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The Society of Motion Picture Engineers

Its Aims and Accomplishments

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

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

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

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

Spring Convention

Hotel Roosevelt, Hollywood, Calif., May 20–24, 1935

The Spring, 1935, Convention will be held at Hollywood, May 20–24, 1935. Headquarters will be at the Hotel Roosevelt. An unusually fine program of technical papers and presentations is being planned by Mr. J. I. Crabtree, *Editorial Vice-President*, and Mr. J. O. Baker, *Chairman*, Papers Committee. All members are urged to bend every effort to attend the Convention.

The Convention Committee, under the leadership of Mr. W. C. Kunzmann, is collaborating with the Board of Managers of the Pacific Coast Section toward making the Convention a most pleasant and profitable one.

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CURRENT DEVELOPMENTS IN PRODUCTION METHODS IN HOLLYWOOD*

H. G. TASKER**

Summary.—*An informal and non-technical commentary on a number of comparatively new aspects of Hollywood production methods. No attempt is made to include all the recent developments in this field, but examples are cited in set construction, lighting, photography, recording, re-recording, and processing.*

Undoubtedly a better title for this paper would be "Seeing Hollywood with a Slide Rule," because most of the material was gathered during recent informal chats with engineering acquaintances in a number of Hollywood studios. I can offer no guarantee that the subject matter represents recent developments, or that the information was given to me in each case by the engineer to whom I ascribe it, and still less assurance that the development, if such it be, was the work of that engineer. In many cases, however, these are the actual facts. I should add also that some of the production methods to be described are now in use in eastern studios as well as in Hollywood.

SCRIPT TIMING

Perhaps we should begin this story at the beginning, when the young scenario, a bit awkward and overgrown, first reaches the studio—and preparations are begun for its production. Even at this early stage in the life of a Hollywood production we find a neat bit of engineering being introduced at RKO under the direction of M. J. Abbott and later adopted by other studios. A group of now experienced script analysts study the proposed story to determine the playing time of each scene of the production and, from the total, determine how long the picture would run. It is at once shortened to proper release length before filming, thus avoiding the common and expensive procedure of throwing away several reels of completed negative in order to boil the picture down to acceptable length.

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* Presented at the Fall, 1934, Meeting at New York, N. Y.

** United Research Corp., Long Island City, N. Y.

They next determine the length of time each set will be occupied, to enable the studio manager to schedule the set construction properly on the various sound stages. It is quite often possible by a deft change of scene or story, to avoid the expense of building a set which might be used for only a half minute or so.

The playing time of each actor is then investigated, with the result that players may be engaged for just the right length of time to complete their parts of the picture. These and other data combine to make possible savings amounting to many thousands of dollars per feature.

LIGHTING

In company with Frank Murphy, genial impressario of lighting, mechanics, and almost everything else at Warner Bros. Burbank Studio, I hiked for several miles through shops and stages, and observed, among other items, how rhubidium mirrors, made by front-surface plating on copper backing, are eliminating the previous high toll for mirror breakage on incandescent studio lights. He showed me also a mile or more of hanging platforms or catwalk structures, on which these lights are mounted. These platforms are obviously direct descendants from the ancient painters' scaffolds, and, like their forebears, are readily adjustable as to height and position, and hence are more convenient than the old semi-permanent hammer-and-nail construction.

THE MECHANIZING TREND

As our journey through the studio continued I could not help being impressed by the trend toward mechanizing almost everything involved in making a motion picture except (I hope) the actors themselves! Camera cranes and camera elevators, both large and small, swing camera men and cameras up and down, left and right, with almost limitless freedom. Motorized sets perform in almost human fashion, their movements synchronized by those interlocking motors that were so long confined to synchronizing sound and picture apparatus. Of the latter, interesting examples are found in the many overgrown clock faces disappearing through the slotted floor in the picture *Dames*, in the symmetrically dividing steps of a musical picture now in production, and in the 16 belt-type tread-mills on which as many horses will race to victory or defeat in another picture soon to be produced. These tread-mills, one of which I saw completed, are some 16 feet long and 4 feet wide, supported at either end by wheels 2 feet in diameter, which will be driven by the interlocked motors. The surface of the tread-mill is made up of 3 by 3 inch slats and is supported along its length by a track and rollers.

The coming of sound sadly impaired the usefulness of the old wind machines, but until recently I have observed no substantial improvement in their construction. New machines are now in evidence with streamlined blades and bullet noses driven by quiet motors up to 25 hp. in size. They can hardly be called silent fans, but are a vast improvement.

Beneath the floor of one large stage, I saw the swimming pool, some 50 by 75 feet in size, which was used in *Footlight Parade.* The sides and bottom of the pool are provided with windows through which lights or cameras are directed, and its water is cleaned by three filters, each some 6 feet in diameter and as many high. The pool has since been used in other pictures.

PHOTOGRAPHY

Al Tondreau, in charge of the camera shop at Warner Bros. Hollywood Studio and originator of many gadgets for the convenient manipulation of cameras, showed me a new arrangement for varying the angle of the finder in accordance with changing focus of the photographic lens so that the field-of-view of the finder always coincides with that of the picture lens in the plane of sharpest focus. Another device was a complete animation camera with many new gimicks and gadgets which was used, not for making Mickey Mouses, but for animation sequences in feature productions.

Fred Jackman, in charge of the special effects department at Warner Bros., introduced me to process photography of the background projection type in actual production. This method seems to have replaced the former color-separation method in Hollywood production, and consists in projecting the background scene upon one side of a translucent screen of any required size while the camera and local action are arranged on the other side. The shutters of projector and camera are synchronized by interlocking motors to avoid flicker. To obtain the needed brilliance of the projected picture, high-density prints are avoided, and the arc lamp current runs as high as 225 amperes, the gate being cooled by a glycerine cell.

This type of process photography is employed for other purposes than to save the railroad fares otherwise necessary to place actors against more or less distant backgrounds. I was much interested to witness a take from *Six Day Bicycle Race,* in which a conversation took place between two riders supposedly tearing around the track at some 20 miles per hour. The difficulty of recording such a conversation on an actual race-track, with both camera and microphones sweeping around the track ahead of the riders, may be easily appreciated. In the process shot the background consisted of a view of the race-track shot wild from the back of a motorcycle leading a group of racers by some 15 or 20 yards. In front of this projected image were the bicycles of the two conversing riders. These were supported on swiveled mounts which were swayed back and forth by stage hands, cleverly representing the movements required by the swirling race-track in the background shot. As the riders pedaled vigorously the front wheels of their bicycles were turned by small motors, and in front of the otherwise stationary riders a microphone was suspended which picked up the conversation between them. In this and many other instances I noted the continuing trend to push complexities of production into technical departments, to the great relief of shooting schedules.

"ONE NIGHT OF LOVE"

Having heard from many sources most interesting comments on the musical quality of Columbia's *One Night of Love,* starring Grace Moore, I searched out Mr. John Lividary, in charge of sound at that studio, and inquired of him as to how it was done. He was most cordial and informative, and at last convinced me that it was not done with mirrors.

In recording the musical scenes two dynamic microphones were devoted to orchestral pick-up, one about 30 feet from the orchestra and a second 90 feet away. The latter was employed to introduce desired amounts of the reverberant quality that may have occasioned much of the popular enthusiasm for the final product. The stage being still too dead, even after introduction of much hard flat surface, a variable low-pass filter was associated with the second mike. Miss Moore desired unusually close association with the orchestra, and so the directional properties of a ribbon microphone, placed in front of Miss Moore and at right angles to most of the orchestra, were employed to provide satisfactory differentiation between voice and accompaniment.

An added chorus called for another ribbon microphone, the bilateral properties of which permitted grouping the male voices on one side and the female voices on the other side in such numbers as would otherwise have required two mikes for such a chorus.

The musical numbers were recorded simultaneously on film and on hill-and-dale disk, of which only the latter were used in the release. The very wide volume-range of the hill-and-dale method enabled successful "canning" of Miss Moore's none too predictable performance, which could thus be re-recorded with care and finesse so as just to reach, but never exceed, the upper volume limit of the release film. It was with some reluctance and only moderate success that the dialog level was lowered and the noise reduction increased to provide still further volume contrast between dialog and Miss Moore's musical numbers.

All in all I am inclined to feel that the very considerable amount of favorable and even astonished comments on the sound quality of the finished picture is a tribute to the skill and the enterprise of an engineering organization that successfully adopted such unusual methods on what was practically their first musical production. One of the most important of these "unusual" methods was quite old in the art; namely, that of first recording on disk and later transferring to the release film.

It would seem that portions, if not all, of the foregoing methods were destined to be adopted by other studios, and I learned from Loren L. Ryder, in charge of the finishing department at Paramount, that hill-and-dale disk recording had been used with excellent results in connection with reels 1 and 7 of their forthcoming picture *Enter Madame*. In their use of hill-and-dale, Paramount has taken advantage of the wide volume-range to equalize the high frequencies upwardly to offset film-transfer losses by an amount not now possible with recordings originally made on film because of increased surface noise.

DISK AND FILM PROCESSING

The successful use of hill-and-dale recording in these examples caused me to inquire of Kenneth Morgan and A. P. Hill, of Electrical Research Products, Inc., as to what had become of the previously too familiar "pops" or "crackles" of the hill-and-dale recordings. For answer they took me to the Hollywood laboratory of the company. There they first let me listen to a number of completely "popless" and very excellent hill-and-dale records, and then showed me the dust-free and air-conditioned portion of the laboratory where the processing of the records is carried on. Complete freedom from dust throughout the operation from sputtering to pressing is said to be the principal key to successful elimination of the "pops."

In the field of film processing I found steps being taken to minimize the directional effects caused by the restraining effects of reaction products of development. To the usual jets are being added mechanical agitators, which are expected to reduce this annoying source of wave-form distortion to negligible proportions.

CELLULOSE DISK PLAYBACK

It is well known that large musical numbers are customarily prescored either on disk or film, and the sound record thus produced is employed to rehearse and finally photograph the movements of the players. Disk records have been most commonly used, but ordinarily involve a time lapse of six hours to two days for the return of a finished record which can be played often enough for these rehearsals. From G. M. Best, of Warner Bros. sound department, I learned of the rapidly growing use of recordings directly cut upon a cellulose disk. Although the material used is somewhat similar to that employed for home recording a few years ago, the method differs essentially in that the record surface is actually cut away as in the former wax-recording, rather than being embossed into a pregrooved blank as in the home-recording method.

Stimulated by the need for more rapid preparation of playback records the development of this type of recording has progressed to the point where the sound quality is very satisfactory and the surface noise substantially lower than in film recordings or the conventional disk. Each record may be played as many as one hundred times, and is used on the set in full sight of the players so that the record may be started, stopped, or re-started at the nod of the director or artist.

These new records are almost instantly available for use. In a typical instance, eight minutes elapsed between the beginning of a playback recording and the time the completed playback record was delivered to the stage and placed in operation.

Cellulose materials available are of great variety: some solid cellulose, some coated on steel or aluminum cores, some clear, some opaque, and, I might add, some good and some bad! In the best instances they have such physical properties that sapphire cutting tools may be employed with a recording life of $2^1/_2$ hours and very excellent results.

All the Busby Berkeley dance numbers, several of which I saw in preparation, are prescored, rehearsed, and photographed with these records directly cut on cellulose disk. A single number is often played as many as two hundred or three hundred times, in which case two or more disks are provided either by direct or re-recording.

SOUND COÖRDINATION

During a conversation with Colonel Nugent H. Slaughter, of Columbia, and Wallace B. Wolfe, of General Service Studio, Inc., the latter raised a technical issue that is an important matter for S.M.P.E. consideration. Mr. Wolfe expressed the opinion that something should be done promptly to bring about coördination of the product of the various studios as to sound quality, particularly with respect to frequency characteristic and output level. In these respects there is still a very wide variation, resulting in much needlessly poor performance in the theater. I was pleased to report to him that the S.M.P.E., through its Sound Committee, L. W. Davee, *Chairman*, was actively studying this problem. A most important initial step, the establishment of a quality yard-stick, has already been undertaken and I have reason to believe that a workable basis for studio coördination will result. The Hollywood section of the Sound Committee will doubtless find studio engineers vitally interested.

FINISHING DEPARTMENT COÖRDINATION

As in most other industries, probably the most interesting department of motion picture production is the assembly plant, where the pieces of the "jig-saw puzzle" are finally fitted together. These operations in most studios are the responsibility of the Sound Department. The manner in which these departments gather together the needed information and material to complete the finished product varies widely from studio to studio, as described by Colonel Slaughter, of Columbia, Loren Ryder, of Paramount, and Chester North, of Warner Brothers, in charge of their respective finishing departments. In some studios the finishing department reads the script and consults with the director early in the course of the production, to determine upon methods of recording or re-recording to obtain the desired results. In others the material is practically completed before the finishing department appears in the picture. In some studios needed accessory sounds or effects are gathered while the production is under way; in others the directors object to this practice and sound-effects are separately created by crews assigned to that duty; and still other studios depend largely upon vast libraries of sound-effects with few additions of new material. In some studios all the sound is re-recorded for the proper blending-in of sounds not present during the original take, or for other modification; while in others as little as half the master negative is derived by re-recording.

The tools of the finishing department have advanced with the art, and notable among them is a device shown to me by William A. Mueller, in charge of sound equipment at Warner Brothers, which automatically regulates music and dialog in certain scenes. This device, popularly known as the "up-and-downer," causes the level of re-recorded music to be automatically lowered word by word in response to dialog so that the latter is clearly heard above the music, while permitting full volume of music to occur at all other times. A very useful example occurs when conversation takes place between a couple on a dance floor.

"MUSICAL MOODS"

As we leave the studio, our Hollywood production safely in the shipping room, it will be interesting to note a bit of "program engineering" which was brought to my attention while visiting the Hollywood Laboratory of Electrical Research Products, Inc., as the guest of Kenneth Morgan and A. P. Hill, of that organization. Noting with some concern the intensely swift tempo of the entire motion picture program as presented in the average theater, Electrical Research Products, Inc., have felt that it might be better balanced and more thoroughly appreciated if some program element could be introduced to slow the pace a bit and relax the audience tension. Accordingly they have created a group of numbers known as "Musical Moods," of which it was my pleasure to observe one, entitled *In a Monastery Garden.* This picture is a delightfully restful yet very interesting combination of good music and beautiful scenes in Technicolor, for which I feel the originators are to be congratulated.

DISCUSSION

MR. RICHARDSON: We often have this situation in the theater: Projection is progressing very well, with the sound at its proper level. Suddenly the sound decreases almost to nothing, or increases to far above its normal level. The dialog may be lost, or the ears of the patrons strained. In either case, it is annoying.

Such a situation is bad enough in two-man projection rooms; but in one-man rooms it is often beyond control, because other duties that can not be neglected keep the projectionist away from his machine. What are the causes of such situations, and how can they be remedied?

MR. TASKER: Certain engineers are inclined to feel that responsibility for most of the trouble that you describe lies at the door of the laboratories, due to inconsistency in processing the film. I am told that upon measuring certain release films that were said to have gone through the printer at uniform light intensity and should also have gone through the developing bath with uniformity, density changes were discovered in the unmodulated portion almost too great to measure. I am told, however, that not all laboratories are guilty in that respect and that there are a number of plants that are doing a really fine job.

MR. EVANS: A year or so ago I proposed a scheme that the Sound Committee thought the Society was hardly in a position to inaugurate. I was not quite convinced that that was a fact.

Two factors determine the reproduction level: One is the percentage of modulation in recording, and the other is the density (or transmission) of the print. It is impossible to maintain the percentage of modulation exactly the same from day to day and under all recording conditions. Variations in recording, however, can be, and are, corrected by re-recording.

It is not possible when printing in large quantities to make the density of all prints exactly the same. It is possible, however, to sort the reels so that the variation in density in any set of reels will cause less variation in level than one fader step on the reproducer. While that has been done, and is being done, it does not seem to me to be a very satisfactory solution of the problem.

My suggestion is that each laboratory determine the correct reproducing level for prints of normal density (transmission) from each negative. With the aid of a density or transmission table the correct reproducing level could then be determined for prints of all other densities from the same negative.

A place should be reserved on the standard Academy leader where the correct reproducing level, in decibels above or below normal, should be stamped. Each theater has (or should have) a normal reproducing level for each machine, and by looking at the level correction stamped on the leader of each reel, the operator could determine how he should set the volume control for that particular reel.

That would not be a difficult or expensive procedure for the laboratories to follow, and it would do much toward standardizing reproduction levels in theaters and make it possible for careful operators to eliminate practically all the level changes that now occur in changing over from one reel to the next.

THE MOTION PICTURE INDUSTRY IN THE SOVIET UNION*

V. I. VERLINSKY**

Summary.—*The growth of the motion picture industry in the Soviet Union during the past ten years is briefly traced; then the troublesome transition period following the advent of sound; and finally the status upon which the present motion picture activities are organized, leading to the production and distribution of highly artistic features, newsreels, scientific films, etc.*

The motion picture industry of the Soviet Union is essentially a growth of the past ten years, but, if I may say so, a substantial and healthy growth. During the czarist régime the industry was insignificant, most of the films being imported from foreign countries. When the Soviet Government came into power in 1917, it found itself in possession of two small studios which represented the entire productive equipment of the country.

Conditions during the next few years were not conducive to the expansion of the industry. The few films made during this period were documentary records of important events during those stormy days, perhaps of no great artistic pretensions, but of increasing historical importance. It was not until the close of the period of civil wars and invasions that the country was in a position to build up the motion picture industry. During the past decade the growth has been rapid. Today there are over ten studios, located in Moscow, Leningrad, Odessa, Kiev, Yalta, and other centers, and the country has become one of the most important world-producers. There are upwards of 30,000 theaters, and the attendance at performances was over 650,000,000 last year. In addition to motion picture schools for the development of its artistic and technical staffs, the industry has its own academy and a special research institute.

The days of the silent pictures brought to the fore some great masters and some great productions, which commanded artistic admiration and respect far beyond the Soviet borders. Eisenstein's

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* Presented at the Fall, 1934, Meeting at New York, N. Y.

** Amkino Corp., New York, N. Y.

Potemkin and Pudovkin's *Mother* were among the pioneers in these great works, and others outstanding in this period included Dovzhenko's *Soil* and *Arsenal* and Pudovkin's *Storm over Asia* and *End of St. Petersburg.*

The transition from silent to sound pictures has been a peculiarly difficult one in the Soviet industry for many reasons, not the least of which is the fact that the Soviet Union is composed of 182 different nationalistic stocks speaking 150 different languages and dialects. Obviously the creation of talking pictures for such a polyglot population presents special problems.

Within a short time after the coming of the talking pictures, the Soviet industry produced a masterpiece in the new form, *The Road to Life,* which won international acclaim. It had no immediate successors of similar caliber. The adjustment to the new medium brought a period of groping and of struggle, and what finally emerged was essentially a collective product, based upon a realism grounded on life within the socialistic structure of the country, and the style of it is termed "socialistic realism." An excellent example of this emergent form was the film *Shame,* made by Ermler and Youtkevitch, which dealt with the life and problems of the Soviet citizens engaged in collective work. The diversity and resourcefulness in subject, treatment, and technic are shown also in the following sound productions: the historical film *Thunderstorm,* taken from Ostrovsky's play and directed by Petrov; *Petersburg Nights,* based on Dostoyevski's novel and directed by Roshal and Stroyeva; *Three Songs about Lenin* by Vertov; the film of the Arctic voyage of the Cheliuskin by Shafran; the first musical jazz comedy by Alexandrov, and the first full-length feature with animated dolls, *Gulliver's Travels.* In addition, the Soviet industry is making its first full-length color film, *Nightingale,* by Ekk, director of the *Road to Life.* The Soviet studios are working beyond their capacity. For 1935, 150 full-length pictures will be produced, in addition to many short subjects and newsreels. The most recent efforts of the Soviet film industry tend toward a mastery of film technic resulting in a finished product of great art. Such films have already been made and have received universal recognition, as was shown at the International Motion Picture Exhibition in Venice, where the Soviet Union was awarded first prize as the producer of the world's most artistic films.

The motion picture industry of the Soviet Union has been developed under the aegis of the Government. Each of the seven constituent

Republics of the Union has its own motion picture industry, operating under the People's Commissariat for Education of the Republic in which it exists. The whole industry is combined in the Motion Picture Trust of the U. S. S. R. It is the problem of each division of the industry to satisfy the public in its territory.

All the silent films produced have to be released with titles in some 150 languages, to accommodate the entire polyglot population of the Soviet Union. The talking pictures are made in ten principal languages, and have superimposed titles for the various minor linguistic groups. In this respect the Soviet industry is faced by a complication that does not affect the industry in the United States.

All the newsreels in the Soviet Union are under the control of the newsreel trust, Soyuzfilmnews, which takes care of the entire territory of the U. S. S. R. Every month Soyuzfilmnews issues three silent newsreels of general interest, three sound newsreels of general interest, two shorts on village life, a special short devoted to children, one on science and mechanics, one on art, and one on national defense. In addition Soyuzfilmnews participates in all scientific expeditions, and in this line has produced films of such expeditions as those of the Sibiryakov and the Cheliuskin and the exploration of the desert Kara-Kum. The trust has over 100 news cameramen scattered over the Soviet Union. The aim of Soyuzfilmnews is to install a system similar to that of the American newsreel companies to enable them to have the newsreels in the theaters 24 hours after being filmed.

All the scientific films are produced by a special scientific trust, which is assisted by the leading scientists, those of the Academy of Science of the U. S. S. R. including the famous physicist Pavlov. In 1933 the trust issued 107 silent short subjects and only three sound; in the first nine months of 1934 there were 177 silent short subjects and 24 sound.

It is only lately that the Soviet Union has begun to develop its own manufacture of raw-stock and equipment. One of the factories operating at the present time delivers tens of millions of film footage per year, but it is unable to meet the demand of the rapidly expanding industry. A new large factory is being built at Kazan, at a cost of 15,000,000 rubles, which will turn out over 300 million feet of raw-stock per year. Under the supervision of two Soviet sound inventors, Professor Chorine (who is a member of the S. M.-P. E.) and Mr. Tager, a large factory and laboratory is being operated which supplies all the sound projectors for the theaters and conducts important research work for improving sound recording. The distribution of the entire film output is in the hands of a special distributing trust, which buys all the products from the producers and distributes them through its branches covering all the theaters of the Soviet Union.

The number of motion picture theaters has shown a fifteen-fold increase during the past nine years. In 1924 there were 1953 theaters; in 1932 there were 29,163. About 2000 are equipped for sound. The following table shows the growth of attendance at motion picture houses.

	1928	1932
In the cities	233,270,000	447,722,000
In the country	6,790,400	188,960,000
Total	240,060,400	636,682,000

The Soviet motion picture industry has a foreign department which takes care of selling Soviet pictures abroad and arranges for the purchase of foreign pictures and equipment. This department has its own representatives in Paris and in New York (Amkino) and has agreements with firms in several foreign countries. The foreign department has recently closed a deal in Paris with one of the major groups of European distributors for exclusive rights of distribution of all Soviet pictures in Europe, with a reciprocal provision for production of European films in the Soviet Union. This mutually beneficial contract may serve as a model for similar distributing arrangements in the United States. Amkino, it may be added, is interested in buying American films suitable for the Soviet market.

The Soviet film industry has the highest admiration for the advanced technic of American production. It offers a market for American machinery and chemicals used in the industry, and has an interest in securing the services of American experts to assist in its technical development. I trust that the friendly ties which exist between the American and the Soviet motion picture industries may continue and grow stronger with the passing years.

REPORT OF THE COMMITTEE ON STANDARDS AND NOMENCLATURE*

The activities of the Standards Committee since the Spring Convention were restricted principally to the completion of the Standards Booklet, which has already been published in the November, 1934, issue of the JOURNAL, and to the consideration of proposals from Europe relating to the standardization of 16-mm. sound-film. It was previously stated[1] that a report from the German Standardizing Committee would receive the attention of the S.M.P.E. Standards Committee and that an official reply would be prepared.

The comments on the German report were forwarded to Mr. M. Flinker, *Chairman*, on June 7, 1934, to which the reply is as follows:

(*I*) With reference to the difference between the German proposals and the American standard regarding the sound-track position relative to the picture, it would seem that the advantages as listed in favor of the German proposals would only result from certain specific mechanical designs, and that exactly the opposite conclusions in regard to advantages can be reached if other specific mechanical designs are contemplated.

The advantages of putting the sound-track on the inside that have been found from actual experience with machines commercially manufactured by three companies in this country, are as follows:

(*1*) Because of the desirability of making the apparatus small and compact, the photoelectric cell can be much more easily shielded electrically and from general illumination quite often coming from a-c. light sources that produce hum.

(*2*) The lamp and optical system are mounted closer to the main supporting frame, assisting in the elimination of vibrations in these parts; vibration of the optical parts being, of course, just as detrimental as vibration of the parts carrying the film.

(*3*) In equipment of this type, experience has shown that the sound optical system is much more easily adjusted and focused by aural methods than visually, so that the ability to observe the light-beam is of little practical consequence.

