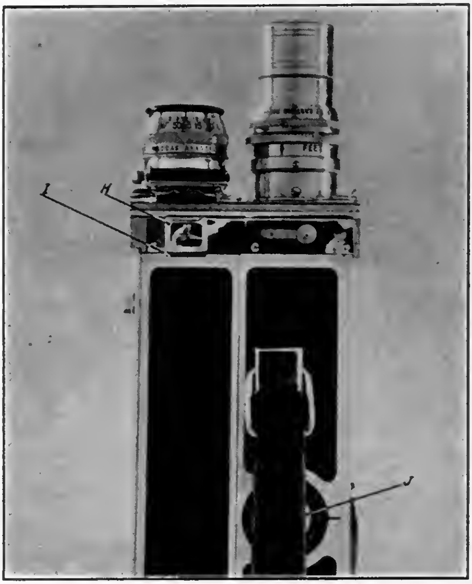

FIG. 2. Ciné-Kodak Special, showing reflex finder.

used as a motor drive shaft. This feature makes the Ciné-Kodak Special very well suited for the making of growth study pictures and the like. *F* is the variable shutter lever. The camera can be operated with the shutter one-quarter open, one-half, or wide open. Each change of shutter position, therefore, gives an exposure change equal to one full lens stop. The shutter on the camera can also be closed or opened gradually while the camera is running, permitting fades and overlap dissolves. *G* is the operating release for the camera.

The Ciné-Kodak Special is equipped with a turret which accommodates two lenses of the interchangeable type. Available for the Special are the one-inch $f/1.9$, 15-mm. $f/2.7$ wide-angle lens; two-inch $f/3.5$ lens; three-inch, $4^1/_2$-inch; and six-inch $f/4.5$ telephoto lenses. Each lens carries its own straight-through finder sight.

The top of the Ciné-Kodak Special is shown in Fig. 2. *H* is a reflex focusing finder which uses as an objective the lens that is in position for taking pictures. When using this finder, a mirror is brought into

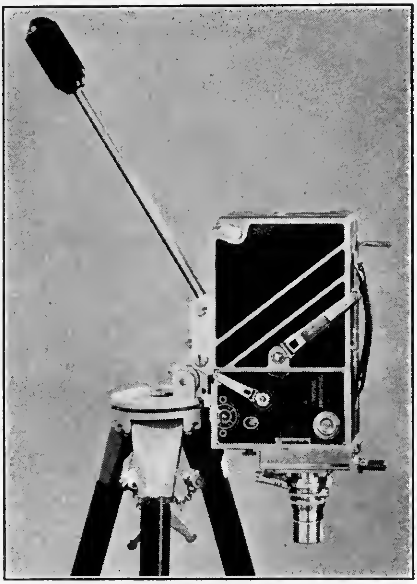

FIG. 3. Ciné-Kodak Special with 100-ft. film chamber mounted on special tripod.

position between the back of the lens and the film, which reflects the image to a ground glass in the finder. Since the ground glass occupies the same position in the reflected beam as the film does in the straight-through beam, it is accurate for focusing and for showing the field covered by any lens. Starting the camera moves the mirror out of the path of the light from the lens to the film. *I* is a mask slot in the film chamber. A set of six masks is furnished with the camera: a pair of vertical and a pair of horizontal half masks, a circular mask, and an oval mask. *J* is a geared footage counter which is essential for double-exposure work.

In Fig. 3 the camera is mounted on a Ciné-Kodak Special tripod. Although the tripod has been designed particularly for the Ciné-Kodal Special, it can be used with all types of amateur cameras. It is extremely rigid, easily adjustable, and very light in weight. The tripod has vertical and horizontal panoraming heads. The camera may be pointed straight up or straight down, and locked firmly in any position. Tension on the panning and tilting heads is adjustable. The twist-lock legs can be locked at any desired height.

The problem of making a camera with the features of the Special was complicated by the necessity for keeping the total bulk and weight to a minimum. The camera is $2^3/_4$ by 5 by 8 inches. When loaded with one hundred feet of film, it weighs only $9^1/_2$ pounds.

DISCUSSION

MR. FARNHAM: Does the dissolve occur in a definite number of frames or does it depend on how fast the dissolve lever is pushed down?

MR. TUTTLE: The dissolve is manually operated. The time that the dissolve takes depends on the operator's use of his finger. The shutter is a variable shutter, adjustable, and the camera can be run with the shutter wide open, half-open, or quarter-open, allowing the exposure to be changed without changing the lens stop. It is useful in Kodacolor, where the lens stop can not be changed, and it saves putting in an adjustable diaphragm or using neutral density filters.

MR. KALLMAN: When you put the mask in, is it visible behind the ground glass?

MR. TUTTLE: No. It is visible through the straight-through finder in which each lens carries its own finder. These masks have red tops, which can be seen through the finder, giving warning as to whether you are doing it right or not at the time.

MR. MITCHELL: Is the footage dial the type that has a lever resting on the roll itself and measures the footage of the roll?

MR. TUTTLE: Yes.

MR. MITCHELL: Does it back up when you back up the camera too?

MR. TUTTLE: Yes.

PORTABLE RECORDING EQUIPMENT*

DON CANADY**

Summary.—*After reviewing briefly the requirements of portable and semi-portable recorders in general, a semi-portable and a portable recorder employing the Zetka-Canady glow lamp are described. The features involved in the design of the types A and Q glow lamps are discussed, with particular reference to the electrical and optical characteristics of the systems.*

Increasing competition among independent producers of motion pictures has resulted in a demand for two types of sound recording equipment. For several reasons, not the least of which is a financial one, the independent producer does not feel warranted in purchasing two complete recording channels, one a permanent rack type installation, and the other of the so-called "suitcase," or trunk type, for location work. This condition has resulted in various combinations, of which the most satisfactory are described below.

(1) *Equipment Installed Permanently in Sound Truck.*—Where garage space is available immediately adjacent to the studio, this method practically amounts to employing a mobile recording room, the equipment being constantly available for location work. A source of power for operating the recorder and the camera may be provided for in the truck, or the power may be obtained from commercial lighting mains. The main disadvantage is that the recordist is usually compelled to work "blind," and in certain types of recording, this may be a serious handicap. The use of an extension mixer surmounts this difficulty; but since it involves not only additional equipment, but also additional personnel, it usually devolves upon the recordist to "do the best he can."

(2) *Semi-Portable Equipment.*—Installations of this type require that both the amplifier and the recorder be transferred readily from the studio to the sound truck, and *vice versa*. The amplifier, which is built into a carrying case, is installed on a special shock-proof

* Presented at the Spring, 1933, Meeting at New York, N. Y.
** Canady Sound Appliance Co., Cleveland, Ohio.

mounting in the truck. As a general rule, 6-volt storage batteries supply the power, duplicate batteries and controls being provided for in the studio and the truck. Experience has shown that this type of installation is adaptable to probably 90 per cent of the work encountered.

(3) *Semi-Portable, without Truck.*—With this arrangement, the power supply and controls are contained in cases, so that the field of action is extended to cover practically all kinds of work except those in which weight becomes a deciding factor.

(4) *Portable Equipment.*—In this case, a much lighter and more compact amplifier is required, although no essentials, either in performance or operation can be sacrificed. The recorder must also be of light weight, and the portability of the equipment must be such that it can be moved for use practically anywhere that a professional motion picture camera may be taken.

SEMI-PORTABLE RECORDER

The new semi-portable recorder described here, together with the other standard units of equipment, is adaptable to any of the foregoing combinations, as well as to others which may be required. The recorder without the magazine weighs only 75 pounds.

The motor and silent coupling are completely enclosed, although adequate provision has been made for ventilation. The glow lamp holder assembly is likewise enclosed by a substantial cover which serves the dual purpose of protecting the glow lamp from breakage, and the recordist from accidental contact with the leads.

Experience has shown that, as far as recording is concerned, there is a direct relation between the number of sprockets and the frequency of "jams" or "buckles." Simplicity of the film path has therefore been sought in this equipment. Entering the recorder from the loaded side of the magazine, the film passes over one side of the main driving feed sprocket, and is engaged by several teeth to assure positive feed. A loop to guard against sprocket pull is next provided, after which the film passes over the specially ground roller which carries it past the recording beam. A mechanical filter on the drive for the next sprocket, together with a heavy, well-balanced flywheel on the roller shaft, assure a uniform speed of the film past the recording beam.

After passing over the filter sprocket, which engages several sprocket holes in the film, another loop is provided before the film passes over the right side of the main drive sprocket and thence into the take-up side of the magazine. Contact with the film is reduced to a minimum, and scratches and "static" marks are thus avoided. Either Bell & Howell, or Canady film magazines may be used.

Idler Control.—With the exception of the idler on the filter sprocket, all idlers are opened and closed by the turn of a single knob. In either position, they are locked.

Glow Lamp Holder Assembly.—Since this unit is involved in the operation of threading and unthreading, it has received special attention, to the end that these operations might be performed more quickly and easily. The glow lamp is held firmly within a slotted cylinder provided with a knurled ring, which, when tightened, locks the tube securely in the assembly. Also on this cylinder are a micrometer adjusting ring and a lock ring. The inner face of the adjusting ring rests squarely against a machined surface on the case when the assembly is in the operating position, thus fixing the clearance between the glow lamp and the film.

By simply turning the knob the entire assembly is moved, with all adjustments unchanged, into either the operating position or the threading or inspection position. The preparation of the recorder for threading is thus reduced to turning three knobs. The horizontal adjustment of the light beam is made by means of two counter locking screws.

Synchronizing Light.—Adjoining the glow lamp holder assembly is the synchronizing or marking light. This lamp is totally different from all other "sync" lights in that the flash is produced by passing a spark between two electrodes. The spark is imaged on the film in line with, but on the opposite side from, the recording beam. The synchronizing mark made with the sparking device is a single sharp striation as compared with the blurred mark produced by an incandescent lamp which requires a finite time both to come up to full brilliance and to cool after the current is cut off.

A succession of marks can be made along the film at various intervals by making connections as desired to a built-in commutator. This light has proved to be dependable and trouble free; and since there is no filament, it does not need periodic replacement.

Automatic Stop.—An automatic stop is provided which shuts off the motor in case of a buckle in time to prevent an appreciable amount of film from piling up. It is believed that this equipment is the first to incorporate such a feature. Contacts are enclosed on the outside of the recorder. The arm which actuates the contacts does not bear on the film except in case of a buckle, and does not interfere with threading or unthreading.

AMPLIFIERS

Semi-Portable Amplifier.—The amplifier, which is contained within a case 26 in. long, 15 in. high, and 5 in. deep, weighs 25 pounds, complete; and in addition to the amplifier circuit, contains a three-position mixer of an improved type, a monitor circuit, a volume indicator, and a control circuit for the glow lamp. Metering facilities are also provided for all plate and filament circuits.

The various units, as well as the wiring, have been specially treated to protect them against extreme climatic conditions that portable equipment must often endure.

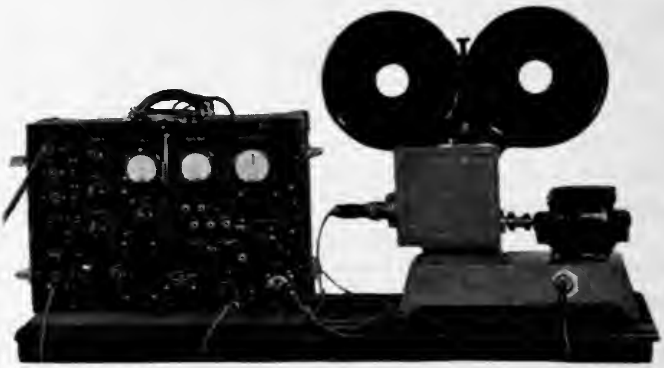

FIG. 1. Portable recorder and amplifier.

Performance curves show a substantially flat characteristic from 25 to 10,000 cycles, and an output in excess of +15 db. without distortion. Due to the full-range characteristics of the Canady-Zetka glow lamp, no compensation is used or needed. Amplifiers which compensate for deficient response of the glow tube inevitably amplify the harmonics of the low or medium tones out of proportion to those of the high tones; and thus the true characteristics of the tones are lost even before they reach the glow lamp.

Each stage of the amplifier is adequately filtered against interaction, and also as a precaution against "motorboating," when used with run-down batteries.

An adjustable low-pass filter is provided for use under certain conditions when it is necessary to reduce or eliminate wind noise, background, or other undesirable sounds.

Portable Amplifier.—Portable amplifiers have been variously described as being of the trunk type, or suitcase type, but this one is more nearly the size of a handbag. The case measures 18 by 12 by 5 inches, outside dimensions, and the complete amplifier weighs 20 pounds. Since a single microphone input is provided, the gain control of the amplifier is the only volume control needed (Fig. 1).

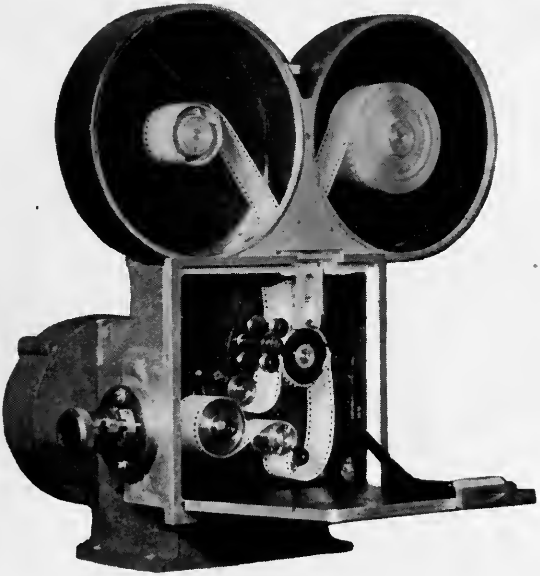

FIG. 2. Interior of portable recorder.

By means of a plug and jacks, filament and plate currents may be read, and also the glow lamp current. A separate meter is provided for the volume indicator. The current to the glow lamp is controlled from the panel of the amplifier, and the cables from the microphone, batteries, and glow lamp are brought in through non-interchangeable connectors. Headphone monitoring is provided.

While nothing essential has been omitted, size and weight have been reduced in this model to the lowest point consistent with reliable operation.

PORTABLE OR MODEL *A* RECORDER

Designed to fulfill the demands of portable recording, where weight and reliability are primary considerations, the model *A* recorder produces excellent recordings (Fig. 2).

The film path through the recorder is similar to that in the larger model (Fig. 3). Idlers, however, are individually controlled. The glow lamp holder is provided with micrometer adjustments and a clamping ring to hold it in the operating position. Light from the glow lamp reaches the film through an optical slit of quartz, with

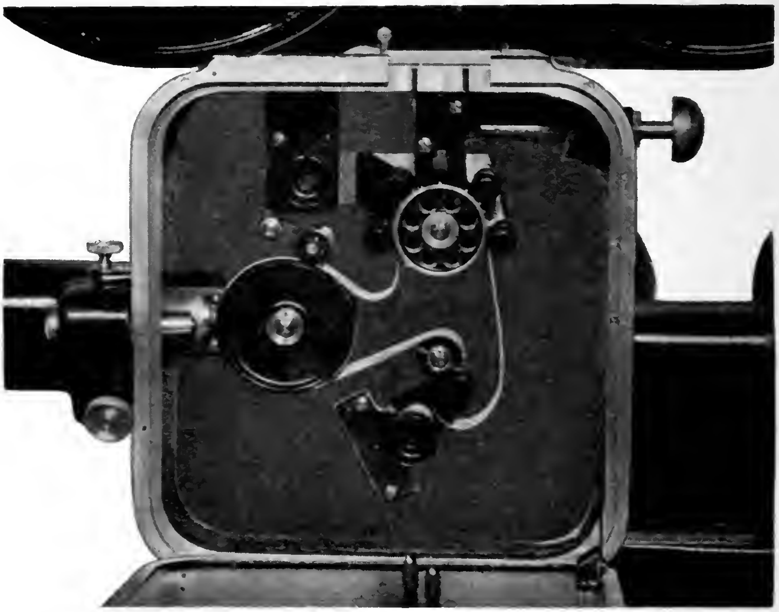

FIG. 3. Interior of studio recorder.

an aperture of 0.0008 by 0.250 inch. The glow lamp holder will accommodate any standard recording lamp. As in the larger model, either Canady or Bell & Howell magazines may be used.

Microphones and Cables.—Microphones of the condenser type with built-in, two-stage amplifiers are standard equipment, and have proved satisfactory and reliable under varying and adverse conditions. Small current, non-microphonic tubes are used in the microphone amplifier, thus reducing background noise, and permitting the use of a longer microphone cable without increasing the supply voltage.

Battery Case.—The new developments in vacuum tubes have made possible the use of smaller size *B* batteries than formerly, and the complete high-voltage supply for the plates of the main and microphone amplifiers and also of the glow lamp, is contained in a case measuring 22 by $10^1/_2$ by $11^1/_2$ inches, which can be easily carried by one man.

Life figures, based on recorded footage, or hours of operation are not available, but where the Canady-Zetka glow lamps have been used, the batteries have lasted six weeks to three months, depending, of course, upon the extent to which they have been used.

Where the equipment is to be used in a studio, either permanently or part of the time, a special rectifier unit is available, permitting operation from the lighting mains.

Storage Battery.—One 6-volt, 80-ampere-hour storage battery supplies the filament currents of both the microphone and main amplifiers, and under average conditions, will do so for a week to ten days before recharging is necessary. Where a 6-volt source is employed for the recorder, a 150-ampere-hour battery is required, so as to permit the equipment to be used away from its base for three or four days without danger of the voltage's falling below a useful value.

Motors.—Standard motors for driving the recorder and camera are of the 110-volt, 60-cycle, synchronous type. Where 220-volt, 3-phase alternating current is available, interlocking motors can be supplied.

To fulfill the need for a reliable drive that would not require a commercial source of power, a special unit has been developed. On the same shaft with the 6-volt motor, and in a common housing, is mounted a 60-cycle alternator. The camera motor is of the synchronous type, its speed being controlled by means of a rheostat in the field circuit of the 6-volt motor. A direct-reading frequency meter is so mounted as to be plainly visible at all times; and, due to the extended scale of the instrument, variations in speed may be readily noticed and corrected. Due to the absence of moving parts, this type of speed indicator is reliable and is unaffected by changes of temperature.

GLOW LAMPS

Type A Glow Lamp.—The two outstanding systems for producing a variable density sound track on film are the mechanical vibrating system and the glow lamp recording system. Up to the present time the difficulty of producing glow lamps which are sufficiently uniform and which fulfill the other requirements imposed have resulted in the adoption of the mechanical vibrating system by some of the leading producers. In this system it has been possible mechanically to peak the response of the device in order to compensate for the loss at high frequences caused by the finite width of the slit used.

In the glow lamp recording system there is one outstanding advantage over the mechanical vibrating system, in that there is absolutely no inertia to be overcome. On the other hand, losses at high frequencies due to slit width must be compensated for in the amplifier.