(*4*) It is quite practicable to design the parts so that cleaning of sound-track guides and optical parts is convenient with the sound-track on either side.

(*5*) The facility with which accumulated dirt or film particles can be removed is entirely dependent upon the design.

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* Presented at the Fall, 1934, Meeting at New York, N. Y.

(6) We do not understand the reason for the statement that with the perforations on the inside, a greater economy in the film movement can be obtained, it being just as important, if not more so, to maintain freedom from eccentricity or inaccuracy of movement of the film at the point of sound reproduction as at the point where the perforations engage the sprocket teeth. If anything, it is preferable to scan the film at a point near the shaft bearings than to have the engaging sprocket teeth at this position.

(7) The American Standards Committee has not concluded that it is important to have the perforations on the inside to facilitate threading and to prevent scratching of the sound-track, because threading is usually done on blank leader where scratching would be of little consequence, and also the threading is no more complicated than it has been for doubly perforated film. Since there are no sprocket teeth adjacent to the sound-track, there would be little likelihood of scratching the sound-track when locating the perforations on the teeth.

There have already been sold in the United States by three manufacturers approximately 1000 projectors. There has been no indication that the sound-track arrangement with respect to the picture is unsatisfactory. Quite an extensive library of films has been established and many publicity and educational pictures have been made.

(II) As regards the position of the emulsion side in the projector, the American Standards Committee is in complete agreement with the German Committee in that it is not possible in every case to establish for all types of film a uniform position of the emulsion side in the projector. The following considerations have governed in considering the necessity for a differential focusing of the sound optical system:

(1) The largest field of use for 16-mm. sound equipment in the American market is believed to be in the use of the equipment as an entertainment medium in the home. The amateur or private user of this equipment has two sources of film:

(a) Film which may be made on an amateur sound recording camera on reversible stock.

(b) Films obtained from a rental library which would be almost universally produced by optical reduction from 35-mm. pictures.

As stated in the German report, pictures made by original exposure, picture and sound on 16-mm. reversal film, should be projected with the emulsion side toward the projection lens.

(2) Reductions from 35-mm. negative stock to 16-mm. film and optical printing from original 16-mm. exposures:

The opinion of the Standards Committee and laboratory technicians consulted is that there is no advantage in optical printing with the two emulsion sides facing one another. There would seem to be no objection to printing through the support, and it is noted that all theater projection is carried out in this manner. Since rental libraries' film will be produced by optical reduction, there is no objection technically to making them conform to the American standard. It is obvious that library films and films produced by the amateur or home movie-maker can be projected with the emulsion toward the screen in both cases and without having to refocus the sound optical system.

(3) Original exposure on color-film according to the Keller-Dorian process:

The American Committee agrees with the German Committee that this film must be projected with the emulsion side toward the light source. This statement also applies to contact prints made from original 16-mm. negatives. Colored pictures by the Keller-Dorian process have not been used extensively in the amateur field, and contact prints very little. Most users of the contact prints use them for some special application in which the machine will be operated almost exclusively for this type of print, and the sound optical system can be focused for such prints without inconvenience or the necessity for refocusing it often.

A note is being added to the drawing of the American standard to the effect that color-film by the Keller-Dorian process, and contact prints made from original 16-mm. negatives, are to be projected with the emulsion toward the light source.

The reply to the German report expressed regret that it had been impossible to reply officially at an earlier date.

On June 22, a meeting was called by the Educational Branch of the League of Nations, of which Dr. DeFeo, General Secretary of the International Educational Cinematographic Institute, was Chairman, at Stresa, Italy, for the purpose of recommending to the League of Nations a standard 16-mm. sound film for use in the educational field. On very short notice, the Society of Motion Picture Engineers was invited to send a representative to the meeting. Dr. Goldsmith, President of the Society, appointed Mr. W. F. Garling, of the London office of an American manufacturer, and a member of the Society, as the S. M. P. E. delegate to the meeting. While this meeting was called for the purpose of recommending to the League of Nations a sound film for educational use, a resolution was passed recommending that a standard be adopted in accordance with the German proposal, and the Society of Motion Picture Engineers was requested to consider changing the American standard to conform to the German proposal. It was stated that unless action were taken by the Society of Motion Picture Engineers within six weeks, it was decided by the Committee meeting at Stresa that the German proposal would become standard in all countries holding membership in the League of Nations for 16-mm. educational films.

When a complete report of the meeting held at Stresa was received by the S. M. P. E., a meeting was called of the Standards Committee to review the minutes of the Stresa meeting, and to give consideration to the proposals made. As a result of the discussion and opinions expressed at the meeting, the Standards Committee Chairman sent a letter report to Dr. Goldsmith. Doctor Goldsmith advised Dr. P. G. Agnew, *Secretary* of the American Standards Association, of the views of the S. M. P. E. Standards Committee by letter of July 30.

Under date of August 10, Dr. Goldsmith officially replied to Dr. DeFeo's letter which advised the S. M. P. E., of the action taken at Stresa. His letter which follows was based on the action taken by the Standards Committee:

In this communication you request that we ratify the agreement reached at Stresa. We regret that we are unable to do so, and desire to place before you the following facts:

It is noted from the communication that the Committee was instructed to limit the discussion to two considerations:

(*1*) They should study the possibility of the use of the sub-standard film for educational films before considering the use of this size for the amateur.

(*2*) They should examine the technical evidence placed before them, and that they put forward a solution of the problem of standardization of sub-standard film for educational use. The Committee was requested to confine their deliberations to this problem, leaving out of their considerations the question of other applications.

A careful review of the minutes of the meeting enclosed with your letter leads to the conclusion that the discussion brought out the fact that there is no basis for a technical choice in regard to the positioning of the sound-track on one side of the picture with respect to the other. There was nothing that was brought out in the discussion, as shown in the minutes, that would seem to justify the resolution in favor of placing the sound-track in accordance with the *DIN* proposal.

The facts are that the German Standards Committee believed that they were adopting the S. M. P. E. standard when their proposed standard was issued. Since the drawing prepared by the German Standards Committee differed from the S. M. P. E. drawing because of a mistake in interpreting the S. M. P. E. drawing, and since the American standard was adopted several months before action was taken by the German Committee and equipment manufactured in America prior to manufacture in other countries, it seems reasonable that these facts should be taken into account.

It is evident that it is unnecessary to establish a new and different standard for the educational work of the League of Nations. A second standard will lead to the usual complications and annoyances that are sure to result if the scope of activity is to be world-wide.

The S. M. P. E. standard is the only one so far as we can determine that is used internationally, and in accordance with which equipment has been manufactured in more than one country. It has been adopted in England by several concerns, and also by one or more in France, and was intended for adoption in Germany, and would have been adopted except for an unfortunate misinterpretation of drawings published in the S. M. P. E. JOURNAL. This standard has been found satisfactory by the concerns having had experience with it. No suggestions which would render it more suitable for the educational field have been received. It is suggested for your application that you give serious consideration to the possibility of adopting the S. M. P. E. standard for the I. C. E.

It is believed that if the Committee had approached the problem from the standpoint of determining whether or not the S. M. P. E. standard was satisfactory, they would have been compelled to find that it was. Such a decision would, apparently, have resulted in an international standard without the necessity for further discussions, and would have fixed a standard for all applications of 16-mm. sound film. As it is, it is believed that this general subject is still one to be acted upon by the official standardizing agencies of each country involved.

The American industry has decided that it is not possible to accept a compromise of the S. M. P. E. standard. We are extremely sorry that two 16-mm. standards will exist, because of the complications and additional expense which may result for those making use of 16-mm. sound film internationally.

With specific reference to your letter of July 17, the friendly spirit of which we appreciate, I may say that we are fully in accord as to the desirability of a single and universally accepted 16-mm. dimensional standard for sound-on-film. Indeed, we believe that the progress of this art and the effectiveness of the application of these films to educational uses in Europe and America may, in large measure, depend upon such general agreement and standardization. It is for this reason that we particularly regret the unacceptable nature of the findings of the Stresa Conference from the viewpoint of the well-established and thoroughly experienced group of American manufacturers of sound-on-film equipment and from the viewpoint of the technical committees of the Society of Motion Picture Engineers. We shall be obliged if you will notify all concerned in the matter that the American motion picture industry and the Society of Motion Picture Engineers are not able to accept the proposals of the Stresa Conference, but will adhere to the present widely used standards of the Society of Motion Picture Engineers.

Dr. DeFeo has replied to Dr. Goldsmith stating his regrets and that he had forwarded a reply to the interested parties, and pointed out the disadvantages of two standards. Dr. Goldsmith has replied to this letter stating that none of the considerations advanced by Dr. DeFeo justified the reconsideration of the subject.

The Standards Committee appreciates the coöperation received from the American Standards Association, the various manufacturing concerns interested in 16-mm. sound equipment and films, and also from Dr. Goldsmith who has devoted considerable time to the necessary correspondence.

M. C. BATSEL, *Chairman*

W. H. CARSON	H. GRIFFIN	C. N. REIFSTECK
E. K. CARVER	A. C. HARDY	H. RUBIN
L. E. CLARK	R. C. HUBBARD	H. B. SANTEE
J. A. DUBRAY	L. A. JONES	V. B. SEASE
P. H. EVANS	N. M. LAPORTE	J. L. SPENCE
R. M. EVANS	C. W. LOOTENS	E. I. SPONABLE
R. E. FARNHAM	D. MACKENZIE	H. M. STOLLER
C. L. FARRAND	G. F. RACKETT	S. K. WOLF
	W. B. RAYTON	

REFERENCE

[1] Report of the Committee on Standards and Nomenclature, *J. Soc. Mot. Pict. Eng.*, **XXXIII** (July, 1934), No. 1, p. 3.

DISCUSSION

PRESIDENT GOLDSMITH: It is desirable to explain briefly two considerations that guided the Society in its correspondence with Dr. L. De Feo (who called the Stresa Conference which resulted in confusion and difficulty for us). The Society does not believe that it can do other than "play fair" with the industry and the workers in this field in the United States; in other words, since 16-mm. sound film was, if not entirely, at least in considerable measure, pioneered in the United States, and since the corresponding standards were thoughtfully and painstakingly worked out, and since the industry adopted those standards after mature consideration, and in good faith built equipment and provided manufacturing facilities for them, and since publication was arranged and approved on the subject of the dimensions, and since millions of feet of film were produced according to those standards, we believed that for no light reason would we be justified in throwing our conclusions overboard and converting into junk valuable projectors and film. We should have to be persuaded by unanswerable technical arguments that there was a sheer and compelling necessity for so doing.

We were, however, not so persuaded; and we have in all sincerity taken a firm stand that we shall not change unless and until some conclusive and persuasive reason for changing shall have been brought to our attention.

In the second place, we objected to educational groups as such, standardizing dimensional standards for film just as we should have objected to industrial groups as such or entertainment groups as such. We felt that it was an absurdity that such specialized standardization should proceed. In other words, if there is to be a 16-mm. sound-film standard for education, it should in our opinion be identical for industrial films or entertainment films. As Mr. Jones has well put it, the whole problem of 16-mm. sound-film standards should be considered at one time.

In the third place, we found certain unusual elements in the entire procedure at Stresa. The International Educational Cinematographic Institute, which Dr. De Feo heads in Rome, is an interesting organization. We do not know its exact relation to the League of Nations. We saw no reason, however, why the Institute should set itself up as an international technical standardizing body, particularly on sound-film dimensional standards. This Society of Motion Picture Engineers has a Standards Committee which is broadly representative. It has prepared standards and these standards will now be handed over to a new Committee, the Sectional Committee on Motion Pictures, which has been authorized by the American Standards Association, under the sponsorship of the Society of Motion Picture Engineers.

I know you will be pleased to hear in that connection that the American Standards Association, which validates and issues American standards, has designated the Society of Motion Picture Engineers as the sponsor of this new Sectional Committee on Motion Pictures, which will handle broadly all branches of motion picture standardization and will have on it full representation of all important individuals, groups, and interests in the motion picture industry who may be interested.

We believe that standards should pass through our Standards Committee to this new Sectional Committee, and after validation they will then become American standards. We believe that those standards should go through the American Standards Association to the International Standards Association if they are to be validated internationally. We are opposed to special procedures whereby particular bodies claiming to cover sections of the motion picture field shall, without our request or authority, and outside the regular procedure described above, allocate to themselves the task of dimensional standardization. It is our present intention to refrain from participation in such activities, since by implication we might otherwise lend a sanction to them.

I am laying these considerations before you in order that the membership of the Society may know what action the Board and the President have taken on your behalf during the past year in connection with this confusing and unfortunate matter. However, so far as our American standards are concerned, we have endeavored to keep our procedure perfectly clear and fair to all concerned.

REPORT OF THE NON-THEATRICAL EQUIPMENT COMMITTEE*

This report is largely supplementary to the general survey presented at the last convention.[1] The intervening period has shown a great increase in the use of sound film for advertising and educational purposes. While a larger portion of the films are on 16-mm., one manufacturer reports a large increase in the use of 35-mm. portable projectors.

As may be gathered from a following section of this report, the use of 16-mm. films, both silent and sound, for advertising purposes received a definite impetus at the World's Fair at Chicago. At least one large motor car manufacturer has allocated the major part of this year's advertising appropriation to talking pictures. The pictures are shown throughout the country on 16-mm. sound outfits, and the success of the undertaking has aroused extreme interest not only among other motor car manufacturers, but among manufacturers in other lines. It seems inevitable that as a result of this successful application, the use of 16-mm. talking films for advertising purposes will spread rapidly abroad.

Impetus has been given to the use of 8-mm. film by the introduction of a powerful gear-driven projector utilizing a 300-watt lamp, enabling brilliant pictures as large as 5 to 7 feet in size to be projected from the small film. Since the last report, 750-watt lamps have become well established for 16-mm. projectors, especially with Kodacolor, and this month a 1000-watt projector was announced as being available soon. It has been announced that at a semi-private showing of this machine a picture 16 × 20 feet in size, of theatrical brilliance, was shown.

From the foregoing it will be seen that 35-mm. films are being used more extensively for non-theatrical purposes; and on the other hand, the newer 16-mm. projectors seem more and more likely to invade the theatrical field—or at least, the semi-theatrical field. This invasion has already taken place to some extent with "sponsored" shows, church and similar organization fund-raising shows, and in the lecture field.

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* Presented at the Fall, 1934, Meeting at New York, N. Y.

A FEW FACTS REGARDING NON-THEATRICAL MOVIES AT THE CENTURY OF PROGRESS EXPOSITION IN CHICAGO

The World's Fair at Chicago was noteworthy in the extensive use of non-theatrical movies for advertising and other purposes.[2] It is also certain that at other fairs of like world-wide importance, non-theatrical movies will play a particularly important part. Every conceivable kind of product was represented among the items explained and *sold* by means of motion pictures—automobiles, pocket flashlights, alloy metals, radios and radio batteries, welding gas, theater carbons, dentistry, scenery, transportation, travel, safety glass for automobiles, glass bottles for commercial and home canning, airplanes and airplane travel, headlamps for automobiles, refrigerators and electric stoves, tires, newspapers, mimeographing machines, toothpaste, gasoline, freight barge transportation, floor scrubbers, college education, fire extinguishers, novel double-keyboard pianos, marvels of curative medicine, the horrors of warfare, mine products, stockings, shoes, paints, carpets, agricultural machinery, tractors and trucks, canned foods of every kind, personal loan services, special educational methods for handicapped children, electric power applications, bread and yeast, cod-liver oil, patent health products, steel, office machines, every type of social service—and, of course, motion pictures to sell motion pictures.

For example, two very noteworthy set-ups at the Fair will be mentioned. One was a model of an ordinary flashlight about twenty times the actual size. In conjunction with this, a continuous 16-mm. projector was aligned to project a picture upon a screen that took the place of the flashlight "lens." The interesting feature of the set-up was that the projector was started by speaking into a microphone. The impulse from the microphone started the projector so that it ran a complete cycle and then stopped.

The other instance involved the use of an automobile operating on rollers. In front of the automobile was a screen on which were projected pictures of other automobiles crossing and recrossing a busy intersection. The driver in the test automobile operated his car, changed gears, put on the brakes, as dictated by the driving conditions shown on the screen. The driver's trials came up thick and fast, requiring quick and correct thinking and acting. After the test the driver was given a certificate rating his ability. As may be appreciated, the test was watched with great interest by large audiences.

At the close of the 1933 Fair questionnaires were circulated among the manufacturers. From these and other data a survey was made from which the following facts were extracted. Seven users of advertising motion pictures said they would use movies for 1934 and assign greater prominence to them; seven were undecided; eight would assign the same space; one would not use them; twenty-six out of thirty declared movies an important help, and fifteen of the twenty-six characterized them as of "primary importance."

The non-theatrical film used at the Fair may be classified roughly as follows:

(*a*) To stop and attract passers-by.

(*b*) Institutional—telling the story of the manufacturer and of how goods are made.

(*c*) Showing products in use, to educate and sell.

(*d*) Instructional—training salesmen.

(There are other uses of films such as training new factory help, micro motion analysis, machine design, *etc.*)

Briefly, the advantages[3] of 16-mm. equipment and film are: low cost, no fire hazard, greater compactness, easier to operate, no expensive operators required, continuous attachments more practicable, lower maintenance cost, and longer film life.

With a few minor exceptions, 16-mm. film was used almost generally at the Fair. The following figures cover the 16-mm. equipment used at the Fair during 1933:

16-mm. silent projectors	61	
sound-on-film projectors	19	
sound-on-disk "	11	
		91
Projectors manually operated	17	
automatic—continuous	74	
		91
Constant operation	51	
Automatic cyclical control	14	
Intermittent schedule	16	
Audience control (by push-button)	10	
		91
Projectors placed out in open	18	
built into display features	17	
" " special cabinets	16	
concealed behind walls	34	
used from proj. booths	6	
		91

Front projection (32)—Direct projection		60
Rear projection (56)—1 Mirror		13
	2 "	16
	3 "	2
		91

About $^1/_3$ of the installations used screens 30″ to 40″
About $^1/_5$ " " " " " 12″ to 20″
About $^1/_7$ " " " " " 20″ to 30″
Mostly 500-watt lamps were used; next in favor was the 400-watt lamp; a few 750-watt units were used.

The final figures are not available for the 1934 Fair, but they are so close to those presented above that the data may be considered quite representative, though a greater number of 750-watt units have been employed. The utmost illumination possible is needed where screen brilliance has to compete with a relatively high level of general illumination. The consistent success of 16-mm. equipment under these most arduous conditions is most encouraging.

REFERENCES

[1] Report of the Non-Theatrical Equipment Committee, *J. Soc. Mot. Pict. Eng.*, **XXIII** (July, 1934), No. 1, p. 9.

[2] "Behind the Scenes at the Century of Progress World's Fair," Bell & Howell Co., Chicago, Ill.

[3] DUBRAY, J. A., AND MITCHELL, R. F.: "A Parallel of Technical Values between 35-Mm. and 16-Mm. Films," *Amer. Soc. Cinemat. Annual*, **2** (1934), p. 329.

A SHORT SELECTED BIBLIOGRAPHY COVERING THE USE OF MOTION PICTURES FOR EDUCATIONAL PURPOSES

The use of motion pictures for educational purposes has been appreciated for a long time, but it has seemed to come rapidly to the fore within the past year or so. Several thousand schools throughout the country are equipped with 16-mm. projectors, both silent and sound, and quite a few universities and other special educational film exchanges are becoming more busily employed in the rigid and efficient exchange of educational subjects. Important international, U. S. Government departmental, and other authoritative investigations being published indicate still more rapid growth in this particular field.

The following comments on some of the literature covering this field have been submitted by various members of the Committee, and are believed to be up-to-date, authoritative, and comprehensive.

Books:

"Motion Pictures in Education in the United States" (*University of Chicago Press*); C. M. Koon, Senior Specialist in Radio and Visual Education, U. S. Office of Education.

A complete and comprehensive survey compiled for the International Congress of Education and Instructional Cinematography at Rome in April, 1934, originally published as Circular No. *130*, of the U. S. Department of the Interior, 1934. The chief headings are:

(1) The Educational Influence of Motion Pictures.
(2) The Motion Picture in the Service of Health and Social Hygiene.
(3) The Motion Picture in Governmental Service.
(4) The Use of Motion Pictures in Vocational Education.
(5) The Motion Picture in International Understanding.
(6) Motion Picture Legislation.
(7) The Technic of Making and Displaying Motion Pictures.
(8) The Systematic Introduction of Motion Pictures in Teaching.
(9) Educational Problems of a General Nature Resulting from the Systematic Introduction of Motion Pictures in Teaching.
(10) General Conclusions.

"The Educational Talking Picture," F. L. Devereux, *University of Chicago Press*, 1933.

This book presents a general view of the field of the educational talking picture. Chapters XI and XII discuss school building requirements for audio-visual instruction, and types of equipment and standards for selecting them. These chapters include such topics as "Past Provisions Made in School Buildings for Visual Education Equipment"; "The Physical Provisions Required for Audio-visual Teaching"; "The Audio-Visual Studio—Its Use, Its Location, and Its Desirable Characteristics in Various Types of School Organization"; "Detailed Standards for Planning and Equipping the Auditorium"; "Detailed Standards for Planning and Equipping the Music Unit"; "Provisions for Pupils with Hearing Difficulties"; "Acoustics in School Buildings"; "The Ventilating System"; "Relative Loudness"; and the like. Chapter XII presents the general standards for selecting equipment of various types.

"Measuring the Effectiveness of Talking Pictures as Teaching Aids"; V. C. Arnspiger, Teachers College, Columbia University, New York, 1933.

Special attention might be called to Chapter VI, in which a rather objective analysis of the effectiveness of certain technical elements of sound-film composition is made. Attention is called also to the data regarding focal length of scenes; the quality of lighting in the films; speech, other sounds, and picture; repetition and integration of audio-visual elements. Attention might well be given to Chapter VIII, in which problems for future research are discussed. In this short chapter emphasis is placed upon the possibility of extending the range of the present curriculum by utilizing the sound motion picture as the most recent device for presenting subject matter.

"Visual Instruction"; McClusky, *et al.*, *Motion Picture Producers & Distributors of America, Inc.*, New York, N. Y.

"Sound Pictures as a Factor in Education"; *Fox Film Corp.*, New York, N. Y., 1931.

"Motion Pictures in the Classroom"; B. D. Wood and F. N. Freeman, *Riverside Press*, New York, N. Y., 1929.

"Visual Instruction in the Public Schools"; A. V. Dorris, *Ginn & Co.*, New York, N. Y., 1928.

"Motion Pictures for Different School Grades—A Study of Screen Preferences"; M. A. Abbott, Teachers College, *Columbia University*, New York, N. Y., 1928.

"Visual Fatigue of Motion Pictures"; A. Singer, *Amusement Age Pub. Co.*, New York, N. Y., 1933.

"Motion Pictures for Instruction"; A. P. Hollis, *The Century Co.*, New York, N. Y., 1926.

Periodicals:

The Educational Screen (monthly); Chicago, Ill.

International Review of Educational Cinematography (monthly); Rome, Italy.

As an example, the January, 1934, issue contains the following articles:

"Problems Involved in the Development of Educational Talking Pictures"; N. L. Engelhardt, Teachers College, Columbia University, New York.

"The Use of Taking Pictures in the Elementary School"; J. A. Brill, Erpi Picture Consultants, Inc., New York.

"Sound Pictures as Factor in Class Size"; A. J. Stoddard, Superintendent of Schools, Providence, R. I.

"Will Sound Pictures Remake the Curriculum?" P. R. Mort, Teachers College, Columbia University.

(The International Education Institute is conducting an international symposium on the use of motion pictures for educational purposes. For two years they have been compiling the cinematographic encyclopedia, which they hope to complete soon.)

R. F. MITCHELL, *Chairman*

H. A. ANDERS	W. B. COOK	H. C. HOLSLAG
V. C. ARNSPIGER	H. T. COWLING	A. SHAPIRO
D. BEAN	H. DEVRY	C. TUTTLE
E. W. BEGGS	R. E. FARNHAM	A. F. VICTOR
	H. GRIFFIN	

REPORT OF THE COLOR COMMITTEE*

For some months past, the Color Committee has been engaged in preparing a glossary of technical and proprietary terms used in color cinematography. At first thought it may appear that such a contribution might be a waste of time and effort, and that the attention of the Committee might more profitably have been turned to something more creative. There are, however, certain factors that raise the labors of the Committee out of the category of the inconsequential.

The various arts and sciences associated with the uses of color are at variance in their nomenclature, and in the language of the public at large discrepancies are even more marked. The very idea of color is so ill-defined in the minds of most persons that the inconsistencies of use of the term in ordinary conversation are sometimes absurd. We may imagine that, at the present moment, one of the lady guests of the Convention is asking a friend, "Are you wearing a colored gown to the banquet tonight?" The friend, thinking of her black dress or her white dress, answers, "No." But had she been asked, "What color dress are you wearing tonight?" the answer would have been "black" or "white" without hesitation.