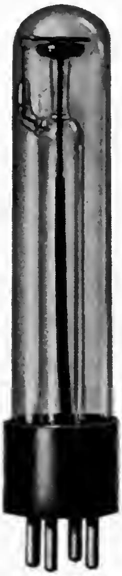

FIG. 4. Zetka recording lamp.

Up to the present time the advantages of the glow lamp recording system have been veiled in practical usage by a number of shortcomings in the glow lamps themselves, which can be listed as follows:

(1) Low light-intensity; requiring that the lamp be used with the mechanical slit, or its equivalent, as close to the film as possible, with the attendant troubles of slit-clogging, *etc.*

(2) Too large wattage consumption in the lamp; causing excessive heating of the bulb and element, and consequent blackening and obstruction of light.

(3) Very short and indefinite life; due to blackening of the bulb or change in the gas pressure or surfaces of the electrodes.

(4) Lack of uniformity; requiring individual calibrations and adjustments for each lamp.

(5) Erratic electrical characteristics during life of the lamp; requiring constant watching and readjustment.

(6) Low sensitivity; requiring a comparatively large output from the recording amplifier.

The design and development of a glow lamp which would obviate these objections has proved a difficult and tedious problem (Fig. 4).

As the primary object of the glow lamp is to radiate actinic light through an exceedingly small aperture, the lamp must be so designed that the glowing spot within the bulb is greatly concentrated and located as closely as possible to the end of the bulb through which the light is to pass. In the Zetka lamp a special glass is used, which is particularly transparent to violet and ultra-violet rays. At the point where the light is required to pass, the bulb is blown very thin, thus further assisting in the transmission of that highly important spectral range.

To avoid premature blackening of the tube it was found vital to select electrodes having the minimum tendency to vaporize under operating conditions. It was also found important to select a mixture of gases and to determine a gas pressure, the combination of which would reduce the vaporization to the lowest possible point. Furthermore, the choice of the gases and their pressure are determined by the desired light intensity. Naturally, the life of a lamp will depend upon the conditions under which it is operated; but the new Zetka glow lamp is capable, under ordinary conditions, of

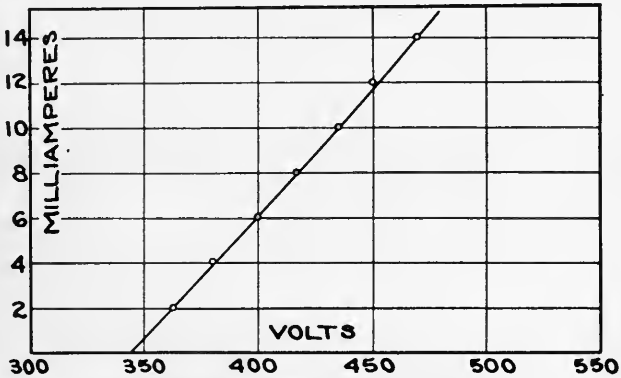

FIG. 5. Static impedance characteristic of Zetka recording lamp.

recording upward of 25,000 feet of sound track. Some recordings have been made as long as 60,000 feet.

Every effort has been exerted to make the lamp as rugged as possible in order to withstand safely the shocks and abuse of shipping as well as those of recordings under "field" conditions. The latest design of lamp has a maximum outside bulb diameter of 1 inch, and the over-all length from the tip of the bulb to the end of the contact prongs is approximately $5^3/_8$ inches. It is mounted in a standard *UX-199* base, only two of the prongs of which are used for electrical connection.

The voltage-current curve of the lamp is shown in Fig. 5, the linearity of which is very unusual with gas-filled devices. This feature is very important from an electrical standpoint because it indicates a constant impedance (5000 ohms) of the lamp during the signal "swings." Duplication of these lamps has been found perfectly feasible when proper care is taken at every stage of their manufacture. The frequency characteristic is shown in Fig. 6.

It is evident that if the lamp is operated at 550 volts, 8 milliamperes, the heat dissipated within the bulb is only 4.4 watts, which is not sufficient to cause undue concern. When operated under such conditions the maximum permissible voltage swing is about 100 volts, thus placing a power demand upon the amplifier of only three-tenths of a watt.

Under those conditions it is easily possible to expose positive film when the lamp is placed close to the film with the usual 0.001-inch, or even smaller, mechanical or quartz slit. When used with an optical system, the light intensity is quite adequate for *VD* film;

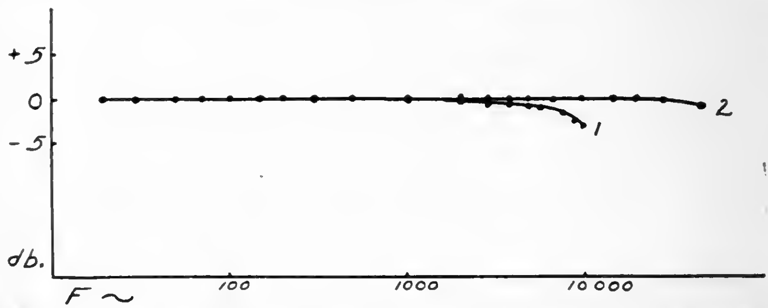

FIG. 6. Frequency characteristics of recording lamps. 1. Old style "Glow lamp." 2. "Q" Recording lamp.

with a calculated slit, at the film, of about 0.0008 inch. The lamp can be used with any standard amplifier having suitable means for controlling modulation.

Glow Lamp Circuit.—In accord with the usual practice, it is essential that a series resistance of at least 10,000 ohms be connected in the circuit of the lamp at all times. A variable resistance ranging from 10,000 to 50,000 ohms will be found satisfactory.

Type Q Glow Lamp.—Light from glow lamps of the type *A* may be transmitted to the film by a mechanical slit, a quartz slit, or an optical train. The mechanical slit tends to collect emulsion and block the light. The quartz slit is more efficient, but due to the extreme thinness of the quartz, it must be handled carefully. The optical system, of course, avoids the mechanical difficulties, but at the expense of light transmitting efficiency. The comparative ability of various materials to transmit the actinic light of the glow lamp is shown in the following table.

Relative Transmission of Various Materials to Glow Lamp Radiation

Material	Transmission (per cent)
Lead glass	20
Lime glass	26
Nonex	38
"E.J." Pyrex	40–46
Corex	68
Quartz	88

Since the losses are cumulative, and increase rapidly according to the number of elements, it is apparent that even very high-grade optical systems introduce serious losses. The problems of spherical and chromatic aberration, and coma must be solved by introducing additional lenses and thus increasing the transmission loss still further. To compensate for the additional loss, the glow lamp must be operated at a considerably greater brilliancy. This means a large current, a higher operating temperature, a consequent reduction in the life of the lamp, and shorter battery life when batteries are used.

A recent development by J. B. Zetka surmounts these difficulties, while retaining the advantages of the lamp. Known as the type *Q* glow lamp, it incorporates both the lens and the slit in the structure of the tube itself. Corex glass is used for this section of the tube. The light aperture or slit measures 0.0008 by 0.125 inch. Improvements in the internal construction of the tube have resulted in ample film exposure with a lamp current of six milliamperes. Life records have repeatedly shown from 75,000 to 100,000 feet of exposed film.

The single system of recording directly on the picture negative at the base of the camera has been purposely neglected in this paper. The shortcomings of the single system have been so serious as to lead to its abandonment by the majority of producers. The larger grain of negative film causes undesirable background noise, and raises the lower limit of sound which may be recorded, while the necessity for a common laboratory treatment of sound track and picture inevitably results in a compromise which fails to realize the maximum possibilities of either. It is also impracticable to cut the common negative, where "flashbacks," inserts, *etc.*, are desired.

UNOCCUPIED MOTION PICTURE FIELDS*

WILLIAM H. SHORT**

Summary.—*A description of the work and purposes of the Motion Picture Research Council is presented, followed by an interpretation of some of the results of this work as regards (1) child receptivity, (2) memory, (3) emotional stress, (4) attitude, and (5) behavior patterns induced by viewing motion pictures. The unexploited motion picture fields are said to be those of (1) teaching pictures, (2) juvenile entertainment (3) entertainment for a large class of adults who do not apparently attend the motion picture theaters for various reasons, and (4) the creation of good-will for the future in respect of adult education, documentary or historical films, and scientific films.*

The Motion Picture Research Council is a body of more than three hundred men and women, widely distributed geographically, and somewhat equally divided between the three allied groups of social workers, social scientists, and socially minded lay men and women. Miss Jane Addams of Hull House (Chicago, Ill.) is dean of our social workers group. Perhaps our social scientist group would agree that Dr. Wesley C. Mitchell is first among equals in that company. From the group of socially minded citizens I should not know whom to mention first but included in the list are the following: John H. Finley, Henry Sloane Coffin, Henry Fairfield Osborn, E. R. A. Seligman, Stephen S. Wise, Francis J. McConnell, Alanson B. Houghton, Thomas J. Watson, Gerard Swope, Frederick Peterson, Clinton Rogers Woodruff, William Danforth, J. Lionberger Davis, Charles M. Moderwell, Charles W. Gilkey, Henry J. Fisher, Herbert S. Houston. The Chairman of the Council is Dr. John Grier Hibben, President Emeritus of Princeton University.†

The purpose of the Council, organized five and a half years ago, has from the first been definitely and positively constructive, and friendly to the motion picture art. All were convinced at the begin-

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* Presented at the Spring, 1933, Meeting at New York, N. Y.

** *Director*, Motion Picture Research Council, New York, N. Y.

† Since deceased, and succeeded by Pres. A. Lawrence Lowell of Harvard University.

ning both that the motion picture is here to stay and that it is potentially a tremendous boon to the human race. For these reasons, the social workers felt the need, as an equipment for dealing with motion picture problems, for a broad fund of scientifically obtained information regarding the potentialities and actualities of motion pictures, especially in relation to childhood and youth. Miss Addams said that she had been serving on motion picture committees for a generation, and that little or no progress had been made just because such knowledge was not available.

The social science group was impressed with the fact that in the motion picture art we have a new and major tool of civilization for the social use and guidance of which their fraternity has an especial responsibility. Dr. Mitchell early gave expression to this conviction in the following words:

> Motion Pictures are one of the most powerful influences in the "making of mind" at the present time. They affect great masses of people, and they affect those masses during the impressionable years of childhood and youth. The industry has developed on a strictly commercial basis into one of our most conspicuous branches of business, demonstrating that moving pictures meet an intensely felt interest. So far, the only social guidance which has been exercised has been of the negative sort—a censorship designed to remove objectionable features. Constructive guidance has been notably slight.
>
> Obviously the moving pictures are doing things to our thoughts and feelings. It is high time we discovered what those things really are. There is no problem that could be of greater concern to those who are interested in the quality of our future citizens.

The lay group of the Council shares both the scientific and the citizenship interests of the other two groups. Together they present a united front of interest and desire to serve in the development of the new motion picture art in the broadest and most socially useful ways.

The Motion Picture Research Council does not oppose censorship, but does believe that the time has come for something other and better than that. It was in this faith that it had its origin and is doing its work. The ultimate and constructive aim of the Council, has, from the beginning, been to develop a plan and recommendations for the motion picture art, as broad and scientifically helpful in every respect as, through four centuries of use, the art of printing has become. And then to devise and stimulate leadership that will enable the motion picture art to achieve this high and honorable destiny.

THE PAYNE FUND RESEARCH

But the Council thought that *it ought first, by careful and patient research, to find out whether it was correct in the belief that in the motion picture art civilization has a new tool of high intellectual and social potency.* It, therefore, invited and received the assistance of the Payne Fund, an agency "interested in enterprises connected with the radio, motion pictures, and reading in their relations to the education of children and youth." The Payne Fund, in turn, organized an Educational Research Committee of qualified psychologists and sociologists from the social science faculties of the Universities of Chicago, Iowa State, Ohio State, New York, Columbia, Yale, and Pennsylvania State College. A program of research was developed by prolonged conference of social workers and the members of this Educational Research Committee; budgets were drawn; the required funds were deposited with university treasurers; and the several research men went to work, under a commission without fear or favor to get the facts in their respective sectors of this broad field, and to pursue their research until amply abundant data had been accumulated to substantiate the conclusions at which they might arrive.

For four years, without interference by publicity or otherwise—yet coöperatively—the research went on. Under the guidance of Dr. W. W. Charters the research guns were kept on the targets. Findings have been obtained that, with unimportant exceptions, fit together like the parts of a well-planned structure to make a body of scientifically obtained data which, taken together, has still greater validity than does any one of its workmanlike parts. The Macmillan Company is now printing the findings in nine scientific volumes and one summary volume. Within a few days these will begin to be made available. The summary volume, in popular language, is by Henry James Forman. Let me summarize in the briefest possible way, just a few of these findings; and state some important conclusions to which, in my own judgment, they point. In due time, as I have already said, the Council itself will make and publish its well-considered conclusions and recommendations.

(1) *Child Receptivity to Movie Ideas.*—Even very young children *take in,* to a remarkable degree, what they see on the screen. Second- and third-grade children (7 to 9 years of age) take in 60 per cent of what a group of young college professors, graduate students, and their wives take in; and the percentage of retention increases rapidly as the children become older. This goes with every class of ideas;

and in the case of both *general information* only incidentally connected with the film story, and the *specific content* of the story—there isn't much difference between the two.

It has been generally supposed that many classes of ideas in the films go quite over the heads of children. Well, they don't; they all register to a significant though not identical degree, even with the second-graders. They remember best such things as sports, crimes, acts of violence, general action, humor—anything that appeals to the emotions. The child who is quite unable to give you a connected story about the film can and does, when appropriate ways of testing are used, show that his intellectual takings-in have been of such inclusive sort and high percentages as I have just stated. Just as the very young child who could not give you a dozen connected sentences, either verbally or on paper, of what he has seen in his own home, has nevertheless acquainted himself there with a thousand folk ways and learned the rudiments of speech; so does he take in and store away the promiscuous contents of the films.

(2) *Remembering.*—Do children remember what they see in the movies, or is it in mind today and gone tomorrow? Here the investigators were slated for much the biggest surprise of the research. The classic investigation previously made to find out how long children remember what they learn from books had shown only about thirty per cent retention after the lapse of a month.

These experiments with the films show that at the end of a month the child recalls nearly, or quite, one hundred per cent of what he knew on the morning after seeing the picture, and not infrequently *more* than one hundred per cent—sometimes as much as one hundred ten per cent. After six weeks, the average retention was still ninety per cent, and after three months practically the same—sometimes even more. The second-grade children beat the professors at remembering.

The only explanation for this lasting impression seems to be that the impact made by the films is of a different sort from that made by books—a dramatic, emotional impression, akin to a vivid experience. You and I, at this moment—even though in middle life or beyond—can recall with vividness and complete detail, certain dramatic occurrences of childhood days; we couldn't forget them if we lived a thousand years. Well, the movie recollections of children are of the same order—visual, dramatic, sometimes poignant *experiences*. As about three thousand persons of varying ages were studied in this memory investigation, by means of twenty thousand testings and eight hundred thirteen thousand items attempted, the findings reported may safely be accepted as established.

(3) *Emotional Stresses.*—In addition to intellects which take in and remember, we also have an equipment of emotions. Any one who has seen mature men and women laughing and weeping over an imaginary screen story does not need other proof that the motion picture is a peculiarly effective instrument of emotional appeal. If, besides, he has been on a Saturday or Sunday afternoon within earshot of a theater that was showing a Western serial to a house

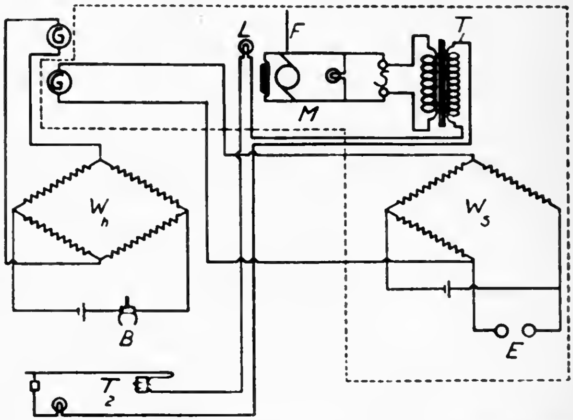

FIG. 1. Schematic arrangement of the psychogalvanometer.

full of children, he will have reason to suspect that children are at least not less affected emotionally than adults.

Well, he will be quite right about it. Exhaustive experiments were made by recognized experts. These were carried on both in the laboratory and under regular theatrical conditions. Children and adults were used, boys and men, girls and women. Some six thousand four hundred readings were made with a psychogalvanometer, two thousand one hundred fifty of them in the movie theater. Heart-beat was also counted by appropriate mechanical devices.

The psychogalvanometer consists of a Wheatstone bridge, W_s (Fig. 1), one arm of which is connected to the electrodes E, into which the child under observation dips the index and third fingers of his left hand. As the balance of the bridge is disturbed, the deflection of the galvanometer G causes a beam of light to oscillate across a roll of photographic film. The adjustable-speed motor M drives the film past the aperture, deriving its power from the service lines S. The transformer, also connected to S, has its secondary connected to the vibrating bar T_2, which interrupts the current through the lamp L, producing a time line on the film in half-seconds. A second galvanometer, G, is connected to another bridge W_h, across which are connected a dry-cell and a pneumocardiograph, B. The latter is a carbon button fastened to a leather strap to be attached to the arm of the child, a coiled spring maintaining the pressure on the skin uniform. The light reflected by the galvanometer connected to W_h impinges upon the same film as that to which the oscillating beam is reflected by the galvanometer connected to W_s. The bridges are used to balance the galvanometers and set their deflections to zero at the beginning of each test.

What was learned? Briefly, that in the case of slapstick stuff, adolescents are roughly under twice as much emotional stress as adults; and young children, between six and eleven years, three times as much. No horror or mystery pictures were used in the experiment, yet, in certain scenes, young children registered from eight to ten times the emotional intensity of the adults. The adult has had experience that enables him to say to himself, "That isn't real; that isn't true." To the child, what he sees is both real and true.

In cases of love scenes and those of suggestive sex, children nine years of age appeared to react with about the same intensiveness as adults. From twelve to fifteen, all children reacted to a still greater degree. During the years following puberty—sixteen to eighteen years of age—the emotional stresses caused by sex pictures are at their maximum—twice as great as is experienced by adults. And that is considerable.

The rate of heart beat was found to be profoundly affected. The experimenters did not venture to use pictures of horror or mystery in any of their experiments with children—only those of quite common variety. Yet, in watching these, the heart beat ran up repeatedly from a normal of seventy-five or eighty to one hundred twenty-five and one hundred forty. Using *The Mysterious Dr. Fu Manchu*, the heart beat of a mature woman, selected for her normal and equable temperament, jumped up frequently to one hundred fifty and one hundred sixty-eight, and on single occasions to one hundred eighty and one hundred ninety-two.

Study of sleep disturbance was also made throughout a two and one-half year period, during which the sleep motility of one hundred seventy boys and girls from six to eighteen years of age was observed. Twenty experimental beds were electrically equipped so that every movement was recorded in a distant room on revolving drums of paper. These beds were occupied on three hundred forty-seven nights—a total of six thousand six hundred fifty child-nights of sleep—that is, for fifty-nine thousand five hundred eighty hours.