At the present time, other agencies are working to standardize the nomenclature of color. The Colorimetry Committee of the Optical Society of America prepared for the fall meeting at Washington a report modifying some of the definitions of its previous report of 1925. The U. S. Bureau of Standards likewise has recently put forward a proposal to change color nomenclature. It seems fitting, therefore, that the Society of Motion Picture Engineers, which is concerned with color both as a science and an art, should propose for general acceptance some of the special terminology of its trade.

The Committee has, accordingly, compiled a glossary of some two hundred terms in common use in the industry. This glossary will be presented in the pages of a forthcoming issue of the JOURNAL.

The list of terms treated by the Committee has been gathered from many sources: Our own JOURNAL, books on color photography, and the colorimetry reports of the Optical Society have been consulted,

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* Presented at the Fall, 1934, Meeting at New York, N. Y.

and supplementary lists have been received from various persons engaged in color cinematography. Some processes of color cinematography that appear to be of no great commercial importance have been omitted for the sake of brevity. Technical terms for which satisfactory definitions are easily found in text-books of chemistry and optics are included in only a few instances.

The last glossary published by the Society—that of the Standards Committee in 1931—contained relatively few of the terms of our present effort. We wish, therefore, to call the attention of the Committee on Standards and Nomenclature to our listing, and to suggest that many of the terms contained therein should be incorporated into any forthcoming glossary to be subjected to the processes of standardization.

C. TUTTLE, *Vice-Chairman*

P. D. BREWSTER R. M. EVANS J. F. KIENNINGER

L. A. JONES

REPORT OF THE HISTORICAL AND MUSEUM COMMITTEE*

The work of the Historical Committee has progressed with good results. Besides many new accessions received for the collection at the Los Angeles Museum and the reconditioning of apparatus received, a number of biographies and autobiographies are in the course of preparation.

These biographies will describe the experiences of the more notable pioneers in their achievement of the motion picture. Their successes and failures in groping toward the "living picture" will be set down in an honest record of their accomplishments. So much has been written about the activities of the pioneers of the cinematograph from hearsay and memory, without foundation of fact, that it was thought desirable to create accurate accounts of the men who made the motion picture a possibility. The phenomenal growth of the art as well as the commercial aspects of the motion picture had done much to keep alive a great number of stories and traditions that credited the invention of many cinematographic devices to the wrong persons. In all fairness this should be righted while it is still possible to do so.

Among the more valuable accessions to the collection is an accumulation of U. S. Patent Papers, brought together by the late Jean A. LeRoy and presented to the Society for the historical display at the Los Angeles Museum by Mrs. Jean A. LeRoy. Among the patent papers represented are those relating to motion picture devices from 1860 to the present. The collection is an extensive representation of the patent literature, particularly of the years *circa* 1900. The last fifteen years are not so complete. A number of the patent papers are being placed on exhibition in swinging frames in the Motion Picture Gallery at the Los Angeles Museum.

Another accession to the exhibit is an Edison Exhibition Model Projector of the type introduced about 1901. It is complete with an arc light, double lenses for stereo projection, lantern slide arrangement and various devices used by a projectionist of the time. The projector was semi-portable and was contained in a wooden box so

* Presented at the Fall, 1934, Meeting at New York, N. Y.

that the whole equipment could be carried about by the travelling showman of that period when the motion picture was shown in vacant stores as a vaudeville act, or as a feature of a travelling carnival, and at fairs. The showman, who was also, as a rule, the projectionist, carried the wooden box with the projector, a wooden base and iron legs, the lamp house with either arc light or lime-light, and the films and other incidentals.

Harrison and Harrison, the filter manufacturers, presented a set of filters, which are being displayed so as to show the visual effects of the various filters. Besides the color-absorption filters, diffusing filters, filters used for producing night effects, and monochromatic viewing filters are shown. The filters will be displayed in front of a suitably colored lithograph so that comparative effects may be seen.

C. R. Hanna, of the Westinghouse Electric & Manufacturing Company, presented a ground noise reduction device used in sound recording circuits, and Electrical Research Products, Inc., loaned a sound recorder and various slits, which have been placed on display.

Among the more interesting loan items is a magic lantern with hand-painted slides of about one hundred years ago. The slides were panoramic views, and as the lantern used only a candle for illumination, only a small portion of each slide could be shown at a time as it was slid through the lantern. One interesting slide in the collection is a panoramic painting of the *Tom Thumb*, one of the first steam trains on the Baltimore and Ohio Line of 1829–30. This lantern was loaned by A. Falvy through the courtesy of Victor Merlo.

Mrs. J. Trebaol loaned a *praxinoscope*, made by Emile Reynaud in 1877. It consists of a drum mounted upon a stand for revolving. Instead of slits through which the pictures were viewed as in the "wheel of life," the device carried a series of mirrors arranged as façets at the center of the drum. When the drum was revolved, the various mirrors reflected the different progressive poses. The praxinoscope is believed to be the first device that showed progressive movement in its drawings. In the other hand-drawings and chronophotographic devices, a horse, for example, would appear to be running upon a continuous belt in front of a fixed portion of the background, whereas in the Reynaud drawings the movement of the subjects was progressive. A man riding a horse, for instance, appeared to be going somewhere. Ransom Matthews, of the Los Angeles Museum, is making a model of the praxinoscope complete in every detail as compared with the original, so that if the original should be recalled from loan, an accurate model will be available.

A large collection of hand-painted travel and astronomical slides of about 1825–35 has been located and purchased for the exhibition. They are beautifully painted, and each one is a masterpiece in craftsmanship and detail. They are circular and vary in size from three inches in diameter or less. Each slide glass is mounted in a wooden frame. Among the astronomical slides is one entitled *A diagram that Proves the Rotundity of the World*, which consists of a painting of the earth on one glass, and of a ship on a second glass. The picture of the ship is in contact with the picture of the earth, the path of the ship coinciding with the circumference of the earth. During projection, the ship is made to move around the earth by a gear arrangement, demonstrating the "rotundity of the world."

A number of collections of photographs, posters, colored lithographs, autographed photographs, props used in making pictures, and apparatus have been presented. The collections are too numerous to mention, but their receipt has been appreciated, and they will form a valuable record for posterity.

Persons having apparatus, literature, books, newspaper clippings, or other material portraying the history of the motion picture should communicate with the chairman of the Historical and Museum Committee. It must be remembered that many valuable collections requiring years to bring together have been scattered or destroyed after the demise of, or loss of interest by, the collector. Such collections must be preserved, and this Committee will assure the proper deposition of whatever is offered so that the material will be preserved for posterity.

A record of the present as well as of the past is being preserved. A number of publishers of magazines and periodicals have placed the Museum on their mailing lists. Among them are *The Motion Picture Daily*, *Hollywood Reporter*, *American Cinematographer*, *International Photographer*, and others.

Appreciation is extended to Sanford H. Place, who spent much time in reconditioning and overhauling historic apparatus at the Los Angeles Museum, Dick Rickard, of the Walt Disney Productions, Kenneth MacKaig, of United Artists, Miss Marcella Peterson, Fred Archer, Frances Christeson, Coleman Sellers, 3rd, Leon Gaumont, Louis Lumière, Wallace Clendenin, and many, many others.

W. E. THEISEN, *Chairman*

G. A. CHAMBERS	W. V. D. KELLEY
O. B. DEPUE	G. E. MATTHEWS
J. A. DUBRAY	T. RAMSAYE

DISCUSSION

MR. CRABTREE: I hope that any of the members who have items suitable for the museum will not hesitate to send them to Mr. Theisen, because at last we have found a suitable repository for such historical material. For many years we have been talking about gathering historical equipment and made an attempt to put some in the Smithsonian Institute in Washington and in the Museum of Science and Industry in New York, but, unfortunately, we were not able to find some one in the East with sufficient interest in the work. Although I should like to see the establishment of a repository in the East, in the absence of some one who, like Mr. Theisen, is prepared to make this a labor of love, I think we should give our entire support to the Los Angeles Museum.

MR. RICHARDSON: Some time ago I turned over to the Society a very valuable Edison spool-bank projector in perfect condition, together with a reel of the original film and various other items. What has been done with them?

MR. KALLMAN: We have the projector and film at the Museum of Science and Industry. We had planned to have a motion picture exhibit, but conditions at the museum prohibited our putting them on display immediately. They are in good order.

MR. RICHARDSON: I believe, Mr. Chairman, we can't conduct two exhibits. The material should be sent to Los Angeles.

REPORT OF THE PROJECTION PRACTICE COMMITTEE*

Inadequate screen illumination has long been a problem of major importance in the projection field generally. Satisfactory screen illumination has been confined mainly to the larger theaters, the smaller theaters being either unable or unwilling to make the expenditure necessary to improve the quality of screen light.

Exhibitors have recognized the need for more and better light on the screen; and they have recognized, too, the fact that the problem was more economic than technical. The situation, already serious, promised to become acute with the increasing use of color in motion pictures.

Happily, the solution of the problem appears to be at hand, in the form of a new type d-c. projection arc which not only materially improves screen illumination but also satisfies the economic urgencies of the situation. This arc, using the new copper-coated *Suprex* carbons, is the topic of this report, the importance of which to the exhibition field is emphasized by the Committee.

This report is based upon an extensive series of tests of the new arc made under actual operating conditions. Through the courtesy of various manufacturers there was made available to the Committee a group of motor-generators, both single- and three-phase rectifiers, and arc lamps of practically all the new types.

The Committee desired to obtain the answers to the following questions:

(1) What is the carbon consumption per hour for values of current from 40 to 50 amperes, using the 6- and 7-mm. combination; and from 50 to 65 amperes using the 6.5- and 8-mm. combination?

(2) What is the ratio of burning of the positive and the negative carbons at different current densities?

(3) What effect does the arc gap exert upon the burning rate of either carbon; and what arc gap affords the best results?

(4) Is there a difference in arc voltage with different sources of supply, such as rectifiers and generators?

(5) Is there any difference in the quality of the projected light when power is derived from either rectifiers or generators?

(6) What increase of light occurs with an increase of carbon current density?

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* Presented at the Fall, 1934, Meeting at New York, N. Y.

(7) How do the various lamps now available compare as to light intensity, for a given current?

(8) What is the efficiency and power-factor of the several power sources used with the new lamps?

(9) What can be done to protect the reflector against pitting?

(10) What are the over-all advantages of this new type of light source?

RESULTS OF TESTS

(1) Tests were made to determine first the rate of carbon consumption for various current densities, the arc gap being maintained constant—that is, at from $^5/_{16}$ to $^{11}/_{32}$ inch; using as sources of current a polyphase rectifier, a single-phase rectifier, a motor-generator, and the regular d-c. power line.

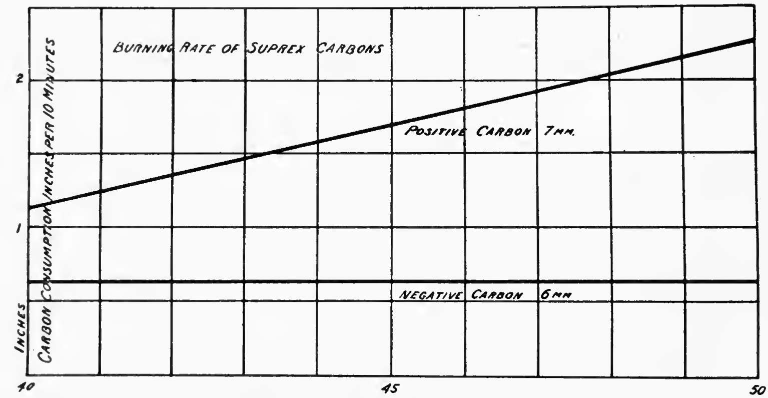

FIG. 1. Rate of consumption of Suprex carbons; 6-mm. negative and 7-mm. positive combination.

The tests (Fig. 1) indicated that the consumption of the 6-mm. negative carbon was constant for currents between 40 and 50 amperes, being $3^3/_4$ inches per hour or $^5/_8$ inch for each ten minutes. The burning rate of the positive carbon, however, varied with the current. For 40 amperes, the rate was $6^3/_4$ inches per hour, or $1^1/_8$ inches for each ten minutes; for 45 amperes, $10^1/_8$ inches per hour, or $1^{11}/_{16}$ inches for each ten minutes; and for 50 amperes, $13^1/_2$ inches per hour, or $2^1/_4$ inches for each ten minutes.

Similar tests were made using the 6.5- and 8-mm. carbon trim at currents from 50 to 65 amperes, with the following results:

For 50 to 57 amperes, the 6.5-mm. negative carbon burned at the rate of $3^3/_4$ inches per hour, or $^5/_8$ inch for each ten minutes—which is identical to the burning rate of the 6-mm. negative at 40 to 50 amperes. However, at 65 amperes, the 6.5-mm. negative carbon burned at the rate of $4^1/_2$ inches per hour, or $^3/_4$ inch for each ten minutes.

The consumption of the 8-mm. positive carbon (Fig. 2) at 50 amperes was 6 inches per hour, or $^{15}/_{16}$ inch in ten minutes; at 55 amperes, $8^1/_4$ inches per hour, or $1^3/_8$ inches in ten minutes; at 60 amperes, $10^1/_2$ inches per hour, or $1^3/_4$ inches in ten minutes; and at 65 amperes, $13^1/_2$ inches per hour, or $2^1/_4$ inches in ten minutes.

(2) The burning ratio between the positive and negative carbons of

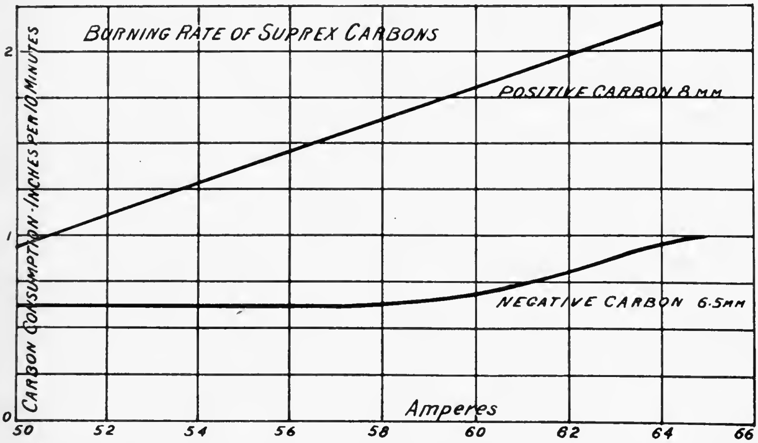

FIG. 2. Rate of consumption of Suprex carbons; 6.5-mm. negative and 8-mm. positive combination.

the 6- and 7-mm. trim at 40 amperes is 1.8 to 1; at 45 amperes, 2.7 to 1; and at 50 amperes, 3.6 to 1.

With the 6.5- and 8-mm. trim the burning ratio at 50 amperes is 1.6 to 1; at 55 amperes, 2.2 to 1; at 60 amperes, 2.6 to 1; and at 65 amperes, 3 to 1.

The tests definitely established that the burning time and the ratio of consumption of the positive and negative carbons do not change whether the arc current be supplied by a single-phase rectifier, a polyphase rectifier, or a motor-generator set, and that the design of the lamp also has no effect upon the aforementioned characteristics.

The rate of consumption of the positive carbon is greatly affected by the current density; whereas the burning rate of the 6-mm. negative carbon is affected little if any by the current density between the limits tested. However, the burning rate of the 6.5-mm. negative carbon varied slightly with the current density, particularly for currents greater than 55 amperes.

Although the operating limits of these carbon trims are generally understood to be 40 to 50 amperes for the 6- and 7-mm. trim, and 50 to 65 amperes for the 6.5- and 8-mm. trim, the tests conducted by the Committee established definitely that best results are achieved when the trims are operated within the upper limits of their rated capacities.

(3) Tests were conducted to determine the effect of the arc-gap upon the burning time and the burning ratio of the carbons. If the arc gap is increased, the current automatically decreases and the positive carbon then burns at a slightly lower rate. Likewise, if the arc gap be decreased, the arc current increases and the positive carbon burns faster.

It is apparent, then, that since a change of current changes materially the burning time of the positive carbon, and only slightly affects the burning rate of the negative, any change of arc gap will change the current and thus the ratio of burning of the positive and negative. This change of ratio tends to move the arc out of focus with the mirror. It is of the utmost importance, therefore, that the arc control mechanism be sensitive enough to hold the arc-gap constant ($^5/_{16}$ to $^{11}/_{32}$ inch), and that the current also be held constant if frequent focusing of the arc is to be avoided.

Lamps having individual feed adjustments for positive and negative carbons, thus allowing the burning ratio to be changed, permit adjustment to any desired current density within the limits of the rating of the carbons. However, lamps having single-feed screws are necessarily limited in operation to the current density, or burning ratio, for which the screw is designed. Deviation from the given ratio will entail constant attention and frequent manual adjustment.

(4) In testing the 6- and 7-mm. carbon combination to determine what differences if any occurred in the voltage across the arc when various sources of power were used, single- and three-phase rectifiers and motor-generators were used. In each test the same lamp and the same carbons were used, and the same arc-gap was maintained under identical conditions. The results obtained are shown in Table I. It will be noted that there is a difference of $3^1/_2$ to 6 volts across the arc in the case of the single-phase rectifier, and a difference of $^1/_2$ volt in the case of the three-phase rectifier, as compared with the motor-generator. This difference is due to the a-c. component of the

TABLE I

Arc Voltages and Currents for 7-Mm. Pos. and 6-Mm. Neg. Suprex Carbons

(Source of Direct Current)	(Amperes)	(Volts)
Three-PhaseRectifier	40	30
Single-Phase Rectifier	40	27
M-G Set	40	30.5
Three-Phase Rectifier	45	32.5
Single-Phase Rectifier	45	28
M-G Set	45	33
Three-Phase Rectifier	50	34.5
Single-Phase Rectifier	50	29
M-G Set	50	35

rectified current. The d-c. voltmeter records only the d-c. value, and since the a-c. component is not registered, it is apparent that the greater the a-c. component, the greater will be the difference of voltage as measured with a d-c. voltmeter. Similar tests were made with the 6.5- and 8-mm. carbon trim, with results as shown in Table II.

TABLE II

Arc Voltages and Currents for 8-Mm. Pos. and 6.5-Mm. Neg. Suprex Carbons

(Source of Direct Current)	(Amperes)	(Volts)
Three-Phase Rectifier	50	30.5
Single-Phase Rectifier	50	27
M-G Set	50	31
Three-Phase Rectifier	55	32.5
Single-Phase Rectifier	55	28
M-G Set	55	33
Three-Phase Rectifier	60	34.5
Single-Phase Rectifier	60	29
M-G Set	60	35
Three-Phase Rectifier	65	38.5
Single-Phase Rectifier	65	..
M-G Set	65	39

The tests indicate that the d-c. arc voltage for a given arc-gap depends upon the source of the current; but with the 6- and 7-mm. carbons, the voltage will range between 30 volts at 40 amperes and 35 volts at 50 amperes; and in the case of the 6.5- and 8-mm. combination, between 30 volts at 50 amperes and 39 volts at 65 amperes—the figures for both trims being based upon a current supply of acceptable smoothness.

(5) Single-phase rectifiers do not deliver current of the same smoothness as do three-phase rectifiers. The three-phase full-wave rectifier fills in with overlapping waves the gaps that exist when a single-phase rectifier is used (Fig. 3). Tests were made to determine the visual effect of an alternating component upon the projected light under normal operating conditions and with the shutter running at the standard speed of 90 feet a minute. With single-phase rectifiers the flicker was easily noticeable; whereas with both three-phase rectifiers and motor-generators there was no discernible flicker. These tests indicated that good screen results were not attainable with single-phase rectifiers. Both the three-phase rectifiers and the motor-generators delivered satisfactory results.

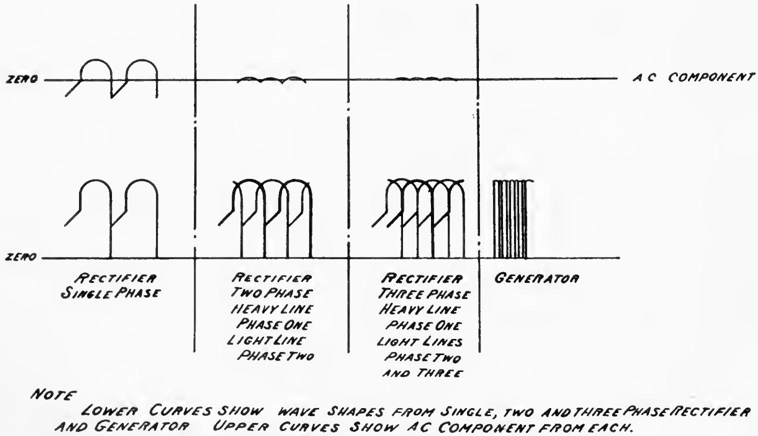

FIG. 3. Illustrating how the three-phase full-wave rectifier fills in the gaps in the current wave that exist when a single-phase rectifier is used.

(6) To determine the change of light intensity for various values of current through the arc, the same optical system and the same measuring instruments were used throughout, and all tests were made with the shutter running. The results are therefore comparative, and are not computed in lumens per square foot (Fig. 4).

Burning the 6- and 7-mm. combination at 42 amperes, the arc consumed 1290 watts and the maximum average light intensity was 54 units. At 45 amperes the arc consumed 1440 watts, and the light intensity was 65 units. Thus, an increase of 11 per cent in wattage afforded an increase of 20 per cent in light. Burning the same combination at 50 amperes, the arc consumed 1700 watts, and the maximum average light intensity was 80 units. Thus, an increase in wattage of 32 per cent gave an increase of 48 per cent in light. This over-all increase was thus accomplished with a 19 per cent increase in current, or a 32 per cent increase in arc wattage (Fig. 5).

When the 6.5- and 8-mm. trim was burned at 50 amperes, the arc consumed 1540 watts, and the maximum average light intensity was 70 units. At 55 amperes the arc consumed 1800 watts, and the

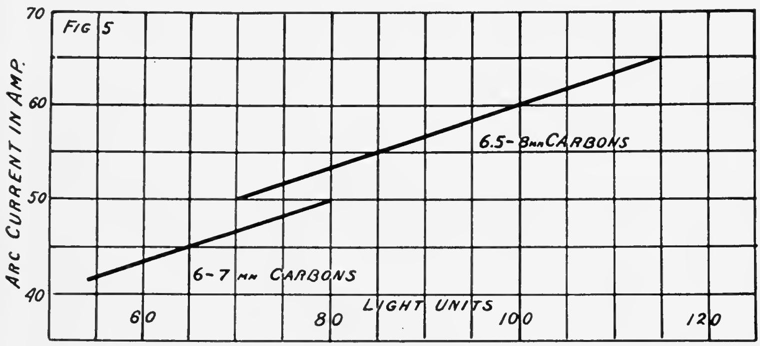

FIG. 4. Variation of light intensity with arc current.

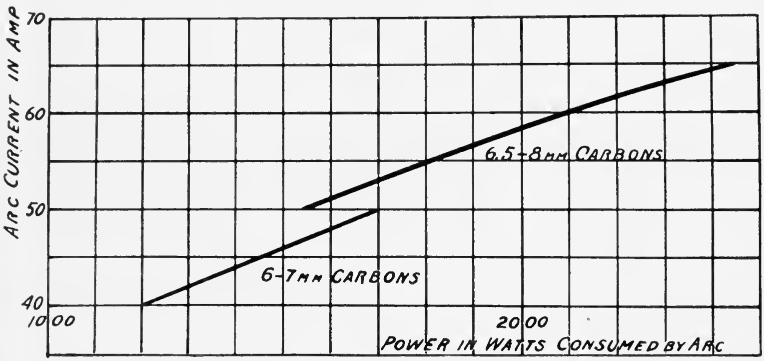

FIG. 5. Variation of power with light intensity.

average light intensity was 84 units. Thus, an increase in arc wattage of 17 per cent provided an increase of 20 per cent in light. At 60 amperes the arc consumed 2100 watts, and the average light intensity was 100 units. Here an increase in arc wattage of 36 per cent resulted in an increase of 43 per cent in light. At 65 amperes the arc consumed 2435 watts, and the average light intensity was 115 units. Thus, with a total increase in wattage of 58 per cent the light was increased by 64 per cent. However, this represents a 30 per cent increase in the current.

(7) Lamps of five different makes, designed for d-c. operation with *Suprex* carbons were tested and compared on the basis of projected light. The same projector was used in all the tests, only the lamps being changed. The results indicated that although the lamps all had reflectors of different sizes and focal lengths, the projected light in every case was of practically the same intensity for the same arc current.

(8) In determining the efficiency and power-factor of the various sources of arc current, the following were considered:

(*A*) 110-volt direct current from power mains.
(*B*) Motor-generator, 80-volt d-c. output.
(*C*) Motor-generator, 60-volt
(*D*) Motor-generator, 40-volt
(*E*) Motor-generator, double generator.
(*F*) Single-phase rectifier.
(*G*) Three-phase rectifier.