The records of movements during every minute of that time were carefully studied. It was found that after attending the "mine run" of movies at a neighboring theater, so situated that the children could be home and in bed by nine o'clock, the average restlessness of girls was increased fourteen per cent and that of boys twenty-six per cent. This restlessness continued for several nights before normal sleep was restored. No mystery or horror pictures were seen during the sleep study. But numerous instances are recorded by other observers in which such films resulted in broken sleep and frightful nightmares for weeks and even months.

There were, as you see, three separate and distinct tests of emotional stresses experienced by children. There were direct objective measurement by means of the psychogalvanometer; indirect objective measurement by observation of the heart-beat; objective measurement of resulting sleep disturbance by the electric hypnograph. These, both separately and collectively, indicate the presence in children of states of high emotional excitement as the result of movie attendance.

The arrangement of the hypnograph is illustrated in Fig. 2. It consists of a bar, *C*, arranged to move up and down, according to the motion of the bed-springs, past brushes *1* and *2*, across which is connected a resistance. Inserted into the bar are inlays, so that the circuit is broken as brush *2* passes from one segment to the next. The operation is as follows: when the child asleep in bed moves, the bar *C* moves up or down; when brush *2* rests on insulation, the current must pass through the shunt resistance, and, as a result, becomes too weak to actuate the electromagnet that produces the record on the tape. When brush *2* rests on conducting material, the resistance is short-circuited, the current is increased, and the electromagnet operates, producing a dip in the otherwise linear record. The tape moves at a constant speed, so that the duration of bodily movements can be determined and studied. The system is so adjusted as to record such movements as those of the forearm when the elbow is bent, or of turning the head, without being so sensitive as to record heart-beat and respiratory movements. The signal light indicates when the bed is unoccupied, or when a fault occurs in the circuit; if the circuit is open, or if the bed is unoccupied and the brushes rest on the bakelite section of bar *C*, the relay operates and the lamp is lighted.

(4) *Attitude Studies*.—These had to do with the effectiveness of motion pictures as an instrument for changing the social attitudes of children in either socially approved or socially disapproved direc-

tions. An attitude is a habitual, or relatively fixed, emotional response to a given idea or situation. It was found that with a single film the attitude could be changed much as the line of mercury is run up or down in a thermometer by the application of heat or cold; and that two or three films of a similar theme were much more effective than one.

Sons of the Gods, a film that shows the Chinese in a favorable light, made a whole townfull of children much more favorable to the Chinese than they were before, while Harold Lloyd's *Welcome Danger*

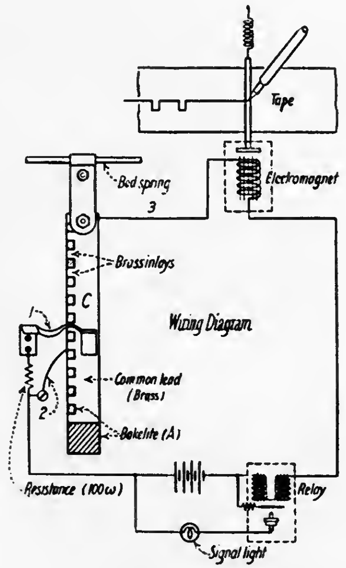

FIG. 2. Schematic arrangement of the hypnograph.

carried Chinese stock, already low, to a still lower level. *Birth of a Nation* resulted disastrously to the standing of the negro among the children of the Illinois town where it was shown. The pro-negro film *Hallelujah,* if it had been used, might have moved popular sentiment toward the negro equally far in the other direction. Extensive tests made with films on different subjects thoroughly established the effectiveness of the film as an instrument of propaganda, even though it was not so intended by the producer.

An effort to measure the *total* influence on children of the hundreds or thousands of films they had seen was not very successful. In view of the conglomerate and conflicting nature of film content it was a heroic undertaking at best. But quite aside from that, the reasons for its comparative failure are easy to see as one looks back upon it. The proposal was to discover and measure the differences between a group of non-movie-going children and an equated group of movie goers. No group of children unaffected by movie attendance and environment could be found. So, a group who went infrequently had to be compared with one that went more often; that was not convincing. In the second place, the technic used was lacking in sensitiveness when compared with the technic used in determining the influence of a single film. Finally, it could not be determined by the technic whether the effects discovered were the result of selection or of movie-going.

The failure of the study does not, of course, cast any doubts on the validity of the results of the other experiments that did successfully measure the changes in attitude caused by single films, or by groups of two or three films of like theme. It has been completely established that the film is a highly effective instrument for changing the social attitudes in great masses of people, and in either socially approved or disapproved directions.

(5) *Behavior.*—The study of behavior patterns and conduct, as molded by the films, was so extensive that I can not attempt here to give even the slightest summary. It shows that the movie theater is an educational system, a school of conduct—it may be desirable conduct, in socially helpful directions; it may be objectionable conduct, leading to vulgarity, delinquency, and crime. What the young child sees on the screen he accepts with much the same trustfulness that the fledgling in the nest displays in accepting food from the mother bird. A South American gentleman of education and culture, who had been several times in the eastern United States, said to a North American friend that in the visit he was then about to make he would land at a California port and see "wildwest." What this gentleman had seen on the screen had had validity for him. How much more does it have validity for the child!

This attitude of trustfulness toward what is seen on the screen is not much shaded until well into high-school years, if even then. Occasionally an entire and startling change in personality takes place in children and youth under the influence of a screen star who is admired. Such influences on conduct reach their maximum effectiveness in the disorganized areas of great cities peopled by the foreign-born and their children. Among such un-Americanized populations the movie is shown to be one of the major resources from which to become acquainted with what they conceive—often mistakenly; sometimes tragically—to be American ideals and ways. What the child sees on the screen he goes out and day-dreams about, imitates in his play, follows in his love-making, becomes a devoted worshipper of the screen stars who guide him into life.

ASSUMPTION OF MOVIE VALUES SUSTAINED BY RESEARCH

The Motion Picture Research Council, as I have already said, set out five years ago in the belief that the new art of the motion picture is, in fact, a highly important tool of civilization. I think we can now agree, brief and inadequate as the foregoing summary has necessarily been, that that assumption has been sustained by the research. *More* than sustained, says the Research Director of the Payne Fund studies in his introduction to the forthcoming summary volume by Forman. "The Motion Picture," he says, in reviewing the evidence, "is powerful to an *unexpected* degree, in affecting the information, attitudes, emotional experience, and conduct patterns of children."

UNOCCUPIED FIELDS FOR MOVIE EXPLOITATION

I assure you that I have introduced only the smallest fraction of the evidence which the research will soon submit for public scrutiny and evaluation. May I not assume, on the basis or evidence already submitted, and on the deliberate judgment of the Research Director just quoted, that we are convinced of this fact, namely, that in the motion picture we are dealing with a sharp-edged tool, which, in the public interest should be used with exceedingly great care and good judgment? If so, it is enough for my present purpose.

These data, scientifically ascertained as they have been, lead me—and I believe that they will lead the public—to the conclusion that there are unoccupied fields for the exploitation of the motion picture of even greater importance than any that has yet been cultivated; that those fields demand immediate attention; and that the scope, the usefulness, the reputation, and the business opportunities of the motion picture will be vastly enlarged thereby.

Where do these unoccupied fields lie? Like the *Acres of Diamonds* in Russel Conway's famous lecture, they are under our very feet.

We have been looking at them and talking about them without really believing that they were there.

(1) *Teaching Pictures.*—It is hardly necessary to say that I do not have in mind mere dry-as-dust facts recorded on films instead of on printed pages—the film has no advantage in a competition of that kind. What I do have in mind is almost a new kind of teaching—the dramatic presentation of truth. There is a growing realization of the fact that in the education of children the school has been addressing itself too exclusively to the intellect and not enough to imagination and emotions. The film is a foreordained instrument with which to re-dress this balance. Can any one see a convincing reason why the dramatic art should not be drawn upon to supplement present methods of instruction?

Again, we all understand that so far the school is creating a bad mess in its attempt to make good citizens. In the light of the moral debacle of the present day, few will be disposed to question that. Has some one said that morality is ethics touched with emotion? Could any teaching medium be more ideally adapted than is the motion picture art for adding emotion to ethical teaching, and thus to emphasize the qualities of citizenship rather than those of grafters, gangsters, and racketeers? I have already pointed out the fact that an effectively made film necessarily becomes an instrument of propaganda, whether or not the producer so intends it. Let us have films for use in the schoolroom intelligently aimed at the production of character. Whether they are made by or for the State—I care not which—we need them, and need them now.

Yet, however important the foregoing considerations may be, the main point of the argument for the film in education is this. From a single viewing, second- and third-grade children gained an increase in knowledge in the field covered by the film ranging from fifteen to twenty-seven per cent; fifth- and sixth-grade children, an increase ranging from three to fifty-six per cent; children in the first two high-school years, an increase ranging from thirteen to sixty-seven per cent. These percentages of knowledge-increase do not appear to be exceptional, but typical and usual. The retention for all those grades over periods of weeks, and even months, is not very much under one hundred per cent; sometimes even more than one hundred per cent. Is it not clear that a teaching medium with which such results are attained can not longer be ignored in the classroom? A glance at the vast organization and equipment used in the text-book trade will show what that means for the film industry.