Measurements were made of the over-all efficiency, or the proportion of direct current delivered to the arc with respect to the current drawn from the supply line (including the ballast resistance, in the case of the motor-generator), for a minimum load of 40 and a maximum of 65 amperes. The values of efficiency follow:

A (110-v., d-c. mains) 27 to 36 per cent.
B (m-g., 80 v.) 26 to 35 per cent.
C (m-g., 60 v.) 40 to 45 per cent, at 40 to 55 amperes.
D (m-g., 40 v.) 45 to 48 per cent, at 40 to 50 amperes.
(The limited capacities of the motor-generators in *C* and *D* did not permit testing them with the 60 to 65 ampere arc.)
E (double generator, single-motor type) 45 per cent, at 45 to 50 amperes.
(Not tested above 50 amperes, the rated capacity of the motor-generator.)
F (single-phase rectifier) 48 to 55 per cent, at 40 to 50 amperes.
(Capacity of rectifier, 50 amperes.)
G (three-phase rectifier) 61 to 72 per cent, at 40 to 60 amperes.
(Although the rated capacity of the rectifier was 60 amperes, the efficiency at 65 amperes was 75 per cent.)

The power-factor of the motor-generator sets tested ranged from 78 to 83 per cent. The power-factor of the single-phase rectifier ranged from 80 to 85 per cent; and of the three-phase rectifier from 85 to 90 per cent.

(9) Examination of reflector mirrors in theaters in which *Suprex* carbons have been used for some time shows that there is continual pitting, resulting in a noticeable decrease in screen light. In order to maintain the screen illumination at its best, the mirrors should be replaced when noticeably pitted.

There has been introduced recently a shield, or mirror guard, made with high-quality optical glass and having the same curvature as the mirror it is intended to protect. This guard fits exactly the inside curve of the mirror and acts effectively as a guard against pitting. Various sizes of mirror guards have been tested by the Committee and found to occasion a negligible light loss.

When the mirror guard itself becomes pitted, it can be easily removed and replaced with another, effecting a considerable saving over the cost of a new mirror. The Committee recommends the use of these guards.

(10) The comparative advantages of the new d-c. light sources using copper-coated *Suprex* carbons may be judged on the basis of two factors: (*a*) quality and quantity of projected light, and (*b*) cost of operation, the latter being of primary importance to the smaller theaters. The following résumé of operating cost per hour is based on the prevailing prices for carbons in standard shipping-case quantities, and an average current cost of 5 cents per kwh.:

Carbon Cost per Hour

(6- and 7-mm. trim, allowing for stubs)

Amperes	Cents
40	10.4
45	14.4
50	18.5

Arc Current Cost per Hour

(5 cents per kwh.)

Amperes	Cents
40	6.0
45	7.2
50	8.75

Supply Line Current Cost

(Allowing for losses)

Amperes	D-C. Line and 80-V. Generator (*cents*)	Average Generator (*cents*)	Rectifier (*cents*)
40	20	15	9
45	24	17.5	11
50	29	22	13.5

Low-Intensity Costs, Cents per Hour, at 30 Amperes

Carbon	4.9
Current on line side of motor-generator, 80-volt type, at 5 cents per kwh.	19.7
Cost with rectifier	11.5

High-Low Costs, per Hour

Carbons	17.2
Current from line side of motor-generator, at 5 cents per kwh.	47

From the standpoint of quality and quantity of light, there is no reasonable basis for comparison between these new arcs using the *Suprex* carbons and low-intensity arcs, as there is a pronounced favorable contrast in those respects in favor of the former. The low-intensity light is dull yellow; whereas the *Suprex* carbon arc delivers an intense white light which is very pleasing to the eye. A comparison of the *Suprex* carbon arc with the high-low arc at a current of from 50 to 60 amperes, showed that the *Suprex* carbon arc provides a light of equal intensity but with a more even field; and, of course, at a much lower operating cost.

The Committee regards the d-c. *Suprex* carbon arc as one of the most important developments in the projection field within recent years. It fulfills the demand for improved screen illumination—both as to quantity and quality of light—in a manner that leaves no room for question. It enables the smaller theaters to offer for the first time a quality of screen illumination comparable with that found heretofore only in the largest and finest theaters. In addition, the Committee's test proved the arc to be economical in operation.

Not only will the screen illumination benefit through use of this new type arc but the general illumination of the theater can be improved, certainly a very desirable advance. Colored motion pictures, the number of which is progressively increasing, demand a light-source of high intensity and good quality, a requirement that is fulfilled by this new arc.

The Projection Practice Committee recommends the use of the *Suprex* d-c. arc.

The Committee extends its thanks to the manufacturers who cooperated by supplying the equipment necessary for conducting the tests. The Committee is particularly indebted to the International Projector Corporation, which not only provided quarters in which to conduct the tests, covering a period of two weeks, but also contributed generously of its personnel, equipment, supplies, and electric power.

H. RUBIN, *Chairman*

J. O. BAKER	S. GLAUBER	R. H. MCCULLOUGH
T. C. BARROWS	C. L. GREENE	R. MIEHLING
G. C. EDWARDS	H. GRIFFIN	P. A. MCGUIRE
J. K. ELDERKIN	J. J. HOPKINS	M. D. O'BRIEN
J. J. FINN	W. C. KUNZMANN	F. H. RICHARDSON
E. R. GEIB		V. A. WELMAN

DISCUSSION

MR. RICHARDSON: I believe we should have included in the report the new a-c. light source, which is very economical and furnishes a very excellent projection light.

The statement was made that a glass guard causes negligible light loss. I understand that a loss of at least 4 per cent occurs for each polished surface of glass through which the light passes. You stated that the negative consumption curve rises gradually to a point after which, comparing it with the curve for the positive carbon, the negative burns rather steadily, indicating that the arc will remain at the focus of the mirror. But when the positive burns faster or slower than the negative, the light source will be out of focus constantly. In this particular case it would enlarge the spot.

MR. RUBIN: As was stated in the report, separate feed screws or adjustments for both negative and positive can adjust that. Actually this is a test curve. In the theater, the arc would be set for 50 amperes, and the adjustment would not be changed.

MR. BRENKERT: As the current increases, the rate of consumption of the positive carbon increases faster than that of the negative. The procedure to follow as the current is increased is to step up the speed of the motor that feeds both carbons, then slow down the negative feed by a separate adjustment. On the arcs put out years ago that could not be done, but it can be done today on most arc lamps.

MR. SACHTLEBEN: The light reflected by the light-guard will be 4 per cent at each surface, but because the surfaces of the light-guard are concentric with the surface of the mirror, the light reflected from these surfaces, except for second-order reflections and a very slight absorption in the glass itself, will be added to the light from the mirror. This loss of light will be very small, as was found by the investigations of the Committee.

MR. BRENKERT: The best optical glass has a reflection loss at each surface, as Mr. Richardson stated, of 4 per cent. The guard provides two surfaces through which the light must pass on its way to the mirror, and on the return the light must pass through those surfaces again. Four such surfaces must be considered.

MR. RUBIN: In all tests that we made, with any instrument, the loss could not be detected. It can not be detected with the naked eye. That is why we could not report on it. The effect of using the guard is merely to make the mirror a little thicker.

MR. BRENKERT: Is the guard made in the same mold as the mirror? The focal length of the reflector is an important factor, and it would, of course, be impossible to put the guard in exactly the same plane as that of the original reflector.

MR. RUBIN: That does not matter; you simply focus the combination of mirror and guard. The fact is the Committee discovered that the focus was just as good with or without the guard. The loss of light was negligible; we couldn't measure it.

MR. SACHTLEBEN: These reflections do occur, but most of the light so reflected adds to the light coming from the mirror. In view of the theory of application of the guard, the findings of the Projection Practice Committee are perfectly acceptable.

MR. RICHARDSON: The Committee may have used a guard the surface of which happened to fit exactly. There are about fifteen different mirrors on the market and they are not all made on one tool.

MR. BRENKERT: Elliptical reflectors are not ground and polished. In other words, they vary in focal length as well as in working distance, or both. It may be possible to make a few sufficiently accurately to superimpose one upon the other, but in production in large quantities I am afraid trouble will result. If you want satisfactory results, in practice all over the country and not in only a few spots, I should prefer to match up the protector with the reflector. Unless the problem can be put to the mirror manufacturers I believe it is entirely out of the hands of the lamp manufacturer to control the accuracy of the reflector. I want to be clearly understood: I don't object to anything that is an improvement, but I do object to anything that is going to cause trouble.

PRESIDENT GOLDSMITH: It may be, of course, that extreme accuracy is not as necessary as we perhaps think. If the auxiliary guards are thin and if their surfaces are reasonably clean, then the major loss of light, of useful light, will result from absorption in the glass, rather than from reflection, and that necessarily will be fairly small in good, clear glasses.

MR. RUBIN: The only question involved here is this: After a week or two of using the Suprex carbons, which pit considerably, will you get more light with the protector, which you claim causes a loss of 4 per cent, than from a pitted mirror? When you sell the exhibitor a mirror, he is not going to buy another one in two minutes. He will allow the mirror to become pitted more and more, for three weeks or a month, or perhaps a year. Which is to be preferred?

THE NON-ROTATING HIGH-INTENSITY D-C. ARC FOR PROJECTION*

D. B. JOY AND E. R. GEIB**

Summary.—*The non-rotating high-intensity d-c. arc is considered in conjunction with equipment that has been developed for applying it to motion picture projection. The current and consumption ranges and the crater opening of carbons when used in this equipment are tabulated. The effect of burning the arc at various currents, arc lengths, and positions is shown graphically in relation to the light upon the projection screen. The important features of the lamp mechanisms and optical systems are discussed. The sources of power used with this new type of arc are grouped in relation to arc stability and general characteristics. The influence of external magnetic flux upon arc stability and appearance of the arc is also illustrated.*

INTRODUCTION

The non-rotating high-intensity d-c. arc has been described in an earlier paper.[1] This arc has the characteristic cup-shaped crater of the well-known d-c. high-intensity arc with the rotating positive carbon, but is produced with smaller size carbons. It also has the desirable features of requiring no rotation of the positive carbon and of eliminating the necessity for conducting the current into the carbon close to the arc.

It was believed at the time this arc was first announced that, with a suitable lamp mechanism and power supply, it could be used to advantage for motion picture projection in houses in which more light and a better quality of light were desired than could be furnished by the low-intensity lamp, but in which the more complicated and expensive apparatus for burning the conventional high-intensity d-c. arc was neither required nor economically justified. The need for this light source is more pronounced today than ever because of the great advances that have recently been made in the technic of producing colored pictures. The projection of colored pictures requires a higher intensity of light at the film aperture than the projection of black-and-white pictures, and preferably the snow-white color characteristic of the light from the high-intensity arc.

* Presented at the Fall, 1924, Meeting at New York, N. Y.

** National Carbon Co., Cleveland, Ohio.

In the previous paper the discussion was restricted to the arc and carbons themselves because, at that time, commercial equipment in which to use these carbons was not generally available. In this paper the arc is discussed in relation to equipment now available and to the light on the projection screen.

DATA ON CARBON TRIMS

The consumption and current-carrying capacity of the carbons has now been more thoroughly determined for equipment actually used in the theaters today, and the results are given in Table I. The values of current-carrying capacity and consumption differ slightly from those previously given because of the development of certain types of equipment that enables the carbons to maintain a steady arc at a lower current than was previously thought possible. These carbon trims have been designed for approximately the same ratio of consumption between positive and negative carbons for corresponding burning rates.

TABLE I

Consumption and Current-Carrying Capacity of Suprex Carbons

Carbon		Range of		Consumption (Inches per Hr.)		Effective Pos. Crater Diam. (Inches)
Pos.	Neg.	Current	Voltage	Pos.	Neg.	
6-mm.	5-mm.	32–40	31–40	6.5–13.5	3.0–4.5	0.14–0.16
7-mm.	6-mm.	42–50	31–40	6.5–13.5	3.0–4.5	0.15–0.20
8-mm.	6.5-mm.	56–65	31–40	6.5–13.5	3.0–4.5	0.20–0.25

The effective crater diameters of the carbons are also given in this table. These figures were obtained by measuring the diameter of the inside of the crater edges, and are approximately 0.02 to 0.04 inch smaller than if the outside of the crater edge had been taken. This dimension is used so that the figures can be applied directly to calculating the magnification of the optical system of the projection lamp.

EFFECT UPON THE LIGHT ON THE PROJECTION SCREEN OF CHANGING THE CURRENT AND POSITION OF THE ARC

At the present time, most of the lamps and auxiliary equipment have been designed to use the 7-mm. positive and 6-mm. negative carbon trim. We have, therefore, based our discussion of the light on the projection screen on this combination burned in a typical lamp. In accordance with previous experience, the light on the projection screen has been studied with a view of giving to the projectionist, as well as the lamp and equipment designer, data that will enable him to obtain the best light possible from his particular piece of equipment. In actual practice there are several variables that simultaneously affect the light on the projection screen, but in this investigation the effect of each variable has been studied independently. By combining the data obtained on the several variables the resultant effect can be predicted. The average illumination of

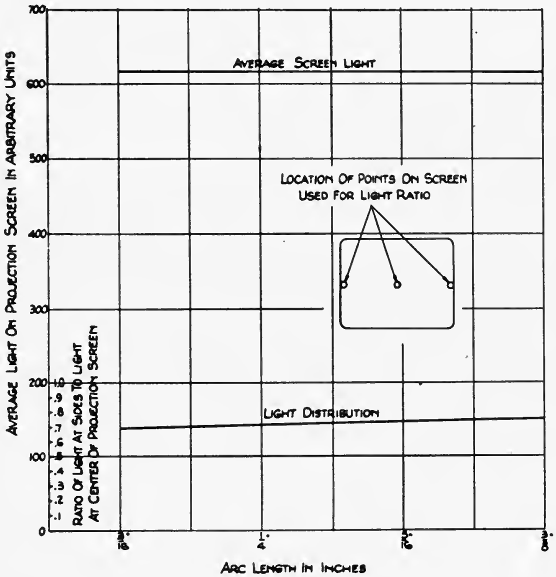

FIG. 1. Light on projection screen *vs.* arc length: 7-mm. pos., 6-mm. neg. carbons; positive carbon 3.76 inches from reflector; constant current, 45 amperes.

the projection screen was measured at nine points on the screen. The light distribution is expressed as the ratio of the light at the center of the screen to the light at the sides of the screen, as indicated by the diagram in Fig. 1.

In ordinary practice the arc length of this 7-mm. positive, 6-mm. negative trim is usually maintained between $^9/_{32}$ and $^5/_{16}$ inch. The effect upon the screen light of varying the arc length, while keeping the current constant and the positive crater at exactly the same position with respect to the reflector, is shown in Fig. 1. It is obvious

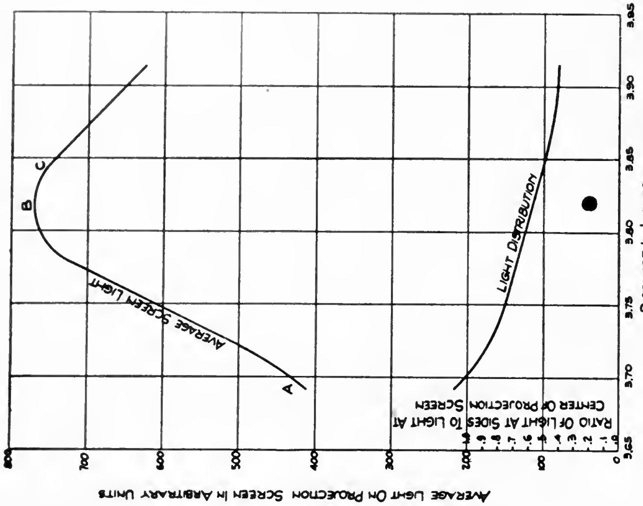

FIG. 3. Light on projection screen *vs.* position of arc: 7-mm. pos., 6-mm. neg. carbons; 45 amperes; $^5/_{16}$-inch arc length.

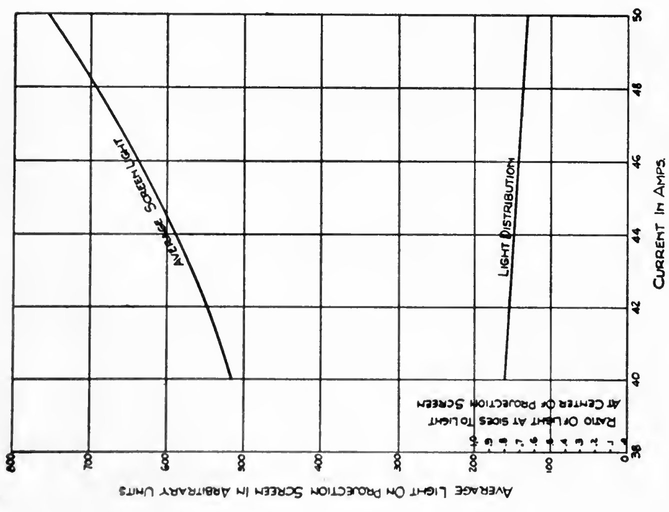

FIG. 2. Light on projection screen *vs.* current: 7-mm. pos., 6-mm. neg. carbons; $^5/_{16}$-inch arc length; positive carbon 3.76 inches from reflector.

from these curves that neither the total light on the screen nor the distribution of the light is materially affected by changing the arc length from $^3/_{16}$ to $^3/_8$ inch, provided the current and the position of the positive carbon remains constant. However, with a very short arc length, such as $^3/_{16}$ inch, there is built up on the negative carbon a reddish deposit which, unless removed, may cause difficulty in re-striking the arc. If, on the other hand, the arc length is comparatively great, say, $^3/_8$ inch or more, there is a perceptible wavering of the arc which tends to cause a fluctuation of the screen light.

If the current is increased but the arc length and the position of the arc with respect to the mirror are held constant, there is a very definite increase in the screen light but very little change in light distribution, as illustrated in Fig. 2. For an increase in current from 40 amperes to 50 amperes, or 25 per cent, the light on the screen is increased by 47 per cent. This increase in light is accompanied by an increase in crater depth and carbon consumption. If the arc current is too small, the crater is very shallow and the light is not uniform in color. If the current is too great, the consumption is excessive and the light is unsteady.

If the current and arc length are maintained constant but the arc itself is moved with respect to the reflector, the screen light and distribution vary as indicated in Fig. 3. The shape of the curve for average screen light is similar to that obtained for the 8-mm. high-intensity a-c. arc or the 12-mm. low-intensity d-c. arc with the same 6:1 magnification of the optical system,[2,3] but has a much sharper peak and the light distribution ratio drops off more rapidly with increased distance from crater to reflector. In other words, to maintain a good distribution of light upon the screen, it is necessary to hold the position of the positive crater within close limits.

At *A* in Fig. 3 the light at the sides of the screen is equal to that at the center of the screen and the edge of the positive crater is 3.70 inches from the center of the reflector. If the arc is moved closer to the reflector the sides of the screen become brighter than the center, which is a very undesirable condition. If the arc is moved away from the reflector, the average light on the screen increases, and the light at the center becomes brighter than that at the sides until the point *B* on the curve is attained, at which the average light is at its maximum. Continuing the movement of the arc away from the reflector results in a decrease in the average screen light and an increase in contrast between the center and the sides. After point C is reached, the contrast between side and center becomes very noticeable. If the distance between points A and C is taken as an arbitrary range, this allows a movement of the arc over a distance of only 0.14 inch. It is therefore quite essential that the position of the arc be accurately maintained near the center of these limits. The narrow range is due to the combination of the curve of light distribution across the crater face, the magnification of the optical system, the diameter of the crater opening, and the dimensions of the film aperture. The dimensions of the film aperture are standard; and the shape of the light distribution curve, with the peak in the center, is characteristic of d-c. high-intensity arcs. This leaves the magnification of the optical system and the crater opening as the controllable factors affecting the screen light. The crater opening is increased when a larger size positive carbon at a higher current is used, as indicated in Table I. It has been found by measurement that the 8-mm. positive carbon with the 6.5-mm. negative carbon does afford greater latitude of movement from the optimal position of the arc as well as more light. With this 8-mm. carbon burning at 60 amperes, the permissible movement of the arc, for the same relative change of volume and distribution of light, is increased approximately 35 per cent. The other option would be to increase the magnification of the optical system. The use of either a larger carbon or an optical system of higher magnification would make it much easier to maintain a uniform light upon the screen. The arc will not operate satisfactorily unless the correct alignment of the positive and negative carbons is maintained.

From the foregoing facts it is obviously essential that the carbons feed uniformly, so as to maintain a given position of the positive carbon and a steady current. This is very effectively accomplished in a number of the lamps now on the market. The positive carbon is fed continuously, and the negative either continuously or at very short intervals of time, giving practically the same results. The ratio of the feed of the positive and negative carbons can be adjusted either in the lamp itself, or by a comparatively simple change in the lamp parts. If it is desired to change the feed ratio without adjusting the feed mechanism, it should be remembered that, for any given carbon trim, as the current is increased the ratio of the positive consumption to the negative consumption increases.

THE POWER SOURCE AND ARC STABILITY

All the preceding discussion assumes the maintenance of a stable arc, but it has been found that the stability of this type of arc is very materially affected by the source of power and the magnetic flux.

The power source that is commonly used, whenever available, is the 115-volt d-c. line. This gives an opportunity to use plenty of

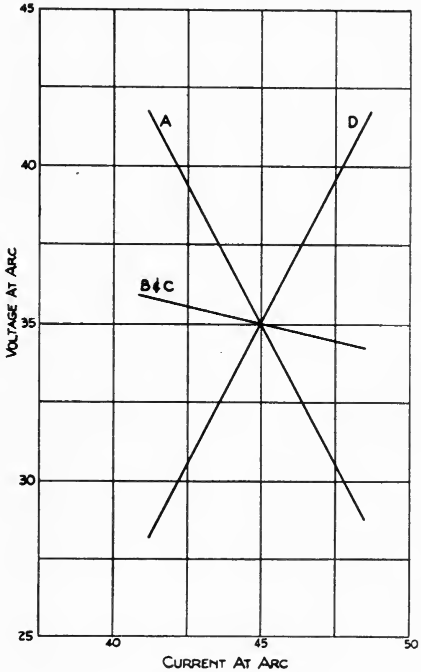

FIG. 4. Volt-ampere characteristics of arc due to power source: (*A*) Constant-voltage source, 115 volts; resistor set for 45 amperes, 35 volts at arc. (*B*) Constant-voltage source, 45 volts; resistor set for 45 amperes, 35 volts at arc. (*C*) Variable-voltage source with falling volt-ampere characteristic. (*D*) Variable-voltage source with rising volt-ampere characteristic.

ballast resistance between the arc and the line, which is necessary, with the low-intensity arc, for stable operation. However, it has been found that the low-intensity arc (*e. g.*, 30 amperes and 55 volts on 12-mm., 8-mm. S.R.A. carbons) is stable with 80 volts on the line. Therefore, in places where 115-volt direct current is not available, a motor-generator set has been used to provide d-c. power service of 80 volts.

These small size d-c. high-intensity carbons require only about 35 volts at the arc. It would therefore be very uneconomical to use either a 115-volt or an 80-volt d-c. source of power. This fact has led to a consideration of sources of direct current, including both generators and rectifiers, that would be more economical than the 80-volt motor-generator sets or 115-volt d-c. line. Several such devices have been developed which give very good results, with a noticeably steadier light on the screen than when the high-voltage source, such as the 115-volt d-c. line, is used.

A consideration of the volt-ampere curves at the arc with these different types of power sources, together with some of the characteristics of the high-intensity arc, will explain the reason for this seeming reversal of well-known facts. The power sources considered had the following characteristics:

(*A*) A constant voltage of 115.
(*B*) A constant voltage of 45.
(*C*) A falling volt-ampere curve and comparatively low no-load voltage.
(*D*) A rising volt-ampere curve.

With power sources *A* and *B*, which have constant-voltage characteristics at the currents that will be considered, a resistance is placed between the source and the arc to reduce the voltage to the proper value. With a power source such as *C* or *D*, the characteristic of the source itself is such that voltage of the proper value is supplied at the operating current. In considering the stability of the arc we are particularly interested in the volt-ampere curves at the arc itself. The effect of the various power sources on the volt-ampere curve at the arc through a small range of current is shown in Fig. 4 for a 45-ampere, 35-volt arc with 7-mm. positive and 6-mm. negative carbons.

Bassett[4] has shown that the voltage drop across the arc stream from the positive to the negative is comparatively low and does not increase materially as the current is increased. On the other hand, the voltage drop in the positive crater is comparatively high and increases materially as the current and crater depth increase. As shown in Fig. 2, this increase of voltage and crater depth at the positive carbon that accompanies the increase of current, causes a very material gain in the useful light at the arc. It is therefore very important that conditions at the positive crater be maintained as constant as possible. If for some reason there is a disturbance in the high-intensity effect, such as, for example, a decrease in the voltage drop in the crater caused by a crooked crater due to poor alignment of the carbons, the resultant effect on the arc may be quite different, depending upon the characteristics of the power source.

The curves in Fig. 4 show only the influence of the power source on the effect that arc disturbances have upon the arc current and voltage. They do not take into consideration changes in the characteristics of the arc itself, which might in turn affect the volt-ampere characteristic.