(2) *Juvenile Entertainment.*—Some attempt—which I refrain from enlarging on here—has been made to have the public believe that child attendance at the movie is a minor and infrequent matter. That is a serious error. The Payne Fund study of child attendance is much the most extensive and careful that has ever been made. It shows that the habit of going to the movies is almost universal among children. Two or three years ago children five to eight years of age were attending, on the average, twenty-two shows a year, seeing therefore about sixty-six films besides trailers. Children from eight to nineteen years of age were attending, on the average, one show a week, seeing 150 films a year. The weekly movie audience of thirteen years and under, in continental United States—calculated on a total weekly attendance, by ages, of 77,000,000—was eleven and a quarter millions. Children and adolescents constitute *thirty-one and one-half* per cent of our total population, but *thirty-seven* per cent of the movie audience. That is in normal neighborhoods. In congested parts of large cities the proportion is very much greater. Child attendance no doubt rises and falls proportionally with the rise and fall of the total motion picture audience. But it is universal, constant, enormous, nation-wide. Children and adolescents *provide* approximately 37 per cent of the total movie audience, however the size of that audience may vary.

While children are entertained by the movies, they do not go to the movies for entertainment in the same sense as do tired and jaded adults. While children pay some attention to the *film story*, it is not in that that their primary interest lies—they may miss the story, or misunderstand it, but at the same time be intensely interested in the film. While children sometimes get a *moral* from the film, it is often overlooked, and may be quite a different moral from that which the adult gets. It is a wholly mistaken idea that a moral at the end of a film will for the child redeem unwholesome subject matter.

The child's primary interest is in the incidents of the film. He goes to the movies to enlarge his world. When he first opened his eyes in infancy it was on a world of which he knew nothing at all. His first interest was in the folk-ways or *mores* of his own home. He wanted to learn what things are, what they are for, how older people do things. A little later, he extended his interest to the neighborhood, but for a good many years he will be neither a moralist nor a philosopher. He is, rather, an observer. He is accumulating the incidents, ideas, and ways of doing things, out of which he will later build a moral (or immoral) system for himself, and a way of life.

In the movies, he finds a new, a larger, an entrancingly interesting world, which he can observe and from which he can learn. "Where should I learn to love, if not from the movies?" asked a young man of college age. He revealed the chief interest that takes children and youth to the movies—to learn a thousand interesting things that neither home, neighborhood, nor school has given them a chance to learn.

In view of this omnivorous interest in the contents of the films, and in view of the findings already reported—that of every category of movie ideas even second-grade children take in on an average 60 per cent of what superior adults take in, and then remember it almost 100 per cent over very long periods—the matter of what they see in the movies becomes one of the very greatest import.

As everybody knows, there are a number of film previewing agencies that pass on the audience-fitness of films for adults, family, adolescents, and young children. Mr. Will Hays' annual report, submitted the 27th of March, 1933, states that of 476 feature pictures previewed during 1932 by seven previewing organizations, 413 (86.7 per cent) were "variously endorsed for family, adult, or child entertainment" by "one or more of these committees."

But manifestly it is more important for the parents of children to know from how many and what percentages of these films approval for child consumption was *withheld* by those previewing committees. Being "variously endorsed for family, adult, or child," to quote Mr. Hays, is not enough. And being approved for one classification—perhaps for adults—does not offset a possibly unanimous disapproval for children.

One of the Committees represents the Women's University Club of Los Angeles, Calif., a constituent member of the Association of University Women. What does that previewing group of university women have to say about the fitness for children of the film output of 1932? They endorse only 19.8 per cent, and to get that high a percentage one has to include films which they pronounce only as "fair," "passable," "probably good," or "probably harmless." The number that receive their enthusiastic endorsement is small indeed.

What, now, do children see when they go to the movies?

(*a*) Love, sex, and crime are the subjects of three-fourths of the feature films. In recent films, romantic love plays a smaller part, and sex and crime a larger part than ten years ago—the world of the movie is largely one of sex and crime.

(*b*) The films appear to be excessively concerned with crime. Crime and violence have lately constituted 40 per cent of film content. Of 115 feature films selected at random "only 26 were free from some sort of crime." In the remaining eighty-nine a total of four hundred forty-nine crimes were depicted, four hundred six being actually committed, and forty-three others attempted. Of these four hundred forty-nine crimes, eighty-three were murders and homicides, fifty-four committed and twenty-nine others attempted; fifty-nine were assaults; thirty-six gambling; twenty-five threatening with weapons; twenty-one kidnappings; twenty carrying concealed weapons; eighteen hold-ups, seventeen successful and one thwarted; twelve verbal threats to kill; eleven fighting with weapons; eleven suicide attempts, nine of them fatal.

(*c*) Life-goals shown in the movies are, on the whole, far from inspiring. In these same one hundred fifteen films, five hundred seventy-four life-goals or ambitions, are set forth. Only nine per cent of them seem to be socially useful. The success striven for is usually personal and selfish. It is very seldom that life-ambitions in the movies are such as we have been accustomed to place before our youth for admiration.

The contents of the films are, you see, a long way from being a cross-section of life. The world of the movies, instead of being better than what we see around us, is worse—*very much* worse. It is decidedly a cock-eyed world that one sees in the movies. Knowing, as the country will now know, how much of this sort of thing the children take in from the films and how tenaciously they remember it; how uncritical they are toward it; how powerfully it stirs their emotions; how it shapes their attitudes and controls their conduct; I can not believe that they will continue to tolerate child attendance at movies of the present kind. Why should they? Why should the motion picture industry want them to?

What the industry wants, I assume, is business. The business of supplying juvenile *books* for children is a distinct, a large, and a reasonably remunerative branch of the publishing trade. It can be made an equally large and remunerative branch of the film trade. Juvenile film classics can be produced at small expense—children like simple rather than elaborate things. Juvenile film classics can be shown from year to year, for there is a large and steady crop of young children. They will earn a profit for as long a period as do the plates of a child's book. The children need and must have films, for, in the expressive words of Dr. Mitchell already quoted, they "meet an intensely felt interest."

(3) *Entertainment for Adults.*—Mr. Terry Ramsaye, a few years ago, estimated the movie-going part of the people of the United States to be 35,000,000—there are, of course "repeaters" that swell the weekly attendance much beyond that figure. Ramsaye may have underestimated the number who had the movie habit in 1925 or 1926—let us assume that it is larger than that now. Let us add 15,000,000 to Ramsaye's estimate of 35,000,000, and call it 50,000,000.* Let us assume also that there are 20,000,000 others too young, too old, or otherwise unable to go. There are still fifty-five millions left who could, but do not go—a pretty sizeable movie audience, larger by five millions than we assume to be going now, even after adding fifteen millions to Ramsaye's estimate.

It is replied that they do not attend when a good picture is offered to them. The adequate reply to that is that a generation has been spent in convincing that intelligent audience that there is little or nothing for them in the movies. Also that a careful study of motion picture advertising made by the Payne Fund shows that the industry is not geared up to appeal to that audience. I can not deal further with this matter, but I am ready to defend the thesis that that intelligent group which has heretofore been ignored or flouted is the largest and most profitable audience in the United States for motion picture entertainment; that it has been alienated; and that it can be won back by making and exhibiting adult drama.

What should be the nature of the adult drama, it has not been a province of the Payne Fund research to determine. Personally, I believe that the industry will have to learn how to deal effectively with other dramatic material than the movie triology of love, sex, and crime. Perhaps it will need to study more assiduously than it has yet done, the nature of the motion picture as an art. I am quite sure that it will have to discard the formula of producing chiefly for the moron and the sophisticate. Whatever may be true of present movie-goers, I am certain that among the fifty-five million non-goers is

* Dr. Howard T. Lewis, Prof. of Marketing in the Graduate School of Business Administration at Harvard University, says in *The Motion Picture Industry* (1933) that the movie-going part of the population in the U. S. is 25 per cent.

a vast potential audience of intelligent and clean-minded persons. Nor do I despair of the present movie audience. Is the motion picture industry interested in this unreached audience of fifty-five millions, largely adults? I think that it should be interested.

(4) *Good-Will.*—There are other unoccupied fields for the films but less likely to return immediate profits. They are, however, of a sort that far-sighted publishing houses are accustomed to cultivate both for their good-will value and for the prospect of ultimate profit as well. The research just completed shows that the film is as effective in imparting information to adults as to children; and that the *field of adult education* in this country appears to be destined to have a rapid development. *Documentary* films such as *Cavalcade* have an important function. In addition, there is the whole *field* of the scientific film.

Surely the movie art has yet many and rich realms to conquer at which as yet it has scarcely more than glanced. It is high time—manifestly—for clear-sighted and high-minded citizens to take council concerning the extension of the usefulness of the motion picture art into these vast unoccupied fields. Scientific research has fully established its claim to equal place at the side of its sister art of printing. This new art belongs to the people—not to any group of men—just as printing, the electric light, the telephone, the radio, the internal combustion engine, the aeroplane, the automobile—products of American genius—belong to the people. No one of them is more basic, and none so replete with social values as is the motion picture art.

I would be the last to say a single word against the showmen whose quick understanding and enterprise gave the engineers their opportunity to perfect the mechanical and technical equipment of the motion picture art, and to present it to their generation complete and adequate for the high services of which we have been speaking. Rather, let my last word be one of regret that others besides showmen have been so slow to see the social values of motion pictures; and my hope and belief that this slowness of vision will soon be amply atoned for. The larger understanding and appreciation of this new and marvelous art that will come as a result of the Payne Fund Research, must surely help powerfully to that end. To that end, also, the Motion Picture Research Council hopes to do its bit in alliance with the many other like-minded groups throughout the country.

NEW MOTION PICTURE APPARATUS

MIRROR TELEPHOTO SYSTEM*

The problem of gaining "distance" in motion picture photography, in contradistinction to that of achieving close-ups, has led to the development of telephoto objectives. When it is required that the focus be increased to a large extent, and if the aperture be kept within the usual range, the length of the required attachment and the diameter of the front lens become rather impracticable.