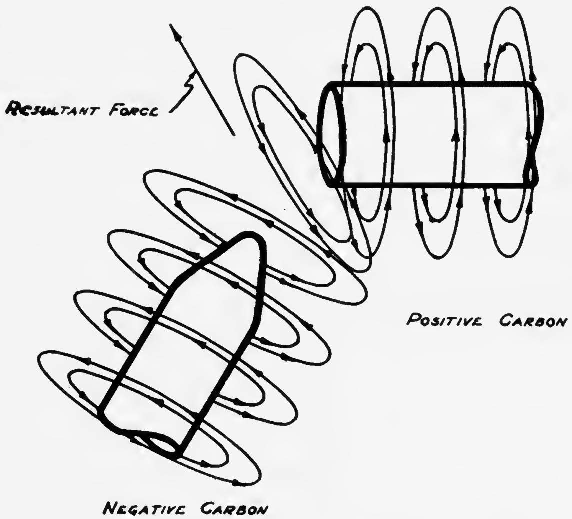

FIG. 5. Illustrating the distribution of the magnetic flux about the carbons set at an angle less than 180 degrees.

Over the small range of current and voltage that is being considered, power sources *B* and *C* can be regarded as having approximately the same volt-ampere curve. With power source *A*, where the voltage is cut down from 115 volts to 35 volts by a comparatively large amount of ballast resistance, the volt-ampere curve is very steep. A decrease of arc voltage would cause a small increase of current from the power source. Power sources such as *B* and *C* display, for the same decrease of arc voltage, a much greater increase of current. On the other hand, power sources having a rising volt-ampere characteristic would show a decrease of current with a decrease of arc voltage, as in curve *D*. It will be demonstrated that these differences in the action of the various sources of power on the arc materially affect the arc stability.

If, for example, some disturbance causes a momentary decrease of the arc voltage of one volt, the immediate action of the power sources on the arc, as indicated by Fig. 4, is as shown in Table II.

TABLE II

Effect of Decrease of Arc Voltage of 1 Volt

(Original Conditions 45 Amperes and 35 Volts at the Arc)

	Power Source	Momentary Arc Voltage	Momentary Arc Current
(*A*)	115-volt constant-voltage power line	34	45.6
(*B*)	45-volt constant-voltage generator	34	49.5
(*C*)	Generator or rectifier with falling volt-ampere curve similar to source *B* at and near 45 amperes	34	49.5
(*D*)	Generator with rising volt-ampere characteristic	34	44.4

With a slight increase of current in the arc, such as occurs with power source *A*, there would be very little tendency for the crater depth to be restored. On the other hand, if the current decreased as the arc voltage decreased, as in case *D*, the crater depth would be further diminished and the condition aggravated. But if the power source *B* or *C* were employed, there would be a distinct increase of current, which would immediately tend to restore the proper crater depth. This, in turn, would increase the arc voltage and cause a restoration of current, arc voltage, and crater depth to their normal values. It is therefore apparent that the use of a power source such as *D* would be intolerable, and the use of a power source such as *B* or *C* would be considerably better than power source *A* in maintaining an arc of constant characteristics. Power source *D* corresponds to the series

FIG. 6. Photograph of arc under conditions illustrated in Fig. 5.

arc generator operated below the knee of the current-voltage curve and, as stated by Dash,[5] is not suitable for even the conventional type of high-intensity arc with rotating positive carbons. The 80-volt generators of the constant-voltage type, common in theaters in which alternating current must be converted to direct current for low-intensity mirror arc projection, are, of course, intermediate in effect between power source *A* and power source *B* or *C*. Power sources *B* and *C* are typical of the power units that have recently been developed for use with the d-c. high-intensity arc using the small size non-rotating positive carbons. Several different types of such units are here listed:

(*1*) A low-voltage motor-generator set with constant-voltage characteristic, and with the two lamps and their individual ballast resistances connected to the generator in parallel.

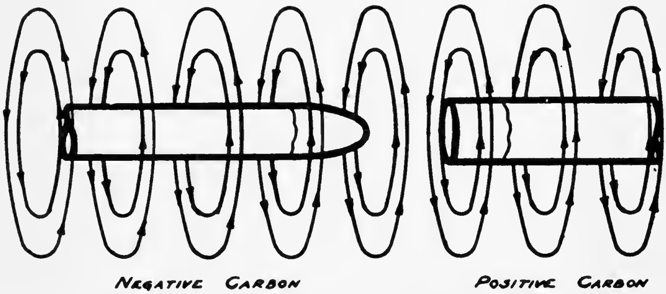

FIG. 7. Illustrating uniformity of distribution of magnetic flux when carbons are aligned, without additional magnetic field.

(*2*) A motor-generator set with a falling volt-ampere characteristic, which, because of its characteristic requires no ballast resistance, but does require a separate generator, possibly driven from a common motor, for each lamp.

(*3*) A rectifier with a falling volt-ampere characteristic. This also requires a separate rectifying unit for each lamp.

These three types of power sources are being manufactured and marketed for use with these non-rotating high-intensity d-c. arcs at the present time. Each power source has its own particular advantages. All, however, are characterized by a comparatively large increase of the current with a decrease of arc voltage at the operating current and voltage of the arc. This is a decided advantage in maintaining stability of the arc. All these power sources are much more efficient than 80- or 115-volt constant-voltage generators with the necessary ballast resistances. It is very desirable that the short-circuit current of these sources of power be as small as possible, for, if the short-circuit current is excessive when the arc is struck, the crater is shattered and the core of the carbon tends to be blown out. This causes unsatisfactory light on the projection screen until a normal crater has been reëstablished.

If three-phase or two-phase rectification is used, the variations in the instantaneous values of the current, voltage, and light upon the screen are comparatively small and are not noticeable. If a single-phase rectifier is used, similar to those commonly employed for low-intensity mirror arc lamps, there is a considerable fluctuation of voltage and current which, with the high intensities of light

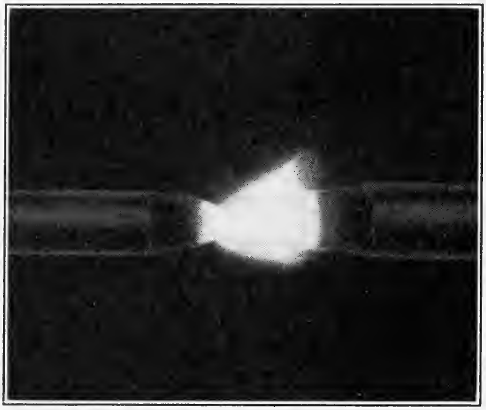

FIG. 8. Photograph of arc under conditions illustrated in Fig. 7.

obtained with the high-intensity d-c. arc, might cause a noticeable beat of light upon the screen under certain conditions. If, however, a sufficiently large choke-coil is used on the output side of the single-phase rectifier, this fluctuation is materially decreased.

THE USE OF MAGNETIC FLUX TO STABILIZE THE ARC

Another very important factor to be considered in stabilizing this high-intensity arc is the use of an auxiliary magnetic flux. The ordinary high-intensity arc, in which the positive carbon is rotated and the current fed into the carbon close to the positive crater, has always been burned with the negative carbon set at an angle of more than 90 but less than 180 degrees to the positive carbon.

Fig. 5 illustrates the distribution of the lines of force generated about the arc by the electric current. Because the negative is at an angle less than 180 degrees to the positive carbon, the lines of force are crowded together directly beneath the arc, while the flux density is less above the arc. This causes a resultant force in the direction indicated by the arrow, which, in conjunction with the natural flow of the arc stream, projects the tail-flame of the arc in an upward and forward direction from the positive crater, as shown in the photograph in Fig. 6.

The lamps developed for burning the new small size, high-intensity,

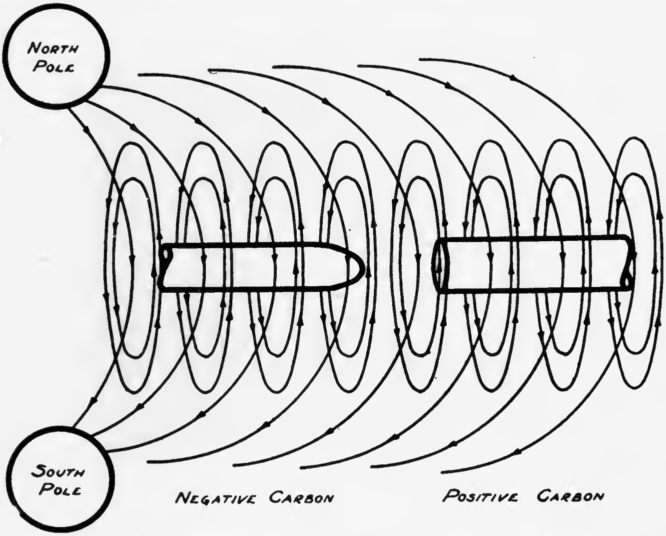

FIG. 9. Illustrating distribution of magnetic flux, using a supplementary magnetic flux.

non-rotating positive carbons are of altogether different design from that of the older types of high-intensity lamps, and, since there is no necessity for rotating the carbon or feeding the current into the carbon close to the arc, the carbons are held and aligned just as in the low-intensity mirror arc lamps. In other words, the angle of the negative carbon has been increased until the negative and positive carbons are directly in line. The lines of force generated by the arc current, as shown in Fig. 7, are distributed uniformly about the carbons, and there is no resultant force in the upward direction except that caused by natural drafts in the lamp. The tail-flame, therefore, surrounds the arc in almost a uniform layer, as shown by the photograph in Fig. 8. Unless the lamp design is such as to eliminate extraneous drafts or other disturbing conditions, a slight misalignment of the carbons causes the crater to burn off to one side. This in turn, particularly with a power source such as a 115-volt d-c. line, causes a noticeable change in the depth of the crater and the light upon the screen. If, however, a supplementary magnetic flux is provided to increase the flux density below the arc and decrease it above, an upward force is established which materially changes the shape and characteristics of the arc. This magnetic flux has been introduced in some of the lamps by means of a magnet,

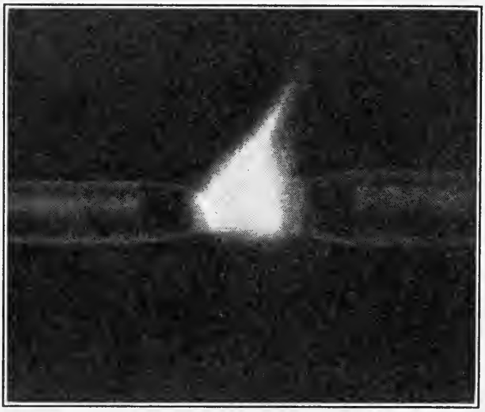

FIG. 10. Photograph of arc employing the supplementary magnetic field; negative carbon lowered slightly.

as in Fig. 9, which illustrates diagrammatically the carbons and lines of magnetic force as seen from above and in front of the positive crater. The flux generated by the current in the carbons surrounds the carbons uniformly, as in Fig. 7, but superimposed upon it are the lines of force emanating from the magnet. This flux from the magnet is in such a direction as to tend to neutralize the flux above the arc generated by the arc current, and increase the total flux below the arc. The tail-flame from the arc lengthens and is driven upward, becoming comparatively stationary and constant in length and direction. The negative carbon should be lowered slightly to compensate for this direction of the arc stream. There is then no tendency for the crater to break away in any direction. A side view of the arc employing the auxiliary magnetic flux is shown in Fig. 10. The improvement attained in the steadiness of the light upon the projection screen by using the auxiliary magnetic flux is very noticeable when a 115-volt d-c. line is the power source. It is less noticeable with power sources such as *B* and *C*, because the high-intensity effect is more stable with power sources of those types.

The effect of the type of power source and of the auxiliary magnetic flux upon both the arc and the screen light are of very great practical importance, and it can be said without reservation that successful operation of this type of arc depends largely upon these two factors. This discussion emphasizes the fact that coördination of the light source, optical system, lamp mechanism, power source, and projectionist is essential to good light on the projection screen.

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DISCUSSION

MR. PALMER: When an arc is operated by a motor-generator set, it produces a perceptible hum. It probably isn't serious in the projection room of a theater, but it is very serious when arcs are used in sound picture studios, where sound pictures are being made. Forty or fifty arcs make a lot of noise.

Various means have been tried to stop the noise, and it can be stopped by putting choke-coils in the circuits; but that is quite expensive. I wonder whether there is any possibility that it might be stopped by some magnetic scheme. In the first place, what is it that causes the sound, and is there any possibility of removing it by a magnetic means?

MR. JOY: I have always believed that the sound was due to the "commutator ripple," which, of course, is a function of the number of commutator bars, poles, and speed of the motor-generator set. I don't believe that any external magnetic effect would decrease the hum.

The hum can be eliminated by a condenser across the line, a choke coil in the line, or, preferably, by a combination of condenser and choke coil.

MR. PALMER: But what is it that actually causes the sound?

PRESIDENT GOLDSMITH: Would it not be thermal expansion and contraction resulting from the changes of current causing changes in heating of the surrounding air?

MR. PALMER: I notice that the negative carbon can be adjusted until the positive crater is in a vertical plane, so as to keep it as nearly in the focus of the mirror as possible.

MR. JOY: Yes. Of course, the external magnetic effect, as we demonstrated, tends to force the tail-flame upward. If the negative carbon were centered with respect to the positive carbon, the crater of the positive carbon would be shallow at the top. If the negative carbon is lowered a few thousandths of an inch this compensates for the upward sweep of the tail-flame and results in an even crater on the positive carbon. All the lamps using Suprex carbons have means for conveniently adjusting the negative carbon. In reference to mirror pitting, it is our opinion that mirror pitting is not caused by particles of copper. The copper plate is melted away from the carbon by the heat of the arc for an appreciable distance back from the ends of the carbons and therefore does not get into the arc itself. The pits on the mirror are caused principally by particles of carbon or core driven out of the arc and striking the mirror when the arc is started and the momentary short-circuit current is very high. The particles are shot out from a reddish deposit on the negative carbon which is formed, as stated in the paper, when the arc length is too short; or occasionally they come from the arc itself. Some of the deposit on the mirror is red in color. This probably led to the belief that it is copper.

MR. SAMUELS: In a certain chain of theaters using other types of power supply, there was considerable pitting of mirrors. After using the Unitwin motor-generator which has a very low striking voltage and small short-circuit current, the pitting was greatly reduced if not almost entirely eliminated. We are not so much concerned as to the actual material that causes the pitting as we are in eliminating it.

MR. ELDERKIN: Does not the pitting continue all the while the arc is burning? If it occurs only during the strike, an inside douser could prevent that. It is my impression that pitting goes on all the time the arc is burning.

MR. JOY: It is our opinion that a very large proportion of the pitting occurs when striking the arc. Some of the new lamps, designed for these Suprex carbons, did not have an inside douser that fully protected the mirror. I believe that is largely corrected at the present time because the lamp manufacturers have come more and more to realize that it is essential, particularly with the high short-circuit starting current, that the mirror should be protected when the arc is first started.

THE DEVELOPMENT OF 16-MM. SOUND MOTION PICTURES*

E. W. KELLOGG**

Summary.—*The history of 16-mm. development and some of the problems with which the engineers were confronted in the effort to obtain good sound quality are outlined. In view of the difficulties with 35-mm. film, and the greatly reduced speed at which 16-mm. film must run, the prospect of obtaining really satisfactory sound was at first far from encouraging; but with careful technic, commercial quality was obtained, and continuous progress has been made since. Elimination of printing losses by recording directly on each 16-mm. film from a good 35-mm. master print with suitable electrical compensation for high-frequency losses, gave the best films obtainable. Improvements in optical reduction sound printers have more recently made this system look extremely promising. Extended studies of film characteristics and processing, and improvements in optical recording systems have contributed in an important way to securing better sound.*

Projector design has centered about questions of compactness, convenience, and simplicity as well as performance. Several of these items are discussed, and expedients employed are described.

The advent of real amateur talking pictures calls for complete sound and picture recording apparatus of utmost portability and simplicity. In this undertaking the quality problems are renewed in more difficult form, and many new problems of electrical, optical, and mechanical, as well as photographic nature, had to be solved.

During the early stages of the commercial development of "talking movies" for theaters, with the sound recorded photographically on the edge of the film, the problem of obtaining satisfactory quality through the application of the same system to 16-mm. film appeared so difficult that only a few of the more courageous and optimistic engineers interested in the problem gave it very serious attention. The best of the film records made on 35-mm. film left much to be desired in the way of clarity of speech articulation. Low-pitched sounds were reproduced very satisfactorily, but high-frequency sounds were so deficient that speech sounded badly muffled. No serious difficulty was encountered in constructing microphones, amplifiers, recording galvanometers, and loud speakers, whose response to high frequen-

* Received May 24, 1934.

** RCA Victor Company, Inc., Camden, New Jersey.

cies was sufficient to give reasonably satisfactory sound reproduction. The photocell, with its connection to an amplifier tube, was in general responsible for some of the loss of high-frequency response, owing to the extremely high impedance of the photocell and the fact that a comparatively small capacity constituted such a load on the circuit as to reduce materially the voltage applied to the grid of the coupling tube. The general availability of screen-grid tubes with their much lower effective input capacities, plus the development of more suitable lamps and better optical systems and the advent of the caesium tube (all of which contributed to increasing the total photocell output, and thereby made it feasible to load the photocell circuit with lower resistances), so helped this situation that the proper performance of the photocell circuit did not long remain a serious problem. The great difficulty was that, although the sound-track on the film was an excellent picture of the low-frequency waves, the high-frequency waves were partly obliterated by fogging and loss of exposure, owing to the necessity of compressing these waves into a very small space. Thus, at 90 feet per minute (the standard speed for 35-mm. film), a 6000-cycle wave measures only 0.003 inch from peak to peak.

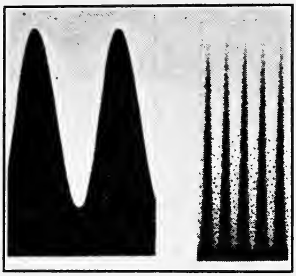


FIG. 1. (*a*) 1000-cycle negative; (*b*) 6000-cycle negative.

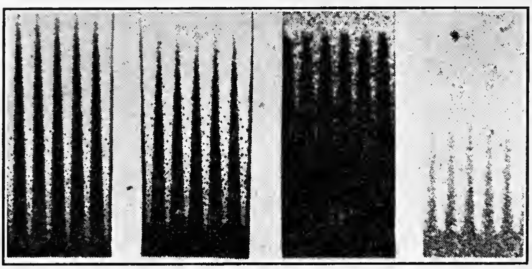
Fig. 1 shows an enlargement of a recording of a 1000- and a 6000-cycle sine wave. The process of enlargement has eliminated some of the fog with which the clear area between the 6000-cycle waves was partly filled in the actual recording. When such a record is run through a reproducing machine, the failure of the areas which should be black to obstruct the light completely, and of the areas which should be clear to transmit all the light, results in reduced light modulation and reduced output from these high-frequency waves. Some of this loss is due to the fact that the light-beam, which should ideally be an infinitely thin line where it strikes the film, has to be of the order of 0.001 inch thick (measured in the direction of film movement) in order to get adequate exposure. This is a considerable fraction of a wavelength at high frequency. We might compare the process with attempting to paint a picture requiring fine detail but using a brush that is several times too big.[2,3] Much of the loss at the high frequency end of the sound spectrum is due to the actual spreading of the light within the film emulsion. If a small area of film is exposed and the adjacent area protected (*e. g.*, by a knife-edge in contact with the film), the resulting film image will reveal a decrease in exposure as the edge of the illuminated area is approached, and a very appreciable blackening extending into the area which was under the knife-edge. The minute crystals of silver halide in the emulsion scatter the light like the particles of a fog, causing it to diffuse in all directions. To revert to our simile, we have given our painter not only too big a brush, but a piece of blotting paper on which to make the picture, and paints that run. The harmful effect of this scattering of the light is reduced by the employment of high-contrast films and also by fine-grained films in which the light is more quickly absorbed and the diffusion does not extend so far.

Other causes of loss of resolution of the high-frequency waves made large contributions to our troubles, and added to the losses for which the film was responsible, giving a quality of reproduction, which, although sufficiently good to start the 35-mm. talking pictures on the road to commercial success, was far from satisfactory, especially to those who had been striving for better quality in radio broadcast and similar work. A 16-mm. amateur film would have to run at not more than 40 per cent of the speed employed for 35-mm. film, and the waves would therefore be correspondingly compressed in length. Thus there would be the same difficulty and losses in attempting to record a 2000-cycle wave on 16-mm. film as were encountered in recording a 5000-cycle wave on 35-mm. film. What hope was there, with such handicaps, of attaining any worth-while quality on 16-mm. film? At least we appeared to be justified in concentrating our main efforts for a while longer on improving the 35-mm. performance. One factor, at least, was encouraging. The kettle always feels better after noting the blackness of the pot. If the high-frequency response from film was poor, so likewise was that of many a successful radio set. Not only were these sets seriously lacking in high-frequency response, as shown by measurement, but they were provided with drastic "tone controls" to reduce still further the high-frequency output; and we were advised that people were generally using the tone controls to their full extent. Perhaps in view of what people were accustomed to in the radio field, we might offer to them what we had in 16-mm. sound quality, which, though far short of our goal, would nevertheless be accepted.

PROGRESS TOWARD OBTAINING BETTER FILMS

In point of time, the development of the 16-mm. sound picture projector, in many of its features, preceded the most important improvements in sound recording, but our story will be more connected if we continue with the story of the films.

It is obvious that the loss of resolution of the high-frequency waves due to the spreading of the light within the film emulsion will occur both in making the negative and again in printing it, and that these losses are added. Fig. 2 shows a negative of a 6000-cycle wave on 35-mm. film and prints made from it with various exposures. The best print is seen to be inferior to the negative. One of the favorable features of the variable-width type of sound record is that a printing operation is not required in order to give correct wave shape



a *b* *c* *d*

FIG. 2. 6000-cycle negative (*a*), and three prints (*b*), (*c*), (*d*).

(a requirement which does apply to variable-density records). We therefore have the choice of playing the negative or the print. Assuming that we have a satisfactory source of sound or of electric currents representing sound, we might make our films by running each film through a recording machine instead of making one negative and duplicating by means of a printing operation. This would eliminate the extra loss of resolution which the printing operation entails. It might appear at first thought that such a method of producing large numbers of films would be excessively costly, but this is not necessarily the case. The principal source of sound pictures for a 16-mm. library would obviously be films previously made on 35-mm. stock. The sound recording on these 35-mm. films would be up to normal theater reproduction standards, and would at least not be impaired by the handicaps to which the 16-mm. sound records are subject, owing to their reduced size. Running a 35-mm. film through a synchronous reproducing machine is not a more serious or complicated operation than running it through a printer. The cost of a complete re-recording channel is not so much greater than that of a printer as to be a serious item in the expense. It was planned that when production of 16-mm. films reached a point to justify the equipment, we should build re-recording systems in which several 16-mm. recording machines are operated in synchronism, all being supplied with voice currents from the output of the one 35-mm. reproducing machine. Even if it should prove that this method of producing duplicate 16-mm. sound films was appreciably more expensive than contact printing of the sound-track, many of our engineers felt that it would be justified because of the better quality of sound attainable. Those who felt that the very best that was possible would be scarcely good enough, were especially inclined to this point of view. The amplifiers for the re-recording channels were constructed to compensate, at least in part, for the inevitable loss of high frequencies which the recording and reproduction of sound from the 16-mm. film involves.

For making the pictures on the 16-mm. film, we could start either with a 35-mm. negative and run each 16-mm. film through an optical reduction printer; or we could start with a 35-mm. master positive, make a 16-mm. negative from it by means of the optical reduction printer, and then make the 16-mm. duplicate prints by contact printing. Direct optical reduction of each 16-mm. film gives a distinctly superior picture, especially with respect to graininess. Here again the better product would cost slightly more, for the reason that the optical step printers run more slowly than continuous contact printers. The operation of printing is itself a small fraction of the total cost of turning out the 16-mm. film.

In the initial work of building up a library of 16-mm. films, the system just outlined was followed: namely, each 16-mm. film was run through the re-recording machine and then through the optical reduction printer. This gave the best 16-mm. film which it was possible to make. The sound quality which it was found possible to obtain in this way justified full confidence in ultimately developing a wide field of application for 16-mm. pictures with sound on the film. In fact, the limitation in quality was in considerable measure set by the 35-mm. films which we were able to obtain at the time.

Intensive study was given to the characteristics of films and developers and of the effects of various exposures and developments.

The outcome of these studies was that no films* were immediately available which were better, all things considered, than the Eastman positive with which we had started, nor was any developer found which was better than the Eastman *D-16*. Equivalent film emulsions were obtained from other manufacturers, and faster films with substantially the same resolving power have since been developed. The standard cine-positive films are, in fact, very well suited to sound recording. They are the finest grained of all of the commercial films, and about equivalent in this respect to special process films, which are rated as extremely fine grained. They are also inherently high-contrast films, a factor which is favorable in variable-width recording, since this high contrast helps enable us to obtain deep blacks and clear whites with relatively sharp lines of demarcation between them. A very complete study of printing and development was made. It appeared in general that a negative from which a print is to be made should have a density in the black portions (density being defined as $\log_{10}$ of the ratio of incident to transmitted light) of the order of 1.8, preferably obtained with a development giving a "gamma" or contrast factor of 2 to 2.2, while the best prints obtained from such negatives had densities of 1.3 to 1.5, with a gamma of about 2.0. Negatives with lower contrast (although they would in some cases give prints having as great a high-frequency output) gave less latitude in printing, and required lighter prints for maximum print output, which is disadvantageous from the ground noise standpoint. Thinner or lighter negatives also called for light printing. Shorter print development was found unfavorable in permitting less latitude in print density, and requiring lighter prints for equal high-frequency output. The best density for a recording to be played directly was found to be of the order of 1.0 to 1.3 (5 to 10 per cent of the incident light transmitted), obtained with a development to a gamma of 2.0 to 2.2.[4] In the course of the experiments with various film emulsions, several were tried which had been panchromatized in order to make it possible to obtain the necessary exposure more readily with incandescent tungsten light sources, which are somewhat deficient in blue light. In all these tests, it appeared that the sensitiveness of the panchromatized films to red and yellow light was obtained at some cost in resolution. This is, no doubt, in part due to the fact

* Recently, certain still finer-grained films have shown their superiority, but they have not as yet been put to commercial use.

that the blue light is more quickly absorbed in the emulsion than light of greater wavelength, and therefore does not spread as far. A film whose exposure depends almost entirely on blue and violet light gives the best resolution. It is possible to go further in this direction by the employment of yellow dyed film (duplicating stock). Although excellent resolution was obtained, the yellow dyed film is of inherently low contrast and this factor is unfavorable, so that the net result was not better than that obtained with standard positive stock.

Improvements in optical systems contributed in an important way to making better 16-mm. sound-films. The fine line of light cast upon the film for either recording or reproduction is an optical image of a slit between metal plates. Although the standard 16-mm. microscope objective was not designed for this purpose, it was found from the start to be admirably suited; and tests with a large number of other lenses, some of them specially designed and corrected for minimum aberration for blue light (instead of for the colors for which the eye is most sensitive), revealed no lens appreciably superior to the standard 16-mm.

The most important improvements were in the recording optical systems, especially in the galvanometer. The first Photophone recording systems employed practically standard oscillograph vibrators with mirrors 0.017 by 0.060 inch. In any oscillograph and in a recording optical system employing an oscillograph vibrator, light is scattered at the surfaces of the lenses and by the edges of the mirror. Specially selected mirrors were employed, and the edges blackened in our efforts to decrease the amount of stray light reaching the film. The galvanometer suspension strips were also blackened, for the same reason; but there was an inherent limitation in the extremely small size of the mirror, and it did not appear feasible to increase the size materially in a vibrator of the standard type. Work on a galvanometer of the moving iron armature type had been undertaken by C. R. Hanna, of the Westinghouse Electric & Mfg. Company, and carried on by G. L. Dimmick, of the General Electric Company and later of the RCA Victor Company.[5] A galvanometer was developed having a sensitivity about equal to that of the standard oscillograph vibrator (same angle of deflection for equal watts supplied), and carrying a mirror 0.100 by 0.125 inch, or over ten times the size of that used in the former type of galvanometer. Better selection and placing of some of the lenses and the development of a better lamp contributed to the working out of an optical system having much less stray light than had been previously possible. The reduction in stray light helps to avoid fog and loss of contrast in the film record, while the increase in the total amount of available light, due again principally to the large mirror, makes it possible to obtain adequate exposure with a narrower slit image at the film. Whereas the first recording systems produced an image 0.001 by 0.060 inch, it is possible with the new optical systems to get plenty of exposure with an image only 0.00025 wide. It has already been pointed out that the width of this slit image or line of light is one of the important factors causing loss of resolution.

Although the building up of commercial 16-mm. libraries, by the process of recording the sound directly on the edge of the film, was undoubtedly feasible, commercial film laboratories foresaw difficulties in introducing equipment of a distinctly different type and calling for a personnel of somewhat different training from that required to operate their standard printing equipment. The fact that it was now possible to make better sound negatives rendered it possible to revert to the system of contact printing and still obtain prints which were considered of adequate quality. Improvements were also made in contact printers.[6] The process of direct recording was therefore not widely applied. Another method of making the 16-mm. prints, however, has shown even better results than the direct recording; and since it is purely a printing process, it is not open to the objections made to the direct recording, namely, to optical reduction of the sound-track from 35-mm. negative.[7,8] Early tests on optical printing had appeared to indicate that it was slightly inferior to the best contact printing. There are two factors, one favorable and one unfavorable. In a contact print all the light which gets through the film is effective in exposing the print. In an optical printing system, on the other hand, the lens subtends only a small solid angle from the negative and collects only the light which emerges in nearly the same direction as it strikes the film. In other words, the lens receives little except specularly transmitted light, and the scattered light is discarded. Since the fraction of the light which is scattered is small in the thin portions, and much greater in the denser regions, the result is that an optical printing system increases the contrast as compared with contact printing, and increased contrast is desirable in variable-width sound recording. Imperfections in the optical system, on the other hand, tend to cause loss of resolution, and the success of an optical printing system as compared with contact printing would depend on minimizing these optical imperfections. The inequality in the reduction in the lengthwise and crosswise directions calls for a special optical system. The width of the sound-track on a 35-mm. film is 0.070 inch while that on the 16-mm. film is 0.060 inch. Thus a reduction in the ratio of 6 to 7 is called for in the transverse direction. In the other plane, the reduction should be in the same ratio as the relative speeds of the films, in order that the image of the negative may move exactly with the 16-mm. film. This calls for a 2.5 to 1 reduction. Several optical reduction systems were worked out, employing cylindrical lenses or combinations of cylindrical and spherical lenses. In these, it was important to employ the cylindri-

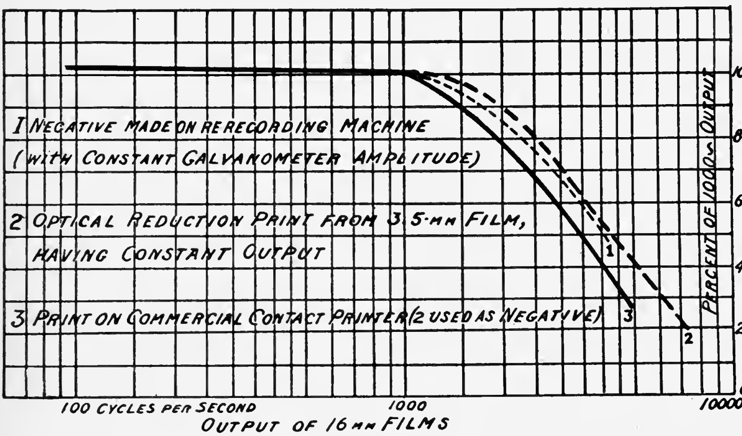


FIG. 3. Characteristics of films made in different ways.

cal lenses (which are available at present only in very simple form) in such a manner that their imperfections resulted in least impairment of the image, while the image in the critical direction (line width) was formed primarily by the highly corrected spherical lens. Variations in the film length due to shrinkage would result in slight departures from the 2.5 to 1 speed ratio, but if the image has to follow for an extremely short distance, the slight creepage of film with respect to the image cast upon it becomes negligibly small. The optical systems employed gave sufficiently intense light so that exposures could be obtained while the 16-mm. film travels 0.005 inch or less. The factor which gives optical sound printing of 16-mm. films from 35-mm. negatives a big advantage over contact printing is that the printing can be done with an almost perfect negative. On the 16-mm. film there does not at present appear to be much hope of usefully recording frequencies higher than 4000 or 5000, and in records of these frequencies, the fogging is such as to cause a loss of output of the order of 50 per cent. On the other hand, a 35-mm. film does not encounter the same difficulties until a frequency of the order of 10,000 is reached, while at 4000 cycles a well recorded 35-mm. negative shows practically no fogging or filling in. The difference is qualitatively illustrated in Fig. 1. It was therefore possible to project upon the 16-mm. raw stock an image of a 4000-cycle wave which had almost the quality of the 35-mm., 4000-cycle negative; whereas, with a contact print the image could be no better than the 16-mm., 4000-cycle negative. Fig. 3 shows the output obtained from 16-mm. films produced by optical and contact printing and by direct recording. It is seen that the optical printing gives even better results than the direct recording. It is, of course, not possible to introduce any compensation for loss of high frequencies in the optical reduction printing, but it has been found unnecessary if we start with a really good 35-mm. film; and it is also better to reduce an imperfection or loss than to compensate for it. Should it appear desirable in special cases to introduce compensation, this is still possible by making a new 35-mm. negative by re-recording from the original.

DEVELOPMENT OF A PROJECTOR

The popularity of "talkies" in the theaters soon led to endeavors to provide sound for 16-mm. pictures. As was the case with the 35-mm. film, the first equipments offered to the public employed disk records. The advantages of having the sound on the film, however, were so great that it needed only to be established that adequate sound quality was attainable to cause the 16-mm. development to follow the same path and abandon the disk.

As soon as the more pressing problems in the development of 35-mm. sound systems had been worked out, a number of engineers undertook the development of 16-mm. sound pictures with the sound recorded on the edge of the film. Reproducing optical systems and photocell arrangements already developed for 35-mm. films were, of course, applicable to 16-mm. projectors, and there was not a great deal of chance for improvement in the optical systems so far as performance was concerned. Developments centered rather around various practical expedients for simplification or reduction in size.

Only a few of the many problems encountered and expedients employed will be mentioned.

Before a projector could be built, it was necessary to decide where to put the sound-track. Simply scaling everything down in the 2.5 to 1 ratio is the most obvious expedient; but it would be very undesirable to narrow the track in the same proportion as the picture frame size because the amount of light which we can send through the 35-mm. track is none too much, and narrowing the track would mean a proportional reduction. Narrowing the track also aggravates the ground noise problem. Furthermore, tolerances in sidewise play of the film[9] can not practically be reduced very far below those necessary for the 35-mm. film, so that either the sound-track or the picture, or both, would have to be narrowed down more than in proportion to the available width between sprocket holes, and the change in shape and size of the 35-mm. picture frame which had been made to accommodate the sound-track was conceded to have been unfortunate. The alternatives were to adopt a wider film, or else to omit one row of sprocket holes. The adoption of a wider film would have meant that our machine could not project present standard silent pictures. The omission of one row of sprocket holes was therefore the preferred solution, provided it did not risk reliability or film life. The success of a number of commercial cameras and projectors whose intermittent claw movements engaged the perforations only on one side was sufficient answer to this question; and with further encouragement by experienced engineers of the film companies, our engineers adopted this plan.

An interesting solution was found for the problem of lighting the exciter lamp without introducing hum. Engineers in sound picture work are quite familiar with the fact that lighting the lamp of a photoelectric reproducing system with alternating current results not only in hum but an objectionable modulation of the audio frequency output, although the fluctuations in light are entirely too small and rapid to do any harm for visual purposes. The use of steady direct current, of course, avoids this trouble. Batteries were not to be considered. Lamps suitable for reproducing systems call for low voltage and relatively high current. Rectifying and filtering the supply would call for extra equipment, which would be rendered all the more bulky and heavy because of the difficulties of filtering a low-voltage high-current supply. On the other hand, the rectifying and filtering system already required for the amplifier could supply the additional power needed for the exciter lamp, but at high voltage and low current. This high-voltage direct-current supply furnished the plate circuit power for a 10,000-cycle oscillator. An extremely simple and light 10,000-cycle transformer steps down the voltage to a value suitable for the exciter lamp.

COMPACT OPTICAL SYSTEM

The optical system employed for 35-mm. projectors is objectionably large and calls for a 75-watt lamp, which presents a heat dissipation problem as well as calling for a large amount of power. These factors are of no serious consequence in a theater installation, and the 35-mm. optical system, although very inefficient in utilizing light, represents about the best we know how with regard to light intensity and perfection of image. A system in which no slit is used, but in which the lamp filament itself is imaged upon the film, is far more economical. One of the arrangements which had some time ago received consideration was to employ a straight filament and image it by a standard spherical lens upon the film. It is practically impossible, however, to meet the requirement that the filament should not deviate from a straight-line perpendicular to the direction of film travel by more than a small fraction of its own diameter. A cylindrical lens, however, will produce a straight line of light from any concentrated source. In the present case, the lamp has a helical filament, approximately 0.008 inch outside diameter, imaged upon the film by a cylindrical lens, with a reduction ratio of $^1/_{10}$. The length of the helix parallel to the axis of the cylindrical lens influences only the brightness of the line of light. The hot part of the helix is about $^1/_{16}$ inch long. If the helix is not parallel to the cylindrical lens axis, the image is widened. It has been found feasible to obtain lamps in which the variations in filament angle are well within the limits required to prevent serious widening of the image. Following a suggestion made by Prof. A. C. Hardy, in connection with a different optical problem, advantage has been taken of the fact that the cylindrical lens may be of shorter focus and placed closer to the film than would be feasible with a spherical lens system, and the impairment of image quality as a result of lens aberration is correspondingly reduced. It is difficult to get cylindrical lenses in any but the simplest form. The lens we are using for these projectors consists simply of a short cylindrical glass rod, one side of which is ground flat. In spite of the crudity of a lens of this type, deviations of the light rays from the ideal directions do not spread the image appreciably, because the misdirected light rays have such a short distance to go. The employment of a very short focus cylinder means that the lamp is also brought moderately close to the film and the entire optical system is reduced in dimensions. Fig. 4 shows approximately the relative size of the 16-mm. and 35-mm. optical systems. The lamp operates on $^3/_4$ ampere at 4 volts. It is, of course, not feasible to operate a lamp of this rating at as high a temperature as the 10-ampere lamp used in the larger system, and the light intensity is correspondingly reduced, although this loss

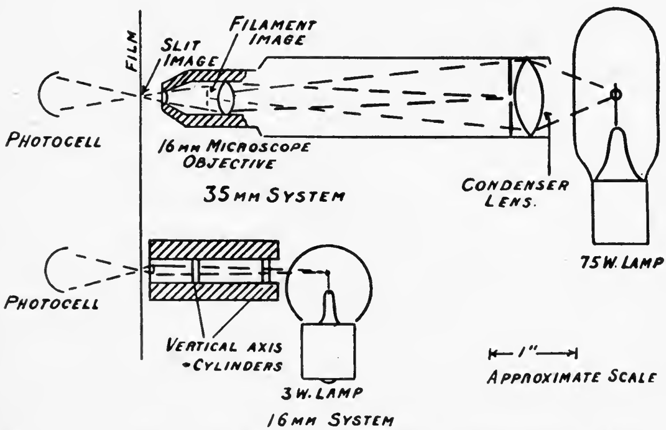


FIG. 4. Relative sizes of the 16–mm. and 35-mm. optical systems.

has not proved serious. An amplifier system has been worked out which is built into the projector unit. The amplifier is so compact that it hardly necessitates any increase in the size of the case above what would be required for the projector itself.

Self-threading has been advocated by many for amateur projectors. Several successful self-threading laboratory models were worked out, employing a number of ingenious devices, but self-threading inevitably means more mechanism, less accessibility, and usually special reels, and the argument for it is based upon the supposition that manual threading is difficult or tedious. Making the manual threading simple and easy is, we believe, a better solution. Self-threading machines have been available for silent pictures for some time but have not been in great demand, and the situation is not made materially different by the addition of sound, for anyone who can thread film into a picture gate with proper loops can certainly perform the much simpler operation of threading a sound element.

The form in which a 16-mm. sound picture system should be offered to the public has been the subject of much difference of opinion. The idea that a complete equipment should be in one cabinet which should be a handsome piece of furniture makes a strong appeal, and a number of manufacturers have built equipment along these lines principally employing disks for sound reproduction. While there is unquestionably a field for units of this kind, they would necessarily be considerably more expensive and have several serious limitations. A single-unit device takes up considerable room and may present more serious problems to the housekeeper than a three-unit outfit (projector, loud speaker, and screen) which can be readily set up when

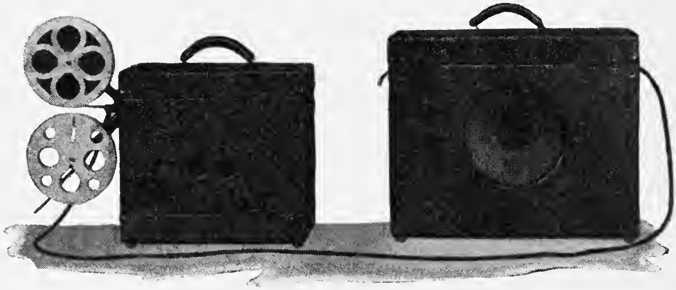


FIG. 5. Complete 16-mm. reproducing equipment.

wanted and be taken away between times. The single-cabinet equipment would also call for a short-throw projection system, and the picture size is limited. One of the most serious objections to the one-cabinet system is that the inevitable projector noise comes to the listener from the same direction as the sound from the loud speaker. We have all observed how much more readily we may concentrate upon a desired sound and ignore a disturbing noise if the latter comes from a different direction. The equipment described here is thus designed for giving the best possible show, and the fact that it must be set up when wanted and taken down between times is compensated by the simplicity of setting it up. Fig. 5 shows the projector and loud speaker cases.* A very convenient and efficient

* A new model is now available having all the features discussed above, but with increased screen illumination and sound output as well as a number of other improvements.

screen is provided which can be set upon a table and unrolled. The loud speaker unit should be placed as close to the picture as possible, usually directly below but somewhat raised from the floor. A 25-ft., 4-conductor cable carries the field and voice currents from the projector-amplifier unit to the loud speaker. The size of the speaker box is dictated by acoustical considerations. The spare space in the speaker box is made available for carrying films, cable, and spare tubes.

REAL HOME MOVIES

Important commercial development of 16-mm. sound pictures would be assured even though all the films had to be taken originally on 35-mm. film and then reduced to 16-mm. The cost and complication of this method of making films would be justified in view of the quality of films that can be made by this process for film libraries (most of the subjects for which are already available on 35-mm. film) for entertainment and education and for commercial demonstration and advertising. The real fun in home movies, however, would be for the amateur to make his own pictures, with his own family and friends as the actors, or for the traveller to record his thoughts and impressions while he takes pictures of various scenes.

Considering the formidable array of equipment which motion picture producers have had to purchase or lease to do their work—the staffs of picture and sound experts, the gigantic sound stages with elaborate sound-proofing and tons of sound absorbing material—what hope could there be of supplying the amateur with simple and cheap equipment of extreme portability, with which he could, without any other special facilities, take satisfactory talking pictures of inexperienced actors?

No story of the development of amateur sound pictures by the RCA Victor Company would be complete without recognition of the important part played by C. N. Batsel.[10] While his associates were struggling with making 16-mm. films by reduction from 35-mm. records, Mr. Batsel, feeling that the 16-mm. system would never be complete until people could take their own home movies, had visions of a complete equipment so simple, compact, and portable that its possession and operation would be within the reach of ordinary nonprofessionals. Without the encouragement, or much optimism on the part of others, Mr. Batsel began working with an adaptation of an existing Bell & Howell camera. Fitting a sound system into a camera not designed for the purpose involves either compromises or greater difficulties than making a completely new design; but in spite of this Mr. Batsel, with his roughly modified Bell & Howell camera, made sound recordings of sufficient quality to make us all recognize that the objective was by no means unattainable. On the strength of these results, a complete camera and recording system was constructed, which brought the project a step nearer to realization. The recording camera was in the form of a brass box about 4 by 8 by 10 inches, weighing about 15 pounds. Amplifier and battery were carried in a case about 6 by 12 by 18 inches, and a camera tripod, a collapsible musician's stand for microphone support, and about 25 feet of three-conductor cable completed the equipment. One man could carry it all, and set it up for operation in less than two minutes. The camera and recording element were driven by a standard phonograph spring, and a phonograph governor was employed to control speed. The recording optical system was the same in principle as the one Mr. Batsel had used. A 3-watt lamp of the kind used in the projectors has its filament imaged by a small condenser lens on the mirror of a magnetic galvanometer; and this, in turn, is imaged on the film by a $^1/_8$-inch focus cylindrical lens to form a line of light about 0.0008 inch wide. Rotation of the mirror shifts the end of this line of light, thus exposing more or less of the width of the sound-track. The system is like that of a standard oscillograph, but on a very small scale.

The brass box camera equipment served to try out the field of amateur movies to ascertain how serious were the acoustical problems, how consistently the equipment would work, and whether extraordinary skill would be required. One of the factors that turned out most fortunately was that for outdoor pick-up the only difficulty was that of finding adequate freedom from disturbing noises. The huge specially constructed stages of Hollywood are necessary for making indoor pictures, at any time of day or night, independently of what is going on in the neighborhood. But in a quiet suburban or country district, a still more perfect sound stage (acoustically) is obtainable without building anything at all. Whereas in an ordinary room the microphone can be hardly more than from one to two feet away from the speaker without ruining the record, we could get distinct speech in a quiet place out-of-doors at distances up to 15 feet or more. A microphone lacks the power of concentrating upon sounds coming from certain directions which a human being with normal hearing possesses, and must be placed much closer to the sound source than one would expect in view of ordinary listening experience. Satisfactory recordings were made out-of-doors so long as the sound reaching the microphone was loud enough to give good modulation on the film. If the persons taking part could remember not to let their voices fall to too low levels, the microphone could be placed far enough away to be out of the picture. Special interest is attached to making sound pictures of children. Children's voices are, in general, harder to record than adult's voices, and it is more difficult for them to keep between reasonable limits of loudness and faintness. A number of excellent pictures of children were made, however, in which the parents, at least, have taken extreme delight.

The experience gained with the brass box camera model was sufficient to demonstrate beyond question that the amateur sound picture was practicable. Up to this point the films had been developed as negatives and contact printed, but for general applications it was felt that the reversal process should be followed. The recording of sound as well as pictures upon a reversal film brought new requirements, but after extended tests the Eastman Kodak Company, whose coöperation in this development has been very complete, found it possible to furnish a reversal stock and process it so as to give the same excellent pictures that are possible in silent motion pictures, and a sound-track superior to that obtained with a negative and print. Fortunately for the amateur, the singly perforated reversal sound stock with its processing will cost him no more than the present silent pictures.

AUTOPHONE CAMERA

Although there was no longer any question as to the practicability of amateur sound pictures, there were differences of opinion as to what would be the most important field for such equipment. It was held by some that the greatest demand would be on the part of people taking trips or travelling in foreign lands, not necessarily to record the sounds made by the subjects of the picture but to record their own comments, descriptions, and explanations. Mr. G. L. Dimmick had at this stage of development demonstrated an extremely simple device with which he had been experimenting, in which the mirror was caused to vibrate by connecting it directly to an acoustically actuated diaphragm. In this Mr. Dimmick revived the principle of C. A. Hoxie's "pallophotophone," which R. P. May had proposed to use in our portable sound recording equipment. Such a device might be substituted for the magnetic galvanometer which we had been using, and would of course require no microphone or amplifier. This appeared to offer the possibility of a still simpler, lighter equipment for use by travellers and for similar service. It was necessary, of course, in order to impart adequate movement to the mirror, to place the mouth quite close to the diaphragm as in talking into an ordinary telephone transmitter, and this precludes recording the speech of the person in the picture; but a recording camera might be constructed in which the mouthpiece was in the back of the camera and the operator could himself talk while looking through the finder and running the camera.

The development of a recording camera for this service brought in a number of new problems. In the first place, the person using the camera would not wish to bother with the tripod or to stoop over to the level of the tripod, as would be practically necessary if he employed a tripod. The camera must therefore be light, convenient to support in one's hands and hold before one's face for a reasonable time without causing weariness. It must also be small enough not to occupy undue space in one's baggage. Complete redesign of the camera mechanism was necessary to meet these new requirements. The utmost simplification of mechanism and lightening of parts was necessary. A number of the detail problems will be mentioned. Obviously, if a sufficiently light and compact camera could be worked out for this autograph service, the same general design might be employed, with the substitution of a magnetic galvanometer and the addition of a separate microphone and amplifier, for general sound picture work.