The Askania Werke, Berlin, has recently developed a mirror telephoto system similar in principle to the mirror system used in astronomical instruments for lengthening the focus. It consists of a large ring mirror perforated at the center, and a small round mirror mounted opposite the larger one. Incoming rays of light from the object being photographed are reflected from the main mirror to the smaller mirror, which, in turn, reflects them to the film in the camera through the hole in the ring mirror. The system is arranged in a tube to be mounted in front of the camera, a small lever extending to the outside of the tube for making fine focal adjustments of the small mirror, which moves axially (See Figs. 1 and 2.)

The distance between the two mirrors is about one-fifth the equivalent focus; the rays are converged after being reflected by both mirrors in the same way as though they had passed through an objective having a focus five times as great as the distance between the two mirrors. The system can be used with motion picture cameras as well as with still cameras.

SPECIAL SPEED CAMERAS*

A high-speed camera has been developed by the Askania Werke, Berlin, using continuously running film, which permits taking photographs on 16-mm. film at the rate of 1000 pictures per second; or 2000 pictures per second if half-sized frames are used. A special disk with 32 lenses is mounted behind the standard objective lens, and is rotated by means of a simple belt drive at a speed of 3750 rpm. The film speed is about 65 feet per second.

For higher speeds a drum camera has been designed, in which a number of pictures are taken on a strip of film 85 or 150 cms. long. The film strip is laid against the inside rim of the drum and pressed firmly against the rim by the centrifugal force developed when the drum is rotated at adjustable speeds up to 6000 rpm.; with the larger drum and half or quarter-size pictures, the speed can be increased to 28,000 pictures per second. Only one objective is used.

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* Described at a meeting of the Chicago section of the S. M. P. E. by H. P. Niemann, American Askania Corp.

A multiple camera, following the original plan of Muybridge in 1877, consists of 12 individual plate cameras mounted on a large disk. Between the objective and the photographic plates a disk having 13 slits rotates at a high speed and acts as a shutter for all 12 cameras. At a shutter speed of 6000 rpm. 14,000 pictures per second are taken. With twice the number of objectives and plates, and the same speed of rotation, the number can be increased to 58,000 pictures per second.

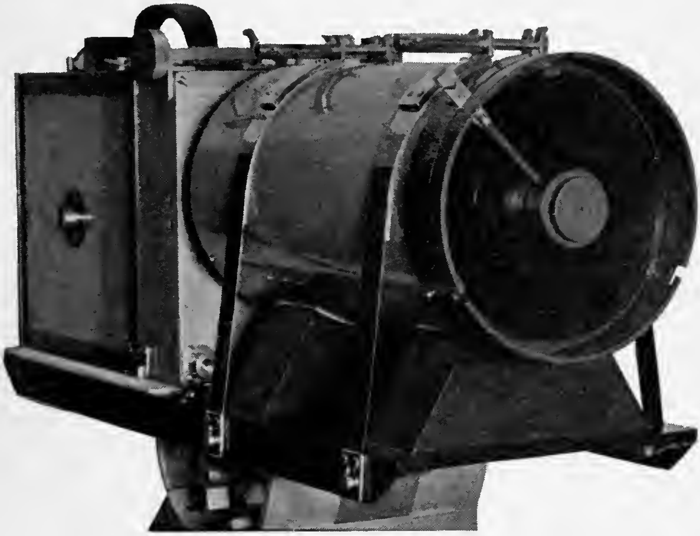

FIG. 1. Exterior view of mirror telephoto system.

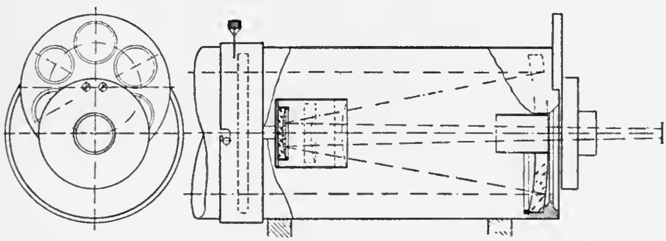

FIG. 2. Schematic arrangement of mirror telephoto system.

AUTOMATIC CHANGE-OVER DEVICE*

The Apasco automatic change-over device represents an effort to substitute a mechanical-electrical device for visual means of depending upon the continuity of motion picture projection from reel to reel. It consists of two magazines 20

* Apasco System, Hollywood, Calif.

inches square and 5 inches deep—one for each projector (Fig. 3). A series of twelve rollers has been arranged to accommodate the 18 feet of film required for the change-over. The film is cut at a point 6 ft. 4 in. from the last scene of the picture; but in the event that the cast of characters occurs at the end of the reel then the film must be cut at that distance from the 19th frame beyond the end of the sound record.

The projectors are threaded in the usual manner; then the slack from the reel is threaded around rollers *1*, *2*, *3*, and *4;* between rollers *5* and *6*, turning roller *5* a complete turn to the left; and thence around rollers *7*, *8*, *9*, *10*, *11*, and *12*, to the reel. Various modifications of the threading are provided for equipment with fast or slow speed pick-up.

As the end of the film leaves the reel, roller *12* drops, starting the oncoming

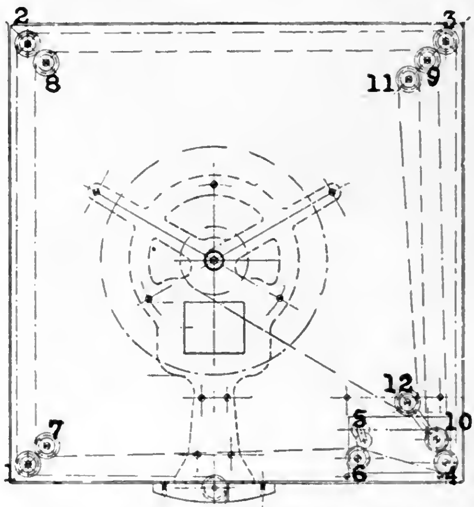

FIG. 3. Automatic change-over device.

machine. Sufficient film has been wound around the rollers to allow the speed of the oncoming machine to attain the required value. As the end of the film leaves roller *6*, roller *5* unwinds to its normal position, making a momentary contact that operates the dousers and changes over the sound by means of a specially constructed double-throw magnetic switch.

THE LUMENARC*

The Lumenarc is a high-intensity, fairly large-current arc discharge occurring between hot cathodes at relatively low tube voltage; in contrast with the conventional low-intensity, low-current neon tube discharges occurring between cold

* Described at a meeting of the West Coast Section of the S. M. P. E. by E. O. Erickson, Electrical Products Corp.

electrodes at high tube voltages. The tubing is larger than neon sign tubing, and the luminous intensity of the positive column of the discharge is much greater.

Lumenarc is available in three colors; red, blue, and green. The red, or orange-red, color is obtained by using neon gas, the blue, by the excitation of mercury vapor in the presence of several of the rare gases, both colors being employed with clear glass tubing. The green color is attained in the same way as the blue, except that an amber or noviol (no-violet transmitting) glass is used. Pyrex is used for tubes of all colors, in diameters of 18 to 25 mm. and lengths up to 12 feet.

The current ranges from 1 to 2 amperes, depending upon the nature of the gaseous path of the discharge, at 600 volts for a 6-ft. length. For indoor use, a gas mixture is used that permits the operation of 6-ft. lengths on commercial 220-volt circuits, or 3-ft. lengths on 110-volt circuits. The tubes are of the

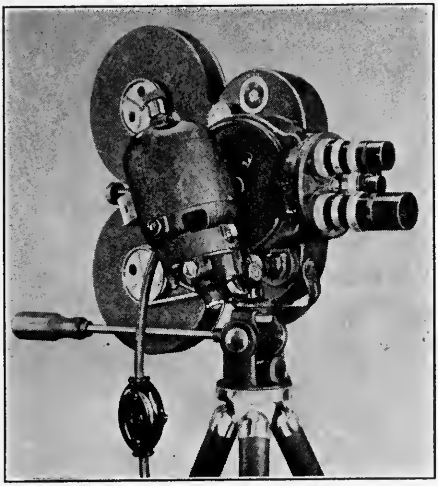

FIG. 4. Semi-professional Filmo camera.

double-cathode type, and high reactance supply circuits are required to stabilize the arc on account of its negative-impedance characteristic.

SEMI-PROFESSIONAL FILMO CAMERA*

The design of this camera (Fig. 4) has been based on that of the Filmo turret-head camera, so that its new features can be applied to the previous models Filmo *70D* and *70DA*. The camera is designed for 16-mm. film, its capacity having been increased by the addition of an external 200-ft. magazine, which does not interfere with alternative use of the camera by the internal loading of

* Bell & Howell Co., Chicago, Ill.

100-ft. spools. It is driven either by a 12-volt or 110-volt synchronous motor, as desired.

An 8 to 1 crank, usable when the motor is removed, permits continuing a scene after the spring motor has run down. The camera governor controls the speed accurately at any desired value between 8 and 64 frames per second, regardless of whether electric motor, hand crank, or spring motor is used.

For lap dissolves and double exposures, the film may be moved backwards by means of the hand crank. A newly designed range-finder is built into the camera door, and subject distances may be quickly and accurately determined. The range-finder is accurate to within one-fourth of an inch, for example, at a distance of three feet. Single-frame exposures may be made by locking the starting button gravity catch out of the operating position.

MICROSCOPIC MOTION PICTURES*

An attachment has been developed for making microscopic motion pictures with the Bell & Howell 16-mm. motion picture camera and any ordinary microscope.