Messrs. G. L. Dimmick and L. T. Sachtleben undertook the further development of the acoustical recording device or "autophone element." One of the problems consisted in causing very small movements of the actuating device to result in relatively large rotations of the mirror. The same problem exists in the magnetic galvanometer, which for this purpose employs a knife-edge on the armature, registering with a groove in a bar which is pivoted by means of strips of phosphor bronze under tension, as shown in Fig. 6. The closer together the stationary and moving pivots or hinge points, the greater will be the mirror rotation for a given armature movement. The center of the effective pivot produced by the bronze strips is only 0.020 inch from the knife-edge, and at this distance a movement of $^1/_{6000}$ of an inch results in a rotation of 0.5 degree, which, in the optical system employed, is sufficient to give full modulation of the light on the film. In the case of the autophone, a double knife-edge construction was employed, the bar which carries the mirror being of a diamond-shaped cross-section, with the two edges 0.020 inch apart. The mirror is 0.100 × 0.125 inch. In order to secure adequate sensitivity, it was of course necessary to make the diaphragm very light; but at the same time the central part must be stiff enough to transmit the forces applied by air pressures from all parts of the diaphragm to the pin which rocks the mirror, and the diaphragm must be reasonably rugged. Aluminum alloy diaphragms of various thick-

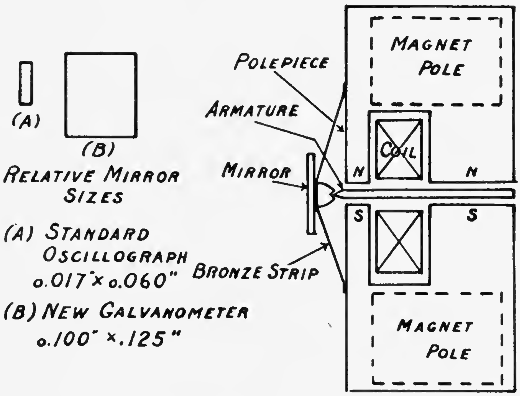


FIG. 6. Features of magnetic galvanometer.

nesses and forms were tried, a diaphragm finally being chosen of 0.0016-inch aluminum alloy, the central portion being stiffened by concentric corrugations, while the outer edge is made as flexible as possible. Such a system necessarily shows a fundamental resonance, the frequency of which is determined by the diaphragm stiffness and the mass of the diaphragm plus its loading by the mirror. Damping of the resonance is obtained by inclosing the air-space behind the diaphragm, except for suitably sized holes covered with a fine porous paper. It was found possible to build up the sensitivity of the device in certain frequency ranges by utilizing broad acoustical resonances. Thus the cavity in front of the microphone can constitute a resonance chamber, with resultant building up of pressure in the neighborhood of the resonance frequency, while the opening of a small air-passage between the front and back cavities gave a resonance in which the maximum pressure variations occur in the back cavity at a much lower frequency.

When one speaks as close to the mouthpiece as is necessary for a device of this kind, puffs of breath produce pressures which are large compared with those due to actual sound. It was necessary to place screening in the mouthpiece and to vent the space behind it in order to prevent the light from being blown off the sound-track, especially following explosive consonants like *P* and *B*. The screens also serve to prevent the moisture in the breath from collecting on the diaphragm. In view of the extremely small movements of the diaphragm required to throw the light spot all the way across the sound-track, special precautions were necessary to prevent shifting of the zero position (which should be such that half the track width is illuminated). Inequalities in thermal expansion, for example, may readily throw the light spot off the track, or at least seriously shift its zero position. To prevent this, it was found necessary to construct not only the diaphragm, but its housing and other parts of the structure, of the same aluminum alloy. This measure alone would not have prevented sudden warming of the diaphragm from the breath with consequent shifting of the light spot, but the mouthpiece screen was evidently effective in preventing appreciable warming of the diaphragm by the breath at a rate faster than could be cared for by the conduction of the heat through the diaphragm to its support. A small vent between the screen and the diaphragm proved effectual in preventing trouble from the puffs of breath.

Both sides of the diaphragm must be shielded as well as possible from noise produced by the camera mechanism. To this end the entire autograph element is housed in its own casting, which completely encloses the space behind the diaphragm. Careful design and close tolerances help to minimize the noise of the intermittent movement.

OPTICAL SYSTEM ADJUSTMENTS AND MONITORING

Although it is not expected that adjustments will often be necessary, it is practically necessary to make the galvanometer adjustable, so that the light spot may be properly centered upon the sound-track. In the case of the magnetic galvanometer, this adjustment is accomplished by rotating the entire galvanometer. With the autophone unit this is not feasible, and the adjustment is afforded by making the groove which registers with the stationary knife-edge capable of being moved a very small amount.

Pushing a small shield aside closes the lamp switch and exposes a peep-hole in the side of the camera, through which the light spot can be seen where the light strikes the cylindrical lens aperture. Marks on the aperture plate show when the light beam is properly centered and how far it must move for full modulation. The person operating the autophone camera can readily have some one check his voice level by observing the amplitude of movement of this light spot while he speaks into the mouthpiece. If the microphone is being used, the operator can check the recording level (which is controllable at the amplifier) by watching the movements of the light spot. An additional means of monitoring is provided in the form of a tiny neon lamp on the amplifier, which flashes whenever the voltage applied to the galvanometer exceeds a certain value. The purchaser of a camera is instructed to adjust the loudness level, by properly coaching his subjects and by adjusting the microphone distance or the amplifier volume control, so that the neon lamp flashes occasionally. A telephone receiver is also furnished with the microphone equipment, so that the operator can judge the quality of the sound being recorded. In this connection, it may be said that (although the device is capable of working satisfactorily over a reasonable range of loudness), as in all sound recording, the results are best when the record is made at the maximum loudness level which can be accommodated without overshooting. This does not mean shouting, but it means especially the avoidance of the tendency which many speakers have, of uttering some syllables quite loudly and others faintly. If the person making the record can remember to hold a fairly sustained and uniform loudness and to speak distinctly and moderately slowly, he may feel confident of an excellent record.

One of the most important adjustments in any photographic sound recording system is the focusing of the line of light on the film in order that it may be as fine and sharp as possible. With the optical system employed, the tolerance in the distance which a given lens may be from the film without appreciable impairment of the recording is about plus or minus 0.002 inch. Once a camera has been assembled and properly adjusted, however, there should be no necessity for readjustment. The arrangement for focus adjustment has therefore been designed with a view to production, and checking, if necessary, by a properly equipped service man, rather than for ready accessibility on the part of the owner. The optical system is focused in a jig in the factory, and an adjustable stop pushed into contact with a boss on the jig, and clamped. When the optical system is placed in the camera, the adjustable stop is placed against the sound sprocket bearing bushing, which has an accurate position relative to the surface of the sprocket. The screws which hold the optical system in place are then tightened, with the distance between the objective lens and the surface of the sound sprocket accurately determined by

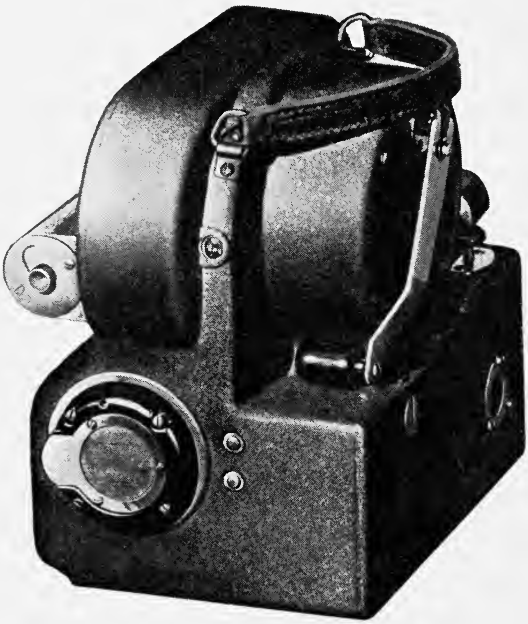


FIG. 7. Autophone camera, showing mouthpiece and finder.

the setting of the adjustable stop. With this arrangement, optical systems are interchangeable in cameras, and changing from autophone unit to magnetic galvanometer or *vice versa* does not upset the focus adjustment.

Fig. 7 is a view of the autophone camera. The finder and mouthpiece are so located that when the operator is looking into the finder his mouth will be opposite the mouthpiece. Just to the right of the mouthpiece and optical system is a compartment containing the three No. 2 dry-cells required for lighting the exposure lamp. This autophone camera is without doubt the smallest complete picture and sound recording system in existence.

GENERAL FEATURES OF THE RECORDING CAMERA

Fig. 8 shows the sprocket and gate arrangement and the path of the film through the camera. The picture gate design is such as to make threading easy, and the shoe can be readily removed to inspect or clean the surfaces. There are no movable rollers or guides, but the film is slipped into place between stationary rollers and the

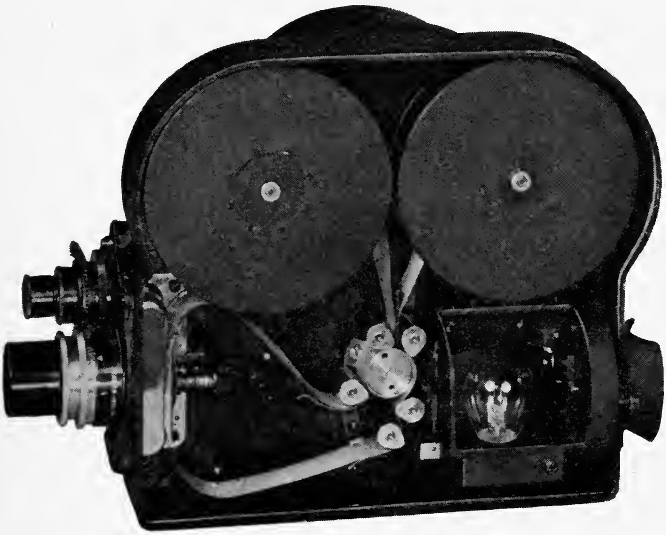


FIG. 8. Sixteen-mm. sound camera, autophone type with covers removed.

sprocket. With the rollers properly placed, we found that this arrangement resulted in greater convenience for threading than a movable roller system.

It is obviously important that the film remain snugly against the sprocket at the exposure point. If the film were under considerable tension, this would not constitute a problem; but where there is little tension on the film, which is a desirable condition for sound sprockets, faulty design often results in a tendency for the film to loop away from the sprocket. A careful study was made of this subject. It was found desirable to restrict the angle of contact to about

90 degrees, and to bend the film back around the guide rollers so that the natural stiffness of the film would tend to hold it against the sprocket. It is this utilization of the natural stiffness of the film which makes it possible to do away with movable rollers. With the arrangement chosen and with a properly dimensioned sprocket, the tooth action is very smooth.

The camera can be loaded in daylight, using the same arrangements that have been employed for the purpose with silent cameras. The take-up reel is driven by gears, with a slipping clutch arrangement which gives more satisfactory action than a spring belt, which has an annoying habit of unwinding some of the film after one has turned the reel to take out the slack.

There are numerous types of friction governors which will hold speed sufficiently closely for silent picture work, but no other type was found comparable with the standard phonograph governor where the close speed regulation required for sound recording is needed. In order that constant speed of the governor may mean constant speed of the film, it is necessary that the sound sprocket be accurate and that the gearing between the two be as simple as possible, as well as accurate. A large diameter gear on the sound-sprocket shaft meshes with a pinion on the governor shaft, and the mounting of the pinion is designed to minimize possibilities of eccentricity. The low-speed gearing between the main-spring and the sound sprocket has not been found to be a source of disturbance, but applies a very steady driving force to the sound-sprocket shaft. The gears on the sound-sprocket shaft are part of the train which drives the highest-speed element, namely, the intermittent movement, and it is necessary to insure that the load of the intermittent shall not react appreciably on the speed of the sound sprocket. The best solution of this problem was found to consist in providing an extra gear on the sound-sprocket shaft which meshes with a pinion on the intermittent shaft, this extra gear being loosely mounted on the sound-sprocket shaft and driven through a spring. The spring incidently serves to absorb the shock from the governor when the camera is suddenly stopped.

Various types of footage counters were tried in preliminary models. The type finally chosen was one which, in effect, measures the radius of the roll of film on the supply reel. Although other types of footage counter may give more accurate readings, this has the merits of reliability and simplicity. Most other types have to be reset when a new film is put in the camera. A good feature of this type of footage counter is that the accuracy of the indication becomes greater toward the end of the reel when the operator must watch his available film most closely.

It is more important with sound recordings than with silent pictures to be able to make a reasonably long run without stopping to rewind, since discontinuities in sound are more serious. To obtain the maximum length of run, the camera must take as little power as possible and the driving spring be as large as weight and space will permit. The present design provides for running 25 feet at one winding. Although a greater length might be considered desirable,

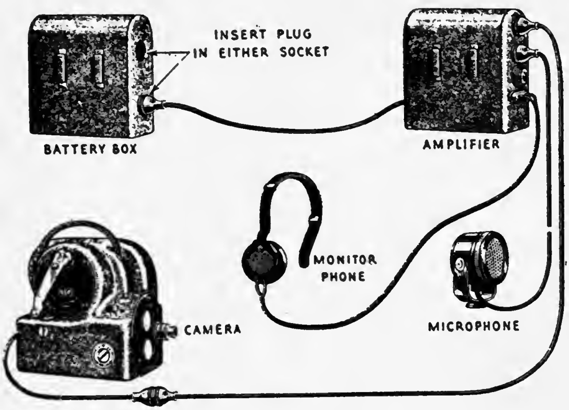


FIG. 9. Complete amateur sound picture recording equipment.

this would mean added weight and bulk, and amateur picture producers would wish, with few exceptions, to make their shots short. A definite stop is provided so that the camera comes to an abrupt stop rather than being permitted to run when the spring is so far unwound that the speed might fall and the sound quality be ruined.

Careful studies of battery life were carried out to make sure that the small cells, which are necessary to keep the weight down, would give the required service without too much drop in voltage for maintaining amplifier output or, what is still more critical, for maintaining the exposing lamp within proper limits of brightness. The battery box carries duplicate batteries, which may be alternated when making pictures of considerable length. The switching arrangement in the camera is such that the exposing lamp is lighted only while the camera is running or while the shield is held aside for monitoring. The operating button may be locked in the running position if desired. This permits the operator to center his attention upon other matters more completely, or to step into the picture.

The finder is like a telescope in form but employs a concave objective and a magnifying eyepiece. This gives an image of reduced size, but very clear and bright. The finder is placed as close to the photographic lens as possible to minimize parallax. A parallax adjustment is provided for use when the subject is less than five feet from the camera.

FIG. 10. Sixteen-mm. sound camera equipment set up on tripod.

A three-lens turret is provided. This adds little to the cost of the camera if only the general-service universal-focus lens is wanted, but leaves open the possibility of special lenses for high-speed or telephoto work. Three rectangles are engraved in the finder, which show the fields included with the standard 1-, 2-, and 4-inch focus lens, respectively. In order that adjustable-focus lenses may be set to give maximum sharpness, a place is provided where a critical focusing device may be added. The turret is turned so as to bring the lens to be adjusted opposite the focusing position, where the image can be viewed through a magnifying eyepiece. The turret is then turned back and the lens will be in accurate focus on the film.

All sound records must be made at the standard speed of 24 frames per second, but in the case of silent shots some saving of film results from operation at lower speed, and the camera is therefore designed with a two-speed adjustment permitting operation at either 16 or 24 frames a second.

Fig. 9 shows the complete equipment, with microphone and amplifier. If maximum mobility is wanted the amplifier and battery boxes can be carried on a belt and the camera in the hands. For general purposes it is more satisfactory to mount the amplifier and battery box on the tripod with the camera, as shown in Fig. 10.

ACKNOWLEDGMENT

The developments described in this paper have engaged the thoughts of many of our engineers and members of the sales staff, and the desirability of various features has been checked by extended trials. While it is impossible to give appropriate credit to all who have contributed, mention should be made of the contributions of A. C. Blaney, in his studies of film emulsions and processing; of A. Shoup, in working out the efficient and compact amplifiers; of R. P. May, R. L. Hanson, H. C. Holden, and B. L. Hubbard in the projector development; G. L. Dimmick and L. T. Sachtleben in working out many of the optical and related problems; C. N. Batsel and I. J. Larson in devising the mechanical features of the camera; and A. G. Zimmerman in adapting its design to manufacture.

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SOCIETY ANNOUNCEMENTS

PACIFIC COAST SECTION

The Annual Election Dinner of the Section was held on December 13, followed by the announcement of the successful candidates for Section offices for 1935. The results of the election were as follows:

Chairman: G. F. Rackett
Sec.-Treas.: H. W. Moyse
Manager: K. F. Morgan

The second Manager of the Section is W. C. Harcus, whose term expires Dec. 31, 1935. Mr. E. Huse remains a member of the Board of Managers as *Past-Chairman*, in addition to holding the post of *Executive Vice-President* of the Society for 1935.

Following the elections and other business, the prize-winning 16-mm. films selected by the American Society of Cinematographers for 1932, 1933, and 1934 were shown, followed by a showing of unusual 8-mm. films.

ATLANTIC COAST SECTION

The usual monthly meeting was held at the Hotel Pennsylvania, New York, on December 19, at which time Mr. W. B. Rayton presented a tutorial paper on the subject of "Lens Design." The paper was non-mathematical, its purpose being to present the subject in a manner understandable by those whose profession is not that of optics, although it contained much information of value to experts.

The results of the annual election of officers of the Section for 1935 were as follows:

Chairman: L. W. Davee
Sec.-Treas.: D. E. Hyndman (reëlected)
Manager: H. Griffin

The second Manager of the Section is M. C. Batsel, whose term expires Dec. 31, 1935. Mr. H. G. Tasker remains a member of the Board of Managers as *Past-Chairman*, in addition to holding the post of *President* of the Society for 1935.

BOARD OF GOVERNORS

The next meeting of the Board will be held on January 11, at the Hotel Pennsylvania, New York, N. Y., at which time the operating budget of the Society for 1935 will be framed, and further arrangements for the Hollywood Convention, to be held on May 20–24, incl., will be made. The new officers of the Society for 1935 will officiate at that meeting for the first time, and arrangements will go forward toward the establishment of the various technical and other committees, and the Sectional Committee on Motion Picture Standardization according to the procedure of the American Standards Association.

SPRING, 1935, CONVENTION

As announced previously, the Spring Convention will be held this year at Hollywood, May 20 to 24, inclusive, with headquarters at the Hotel Roosevelt. Members of the Society are urged to make every effort to attend, and contribute to making this Convention the greatest and most interesting in the history of the Society. The Pacific Coast Section Board of Managers, under the Chairmanship of Mr. E. Huse, is collaborating with Mr. W. C. Kunzmann, *Convention Vice-President,* in arranging the details of the Convention; and the Papers Committee, directed by Mr. J. I. Crabtree, *Editorial Vice-President,* and Mr. J. O. Baker, *Chairman,* promises a most outstanding program of technical papers and demonstrations.

Those members who do not reside in the West are urged to arrange their vacations to coincide with the Convention, in case their business arrangements do not otherwise permit their attendance. Advantage can be taken of the special tourists' railroad rates effective May 15.

PROJECTION PRACTICE COMMITTEE

At a meeting held at the Paramount Building, New York, N. Y., December 12, plans were laid for the work of the Committee during the coming year. Among the various subjects to be considered are the possible recommendations for projection screen brightness, and simple and practical methods and instruments for measuring it; and a complete re-presentation of the projection room layouts and maintenance technic presented in the 1931 report of the Committee, bringing it up to date and in accordance with the latest and most acceptable practice in connection therewith. The earlier report, published in the Aug., 1931, issue of the JOURNAL, has been widely used throughout the industry, and its growing importance has justified and made requisite some revisions in accordance with the changing needs and practices.

STANDARDS COMMITTEE

At a meeting held at New York on December 14, subjects for study and possible standardization in 1935 were considered, among which were: screen brightness; sound sprockets; edge-guiding of film in cameras, printers, and projectors; and camera mechanisms.

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SOME CHARACTERISTICS OF 16-MM. SOUND BY OPTICAL REDUCTION AND RE-RECORDING*

C. N. BATSEL AND L. T. SACHTLEBEN**

Summary.—*Some characteristics of 16-mm. sound by optical reduction and re-recording from 35-mm. film are discussed: by means of loss curves characteristic of the two methods; by reviewing the effects upon the sound quality of compensation for such losses; and by noting the effects, other than simple output loss, that arise in some of the steps of each process.*

Sixteen-millimeter sound is obtainable from 35-mm. film by optical reduction or by re-recording. Many variations of the optical reduction process are possible, since it is wholly an optical-photographic process; but in re-recording it is necessary to work always from a print so prepared that distortions of a photographic nature are eliminated as far as possible, because distortions of a photographic origin can not be compensated for in any way once they have been impressed upon an electrical circuit. In this paper two variations of the optical reduction process are discussed in relation to the standard re-recording process.

The apparatus used in optical reduction printing is an anamorphote optical system imaging the 35-mm. sound-track upon the 16-mm. film in accordance with S. M. P. E. standards, and is described in a previous paper.[1] The films are moved uniformly past the scanning and printing points by a suitable mechanical arrangement that insures against speed variations. When working from an original negative to a final positive print no additional apparatus is required; but when working from a positive, a 35-mm. contact sound printer and a 16-mm. contact sound printer are required for producing the original positive and the final 16-mm. positive after the 16-mm. negative has been produced by optical reduction. Both these variations of optical reduction are discussed in this paper.

In re-recording, the apparatus required comprises a 35-mm. contact sound printer for preparing the print, a 35-mm. reproducing head

* Presented at the Fall, 1934, Convention at New York, N. Y.

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

with optical system, an amplifier, a 16-mm. recording head with optical system, and a 16-mm. contact sound printer for preparing the 16-mm. print.

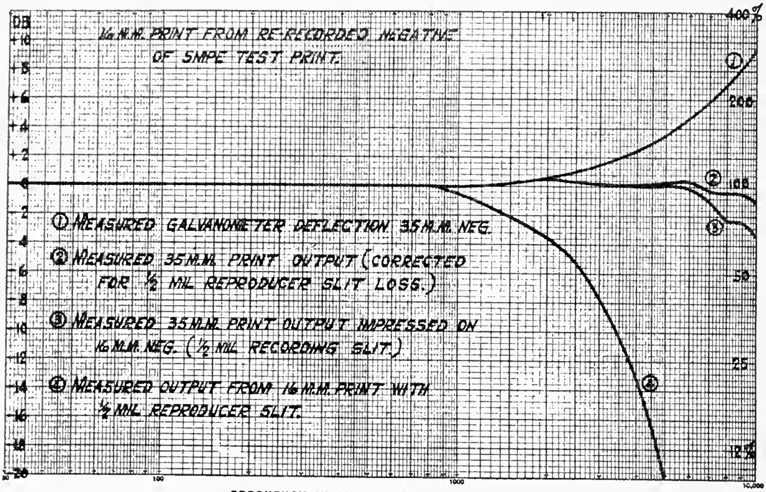

FIG. 1. Frequency characteristics of various steps in re-recording 35-mm. sound on 16-mm. film.

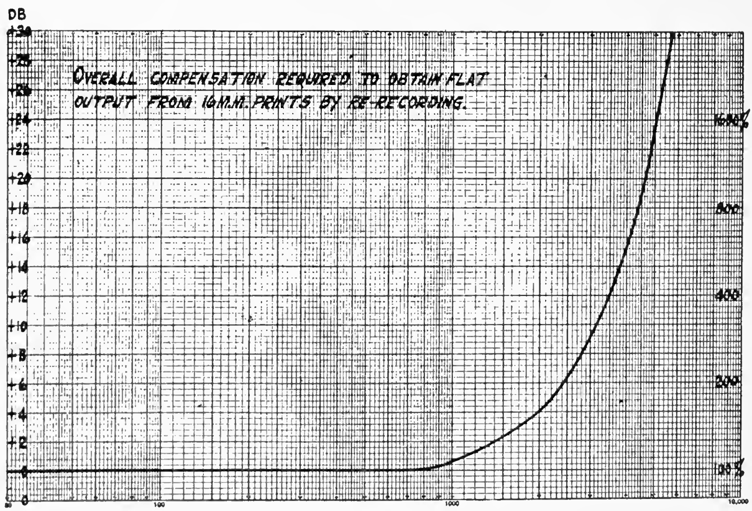

FIG. 2. Over-all compensation required for constant output from 16-mm. prints by re-recording.

The data presented here were obtained during the course of developmental work on both optical reduction printing and re-recording apparatus from frequency films prepared to show the performance of the two systems, and care was always taken so to expose and process the sound-tracks that distortion was kept at a minimum.[2] All recording and reproducing equipment involved in this work, both 16-mm. and 35-mm., used $^1/_2$-mil recording and reproducing slits, and the data are therefore based upon these values. Only the variable-width system was employed.

Considering first the re-recording process, the sound is electrically reproduced from a properly prepared print of the original 35-mm. negative, amplified, and fed into a 16-mm. recording system, to pro-

Step	*Accrued loss at 5000 cycles*	
35-mm. Negative	4.3 db.	39%
35-mm. Contact Print	3.3	32
35-mm. Reproducer	3.5	33
16-mm. Negative		
16-mm. Contact Print	21.6	92
16-mm. Reproducer	23.6	92.5

FIG. 3. Steps and losses in re-recording 35-mm. on 16-mm.

duce a 16-mm. negative from which the final properly prepared 16-mm. print is obtained. Six definite steps with associated losses are involved before reaching the loud speaker of the 16-mm. reproducer.