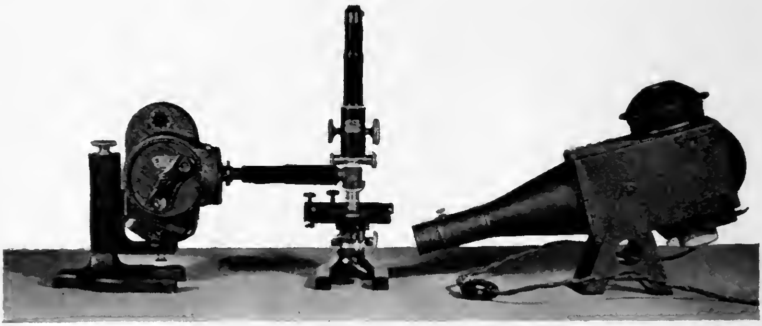

FIG. 5. Equipment for making microscopic motion pictures.

The device consists of a horizontal tube mounting a split-beam prism, which deflects about 90 per cent of the available photographic light in a parallel ray into the standard 1-inch $f/3.5$ camera lens, which remains set at infinity. The remainder of the light passes up the microscope tube, set at 160 mm., over which fits a finder-sleeve fitted with a mask that shows the limits of the field being photographed by the camera. (See Fig. 5.)

The reduced amount of light reaching the eye makes it easy to observe the object that is being photographed and to keep it in sharp focus by means of the fine adjustment of the microscope itself. The third part of the accessory set-up is an adjustable camera stand that raises and lowers the camera to the exact height made necessary by the particular object under the microscope objective. It is heavy enough to hold the camera rigid and parallel to the microscope tube.

* Bell & Howell Co., Chicago, Ill.

THE EYE-EASY EDITOR*

A new type of editing device for 16-mm. film, known as the *Eye-Easy Editor*, projects a large "still" of the frame being inspected, and thereby relieves eye-strain and facilitates editing.

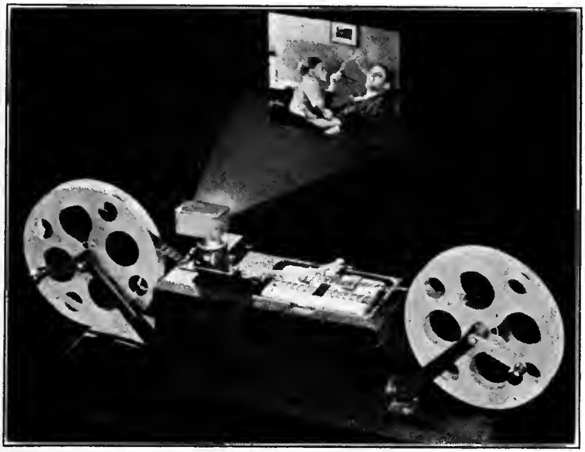

FIG. 6. The "eye-easy" editor.

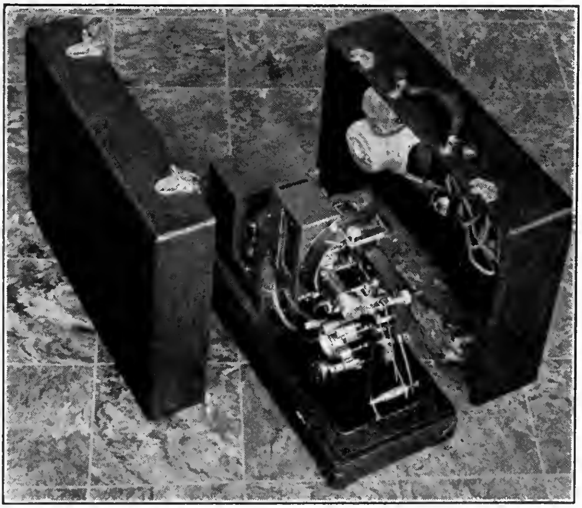

FIG. 7. S-O-F Animatophone.

* Victor Animatograph Corp., Davenport, Iowa.

It is equipped with a special prism and projecting head which permit the picture to be projected any convenient distance and viewed right side up. It is also equipped with a rewind which may be used with or independently of the projector head and the built-in splicer which is also a part of the standard equipment (Fig. 6). An interesting feature of the splicer is that it is heated to a given temperature to insure quick and positive bonding of film.

Available as an extra item is a small film-pack camera which attaches to the editor in place of the prism. The camera is complete with film-pack adapter, ground glass, and camera lens. It is of the fixed exposure type and easy to operate.

ANIMATOPHONE*

Threading and operating the Victor *S-O-F* projector (Fig. 7) are no more complicated than with a silent projector. The sound head, comprised of exciter lamp, lens, sound gate, photoelectric cell, and threading rolls, is side-mounted on the support base of the projector and occupies a space of only $2^1/_2$ by $4^1/_2$ by 6 inches. The amplifier (5 tube) is mounted at the rear of the projector and occupies a space of only 6 by 7 by 8 inches. Auditorium speaker and 50-foot cord are housed in a removable side of the projector carrying case. The entire equipment in carrying case weighs only fifty pounds. Sound volume and picture illumination are sufficient for comparatively large school and church auditoriums.

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* Victor Animatograph Corp., Davenport, Iowa.

SOCIETY ANNOUNCEMENTS

WILLIAM K. L. DICKSON

At the last meeting of the Board of Governors, held at Chicago on Oct. 15, 1933, Mr. William K. L. Dickson, pioneer motion picture engineer who collaborated with Thomas A. Edison in the early work on motion picture projectors, was nominated for the grade of Honorary Membership in the Society of Motion Picture Engineers. On the following day, Oct. 16, 1933, at the opening of the Chicago Convention, the general membership of the Society voted unanimously to approve the nomination made by the Board. The Society felicitates Mr. Dickson, and will send to him shortly a formal certificate of Honorary Membership endorsed by the officers of the Society and the Board of Governors. (A history of Mr. Dickson's work is presented in this issue of the JOURNAL, on page 435.)

NEW YORK SECTION

The results of the recent balloting for officers of the Section for the year Oct. 1, 1933, to Oct. 1, 1934, were as follows:

Chairman, H. G. TASKER
Sec.-Treas., D. E. HYNDMAN (reëlected)
Manager, M. C. BATSEL (reëlected)

The second Manager of the Section is J. L. Spence, whose term expires Oct. 1, 1934.

PACIFIC COAST SECTION

The results of the recent balloting for officers of the Section for the year Oct. 1, 1933, to Oct. 1, 1934, were as follows:

Chairman, E. HUSE (reëlected)
Sec.-Treas., G. F. RACKETT (reëlected)
Manager, W. C. HARCUS

The second Manager of the Section is J. A. Dubray, whose term expires Oct. 1, 1934. The Annual Business Meeting and Dinner of the Section were held on Nov. 7, 1933, at which time the new officers were inducted and a paper was presented on the technical aspects of the Hollywood Planetarium, now being constructed, by Mr. W. Hartman.

CHICAGO SECTION

The results of the recent balloting for officers of the Section for the year Oct. 1, 1933, to Oct. 1, 1934, were as follows:

Chairman, E. COUR
Sec.-Treas., C. H. STONE
Manager, B. E. STECHBART

The second Manager of the Section is O. B. Depue, whose term expires Oct. 1, 1934. A meeting of the Section was held on Nov. 16, 1933, at which time a paper entitled "The Use of the Weston Photographic Exposure Meter in Cinematography" was presented by Mr. P. A. Westburg.

CONSTITUTIONAL AMENDMENTS

There have recently been mailed to the Active members of the Society the following items: (*1*) a pamphlet describing the proposed amendments of the Constitution and By-Laws as presented at the Chicago Convention, Oct. 16–18, 1933; (*2*) a transcript of the discussion that followed the presentation of the proposals at the Convention; (*3*) a copy of the present Constitution and By-Laws; and (*4*) an official ballot for voting on the Constitutional amendment. The proposed amendments of the By-Laws had already been approved by the Society at the Chicago Convention subject to the subsequent approval of the proposed amendments of the Constitution; this balloting, therefore, pertains only to the proposed Constitutional amendments. The Active members are urged to return their ballots to the General Office of the Society as quickly as possible: they must be returned not later than Jan. 14, 1934, in order to be counted.

SOCIETY OF MOTION PICTURE ENGINEERS

REPORT OF THE TREASURER

FOR THE PERIOD OCT. 1, 1932, TO SEPT. 30, 1933

Balance, September 30, 1932			$18,200.86
Receipts during Period			
Dues and Fees			
Dues of active members	$4,712.87		
Dues of associate members	2,980.39		
Dues of sustaining members	2,200.00		
Admission fees	225.00	$10,118.26	
Publication Income			
Journal sales	2,478.60		
Reprints	1,045.79		
Advertising	1,666.81	5,191.20	
Other Income			
Interest on bank balances	589.54		
Certificates, badges and binders	11.40		
Convention receipts	961.00		
Miscellaneous receipts	25.43	1,587.37	16,896.83
			$35,097.69
Disbursements during Period			
General Expenses			
Convention expenses	918.08		
Office rent and expenses	3,052.73		
Salaries	7,100.16		
Officers expenses	283.21		
Committees and Sections	1,061.55		
Contingency	87.35		
Reporting discussions	161.40		
General Society expenses	101.40	12,765.88	
Publication Expenses			
Journal	5,469.18		
Reprints	789.14	6,258.32	19,024.20
Balance, September 30, 1933			$16,073.49
Manufacturers' Trust Co.		$ 1,275.64	
Genesee Valley Trust Co.		5,320.26	
Rochester Savings Bank		7,565.02	
Bowery Savings Bank		1,912.57	$16,073.49

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