Losses occur in the 35-mm. negative due to the finite width of the recorder slit and due to certain film characteristics. A slight gain occurs in making the 35-mm. print. Correcting for reproducer slit loss, the total loss incurred in recording and producing a print of the 35-mm. negative is determined by subtracting curves *1* and *2* of Fig. 1, which are the response curves of a 16-mm. print of the S. M. P. E. test print by re-recording. At 5000 cycles, this loss amounts to about 3.3 db. A further loss results from scanning the print with a finite slit, bringing the total loss to about 3.5 db. This same series of losses is repeated, wavelength for wavelength, in recording, printing, and reproducing the 16-mm. sound record, resulting in the response curve *4* of Fig. 1, which shows the over-all loss, and therefore the over-

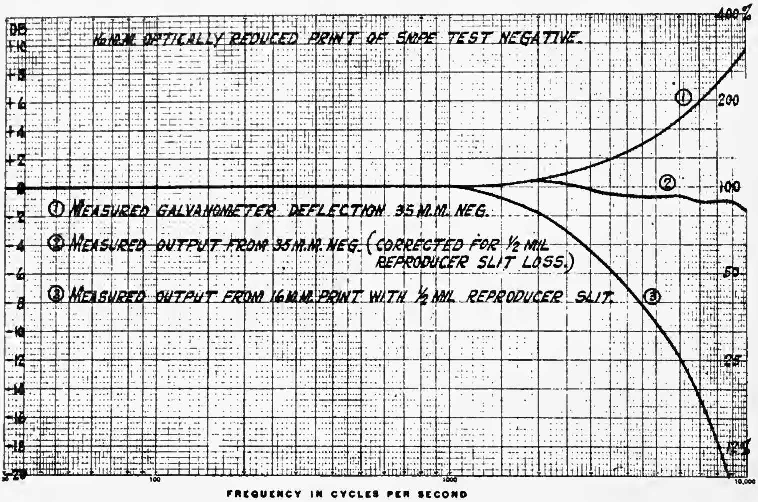

FIG. 4. Frequency characteristics of various steps in optically reducing 35-mm. sound to 16-mm., working from the negative

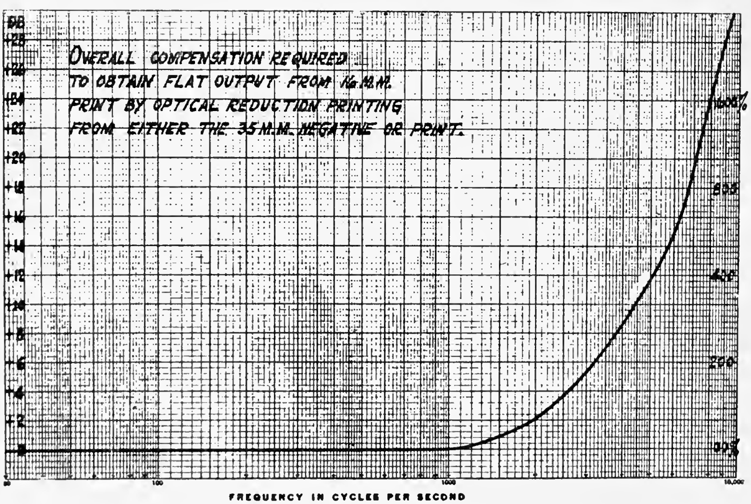

FIG. 5. Over-all compensation required for constant output from 16-mm. print by optical reduction from either the 35-mm. negative or the print.

all requisite compensation at 5000 cycles, to be 23.6 db. Fig. 2 is the over-all compensation curve required in re-recording, and Fig. 3 is a block diagram of the steps involved in re-recording and the accrued losses at the end of each step, for a frequency of 5000 cycles.

When printing the 16-mm. sound-track by optical reduction from the original 35-mm. negative, using the anamorphote optical system, only three loss-producing steps are involved. The 35-mm. negative is prepared as for re-recording, but no steps involving reproducing or recording losses intervene between it and the final 16-mm. print, because it is produced by optically imaging the 35-mm. negative upon the 16-mm. emulsion in the ratio of the normal speeds of the two films as they pass uniformly through the printer. (In the transverse plane, the 35-mm. negative is optically imaged upon the 16-mm. emulsion in the ratio of the standard widths of the two sound-tracks.)

Step	*Accrued loss at 5000 cycles*	
35-mm. Negative	4.3 db.	39%
16-mm. Optical Reduction Print	10.6	70.5
16-mm. Reproducer	12.6	76.5

FIG. 6. Steps and losses in optical reduction printing 35-mm. to 16-mm., working from the negative.

Fig. 4 is the response curve of an optical reduction print of the S. M. P. E. test negative, and shows an over-all loss of 12.6 db. at 5000 cycles, including the final reproducer scanning loss. Fig. 5 is the curve of over-all compensation required in optical reduction printing from a 35-mm. negative, and Fig. 6 is a block diagram of the steps involved and the accrued losses at the end of each step, at 5000 cycles.

The superiority of 16-mm. prints made by this process lies not only in the improvement in the frequency response indicated by these results, but in eliminating the contact printing steps that always introduce a certain "fuzziness" into the print as a result of slippage and poor contact between the negative and the raw positive stock.

The optical reduction process may be varied so as to work from a 35-mm. print rather than from a negative, in which case a 16-mm. negative is first obtained by optical reduction, from which a 16-mm. print is subsequently made by contact printing. Five steps, introducing losses, are involved before reaching the reproducing loud speaker. By examining Fig. 7 it is seen that the final response of the 16-mm. copy of the S. M. P. E. test print does not differ appreciably from that of the optically reduced print of the S. M. P. E. test negative.

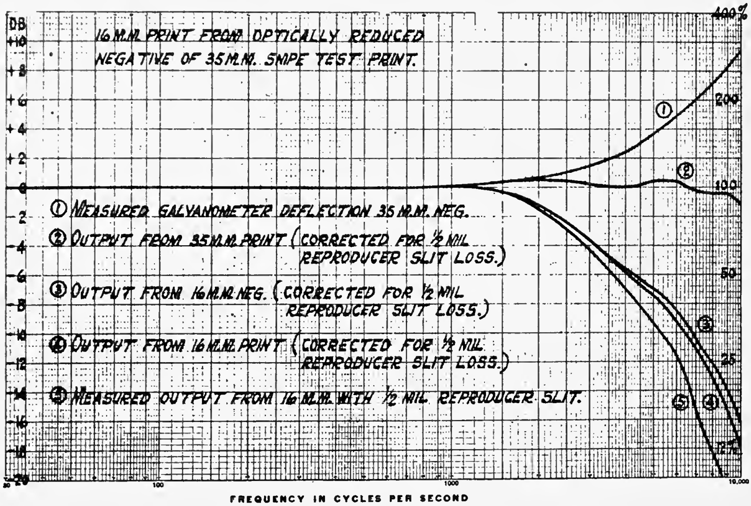

Fig. 7. Frequency characteristics of various steps in optically reducing 35-mm. sound to 16-mm., working from the print.

Step	*Accrued loss at 5000 cycles*	
35-mm. Negative	4.3 db.	39%
35-mm. Contact Print	3.3	32
16-mm. Optical Reduction Neg.	10.7	71
16-mm. Contact Print	11.1	72
16-mm. Reproducer	13.1	78

Fig. 8. Steps and losses in optical reduction printing 35-mm. to 16-mm., working from the print.

This should be expected, since the first step, that of contact printing the 35-mm. negative, results in a gain in response over the negative, which probably offsets subsequent losses in printing the 16-mm. optically reduced negative, the wavelengths of which are much shorter. It is obvious that the over-all compensation required for either variation of the optical reduction printing process is the same. Fig. 8 is a block diagram of the steps involved in optical reduction printing from a 35-mm. print, and the accrued losses at the end of each step, both in decibels and in per cent, at 5000 cycles.

To summarize, an examination of the characteristics of 16-mm. sound by optical reduction and re-recording shows that the comparison stands in favor of optical reduction, as producing a better 16-mm. sound record when no compensation is introduced, and as requiring vastly less compensation when the aim is to produce a 16-mm. print having a flat response curve, the difference at 5000 cycles being approximately 12 db., which represents a compensation ratio of 4 to 1. Thus, in producing 16-mm. sound records flat to 5000 cycles from 35-mm. film, the optical reduction process permits the average recorded level of the 35-mm. negative to be greater than that permitted by the re-recording method, depending upon the frequency content of the sound. For this reason, the ratio of distortion introduced by compensating for the higher frequencies to the average signal level will be less in optical reduction than in re-recording.

The gain that optical reduction shows over re-recording lies mostly in eliminating the 16-mm. recording loss, which at 5000 cycles amounts to about 12 db. (equal to the loss of the 35-mm. film at 12,500 cycles). It should be noted that this gain can not be achieved except when the optical reduction is in the true ratio of the speeds of the two films, as in the case of the anamorphote system or a system that reduces the track width also in the same ratio. Reduction optical systems that work near unit magnification and employ fine slits to compensate for the difference of film speed involve in greater or lesser degree the losses inherent in the recording phase of re-recording. This may be readily appreciated when it is remembered that in both cases the 16-mm. sound record is produced by exposing a moving emulsion to a slit image of varying length. In so far as contact printing may be used in the two processes, the effect is about the same.

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BACKGROUND PROJECTION FOR PROCESS CINEMATOGRAPHY*

G. G. POPOVICI**

Summary.—*A process of background projection is described employing a side-guided projector, and a cut-out in the gate permitting images of the edge of the running film and two film perforations to be projected upon the screen simultaneously with the image of the picture, so as to check the steadiness of the picture. Screen illumination requirements, effects of film shrinkage, and pilot-pin registration are discussed.*

Background projection for process photography now used extensively in all motion picture studios is more economical than the Dunning process, the color-separation method, the use of printing masks, and other arrangements. It is probably the simplest process that has yet been devised, and with proper care can produce satisfactory results. It consists in projecting a picture of the desired background, which has been photographed previously, upon a translucent screen, the foreground action of the picture taking place in front of the screen. The foreground objects are so lighted as to balance the screen illumination, and the whole is then finally photographed as a composite scene.

The most important factor involved in the background projection process is steadiness of the picture. To begin with, the negative film used for making the "plate" or "key," which are the names given to the scene to be projected, has to be very accurately perforated, and only fresh stock must be used. Eastman and Du Pont have both developed such an accurately perforated film, having a finer grain with a slightly lighter contrast than the regular negative emulsions, and having approximately the same camera characteristics as the regular Super-Sensitive Panchromatic negative stock.

The camera used for shooting the plates must produce absolutely steady pictures. Its ability to do so depends upon the mechanism of the camera itself and the manner in which the camera operates. A standard Mitchell camera having a shutter opening of 170 degrees

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** Eastern Service Studios, Inc., Long Island City, N. Y.

is used for making the plates, and its steadiness is carefully checked periodically to assure good results.

The prints to be projected present a problem that has not as yet been solved satisfactorily. Due to pilot-pin registration in step printing, shrinkage of the developed negative causes some difficulty. If the pin is designed for the sprocket-hole of fresh positive stock, using the Bell & Howell perforation, during printing the negative sprocket hole will be forced down upon the pin by a slight movement of the finished positive due to shrinkage. No matter how the pin is designed, so long as shrinkage is to be considered some difficulty will always exist. Only unshrinkable stock would be completely satisfactory for pilot-pin registration.

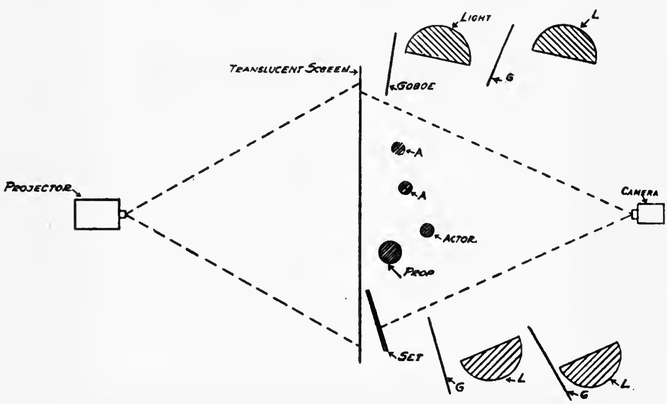

FIG. 1. Set-up of projector, camera, translucent screen, lights, and actors, for rear projection process photography.

Projection of the plate positive has successfully been accomplished in our studios. Contrary to West Coast procedure, we use a side-guided projector, designed by the International Projector Corp. To assure perfect steadiness, the gate and film-trap have been especially designed. The steel guide is hard and has been ground. The tension springs are carefully balanced to assure perfect side-guiding and proper gate pressure. The Geneva intermittent movement is selected for its precision, having no tolerances, and the intermittent sprocket is of the type recently approved by the Society and has also no tolerances.

An ingenious device incorporated in this projector enables the projectionist to check at any time the steadiness of the projected picture. Unsteady projection may be attributed to the print or to the projector. To be able to check one or the other at once, a cut-out is provided in the gate permitting an image of the edge of the running film and two sprocket holes to be projected upon the screen with the picture. If the image of the sprocket holes is steady and the picture image is unsteady, the print is obviously the cause of the unsteadiness. If the sprocket hole image is unsteady, there still remains the question whether the projector is working properly, because instances have been found in which the film had shrunk unevenly, causing the sprocket holes to be unsteady. Such a test should always be made with fresh stock. (It is of vital importance that the projector always be kept clean, because an accumulation of dirt may cause unsteadiness of the projected image.)

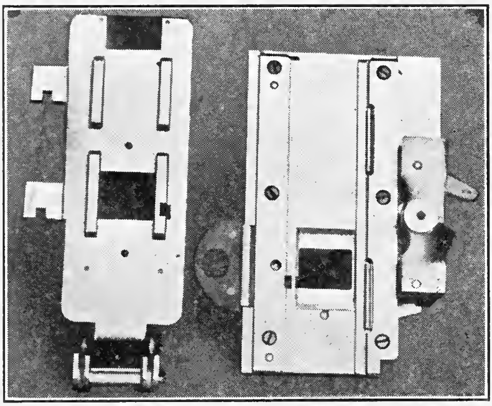

Fig. 2. Projector gate dismantled, showing aperture through which the image of the film perforations is projected.

The advantages of this projector over those employing the claw movements are outstanding. This projector has a shutter opening of 270 degrees, as compared with 180 degrees for the claw movement type. The picture can be framed, whereas with the other type it can not; the intermittent works cold: only the film is exposed to the heat, whereas in the claw type machine the claw and pins are continuously exposed to the heat, and subject to expansion.

The lamp is a Hall & Connolly *HC-10*, of the thermostatically controlled type, using 13.6-mm. positive and 11-mm. metal-coated negative carbons. The current is 165 to 200 amperes. The condensers are standard *5127* for the rear, and *5128* for the front element. The position of the condenser lenses with respect to the arc and projector differs from that in ordinary theater projection, owing to the necessity of eliminating the hot spot which ordinarily would appear upon the screen after the rephotographing.

The projection lenses are the Apermax-Cooke $5^1/_2$-inch $f/1.9$, and the $6^1/_2$-inch $f/2.3$. These lenses proved to be superior to any other lenses tested so far.

In the beginning a Trans-Lux screen was used, having very good diffusion but low transmission, thereby handicapping scenes requiring big picture sizes. However, it proved very satisfactory so far as the hot spot and satisfactory viewing angle were concerned. Later a rear projection screen made by Fox on the West Coast was obtained,

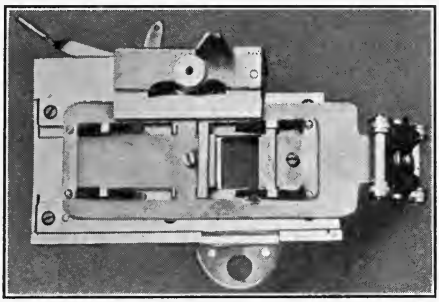

FIG. 3. Projector gate assembled.

having nearly double the transmission of the Trans-Lux screen but a narrower satisfactory viewing angle.

Photographing the plate requires experience and skill on the part of the cameraman in charge. He must visualize in advance what the projected image should be, and looking through the finder of the camera when photographing the plate he must take into consideration the foreground that will be in front of the screen when making the composite scene. Moreover, he must judge accurately the exposure required for a negative density contrast of 0.80 to 0.95 after the film is normally developed.

When buildings or other subjects that must appear steady on the screen are photographed, the camera must stand very steadily upon its tripod, which may have to be tied down. When photographing from bridges, long focal length lenses must be avoided because of the vibration of the bridge. Wind also causes unsteady negatives, and it is suggested that plates be not photographed on windy days.

From the finished negative plate three positives are made: one called "normal," another one printer-light higher, and the third one printer-light lower. From these prints the one best suited to the composite scene is chosen. These prints are special in so far as they are made on a selected step printer. For lining up the scene an ordinary print made on a continuous-running Bell & Howell printer is used. Each work print is preceded by 15 feet of a sharp criss-cross chart to permit focusing the picture accurately.

The actual operation is as follows: Required sets and props are built and erected before the translucent screen. Necessary lighting equipment is approximately placed in position. Plenty of gobos are on hand to shade the screen from light striking the foreground. A projected picture of the approximately correct size is thrown upon the screen. If the size is not satisfactory, lenses are changed or the projection machine is moved to attain the desired result. Then the lighting is balanced by measuring first the light striking the foreground, and then the intensity of the projected light. The measurements are made with the Weston photronic meter.

A final photographic test is made as follows: The foreground is illuminated, an interlocking phase is switched on, and the camera shutter is set to a standard position. Then the clutch of the projector is closed in the corresponding shutter-synchronizing position, and the projector and camera are operated synchronously for about 30 feet of film. From the end of this test-exposure two feet are developed and fixed by hand, and then enlarged on paper so as to show what changes might be required. After obtaining a good test, the scene is finally photographed and recorded.

In conclusion, the author expresses his sincere appreciation to Messrs. L. W. Davee and H. Griffin who coöperated in making this background projection process a success.

DISCUSSION

Chairman Crabtree: In the scene of Riverside Drive, where the girls were seated on the parapet and the boys were going through their antics in front of them, the girls didn't seem to be in the least interested in what the boys were doing. Obviously, if there are any animate objects in the picture when the background scene is shot they ought to be doing what you intend them to be doing in the composite picture.

How are the screens made? Originally ground glass was used, but I understand that most screens consist of fabric sprayed with, say, cellulose acetate or some similar transparent material.

MR. POPOVICI: I am sorry I can not give you any definite information on cellulose screens, because we used only the Fox screen, which, so far as I know, is made by spraying certain materials upon a flat plate of glass, and then peeled and processed in a secret way. As regards the Trans-Lux screen, which was used on the shots you saw today, it is silk impregnated with gelatin with a little color pigment in it. The gelatin is pressed against a matte surface in such a way as to provide a high diffusion factor. The transmission of the screen is, however, very low; the one we have used so far transmits only 17 per cent of the light. The viewing angle decay is very, very small, even enabling us to make shots when running with a camera from the side, or in and out, without difficulty or without any difference of density in the re-photographed image.

On the Fox screen, however, the slightest angle that is introduced between the camera and the projection axis will cause trouble. It is a high-transmission screen, however, transmitting 30 per cent of the light, and enabling one to balance out the front lighting very easily in order to attain a good over-all balance of lighting. The "hot spot" is a little more noticeable on a Fox screen than on a Trans-Lux. That is why we place the projection machine as far as we can from the screen.

MR. MITCHELL: You said that you use the condensers to eliminate the hot spot. Can you give us any details?

MR. POPOVICI: It has been a very empirical procedure. The Bausch & Lomb specifications require that the condenser be set about 14 inches from the projection machine aperture and the distance from the carbon to the condenser lens about 8 inches. I arrived at my settings, as a matter of fact, after much experimenting, measuring the light on the other side of the screen with a Macbeth illuminometer and a Weston photronic meter. I found a large difference between readings made with Bausch & Lomb specifications and our own. The distance between the condenser lenses remains unchanged. The lamp house is pushed back $21^1/_2$ inches, and the distance between the condenser lens and the carbon is only 3 inches, instead of 8.

The projected concentrated spot from the condenser lenses on the aperture is quite characteristic in that a concentrated spot of great intensity covers the aperture, and from that point on, the remainder of the circle, which is not used, is of lower intensity. We try to get collimated light, which would be ideal for that kind of process, but so far we haven't been able to get it with sufficient intensity for all requirements.

MR. FRANK: In most instances are the original outdoor scenes taken specifically for the picture, or do you have a library? Are sound effects ever recorded with the original outdoor scene, or are they always dubbed separately onto the final film?

MR. POPOVICI: There is, so to speak, a small library for outdoor scenes, but we do not use it for shots that have to be steady. We would rather send out a cameraman to shoot a new scene, because the negative has lain quite some time in the vault and has shrunk, and it is difficult to print a shrunken negative. It is cheaper to make the shot anew. For scenes of the kind required for taxicab shots or running automobiles or trains, where steadiness is not required, we use library shots, of course. Synchronizing the sound effect is usually done in dubbing.

Mr. J. Crabtree: I believe those are Bell & Howell perforations on the negative and square perforations on the print. Have you used the same kind of perforations on both negative and print?

Mr. Popovici: We use exclusively the Bell & Howell perforation all the way through.

Mr. J. Crabtree: Is it preferable to the square perforation?

Mr. Popovici: It is, because the print has to be very steady, and running Bell & Howell perforations against Eastman perforations would be quite a difficult task.

Mr. J. Crabtree: But the Society has recommended the adoption of the square kind of perforation throughout.

Chairman Crabtree: The question is why would not the square perforation with the square pilot pin be just as good as the Bell & Howell pilot pin with the Bell & Howell perforation?

Mr. Popovici: It would be, so far as pertains to printing, but in printing there are two sprocket holes to accommodate. The negative has shrunk a small amount, and the positive fresh stock has not shrunk. If you take a positive stock that will fit snugly upon a pilot pin, this undeveloped stock will be too big for the hole of the negative that has been developed and shrunk, and you will have to force the negative over the pilot pin.

Mr. J. Crabtree: That is true irrespective of the type of perforations. Why not measure the pitch of the negative, and perforate the material on which you are going to print it to the pitch of the negative.

Mr. Popovici: That would be one way out. We are designing a printer that has no pilot pin registration. It has only one up-and-down registration to make sure that both holes are registered in the up-and-down way.

Mr. J. Crabtree: My question was put simply to determine whether the recommendations of the Society, since they have been adopted, are causing any difficulty in using the square perforations.

Mr. Popovici: I have nothing against it. As a matter of fact, it would be all right to use only one kind of perforation, but the difficulty lies in the existing camera equipment using the Bell & Howell perforation, which is scattered all over the world.

Chairman Crabtree: As Mr. Popovici says, in view of the fact that there are a large number of library shots having the Bell & Howell perforation, apparently the producers prefer to standardize on the Bell & Howell perforation, unless someone can establish practical advantages for the square perforation.

Mr. Ricker: We have found it necessary to use the Bell & Howell perforation in similar work with the positive.

Chairman Crabtree: Why?

Mr. Ricker: Because we got a steadier picture.

Chairman Crabtree: Did you try a special pin to fit the square perforation, or did you use the old Bell & Howell registration pin?

Mr. Ricker: I presume we used the old Bell & Howell pin.

Chairman Crabtree: Obviously, it wouldn't work.

MR. RICKER: I want to add one word of caution. Sometimes a cameraman or laboratory man will have occasion to rewind film. Since in the film factory the film is undoubtedly edge-guided during perforation, after slitting the film from an edge-guided side, you must be careful to keep that same edge-guide inside, both in the camera and in the projector, because you will find when it is edge-guided for perforation on one side, reversing the film and projecting it guided on the other side will result in a variation in the position of the perforations.

MR. POPOVICI: That is true. As a matter of fact, we know which side is guided during perforation and we always try to keep the same side guided all the way through.

CHAIRMAN CRABTREE: Has anyone made registration pins specifically for the square perforation, and compared them for steadiness against the Bell & Howell pin with the Bell & Howell perforation?

MR. MITCHELL: We haven't made really exhaustive tests in that way, but we studied the matter a lot when the rectangular perforation was first proposed. The Bell & Howell perforation, of course, has curved sides. If there is any shrinkage, the pilot pin of the camera or the driving tooth of the printer sprocket fits in the way of a taper fit. In other words, if there is any shrinkage of a reasonable amount, it is to some extent self-compensating.

Hollywood prefers the pilot pin for registration. There has been quite a tendency to use oversize pilot pins. We have been called upon quite often to make pilot pins that would be exactly 0.0001 inch greater than the perforation size, the feeling being that the film is jammed down upon the pin and that the film is sufficiently elastic to stretch during registration and shrink back to its original shape without deformation. Within certain limits I believe that that characteristic of the film would apply also with shrinkage, and that the stretching characteristic of the film would accommodate at least a small percentage of shrinkage.

MR. POPOVICI: Oversized pins are very good in optical printing where you make two or three pictures a second. But when the movement is fast, you will agree that the sprocket hole is definitely deformed when it goes over the pilot pin. Disregarding printing, and considering now projection, the projection machines on the coast are all equipped with pilot pins. The pins start to work in the cold state; when 200 or 300 feet of film are shot on a screen, the pilot pin becomes hot and expansion occurs. The film has a tendency to shrink from the heat; the pilot pin swells. What results? A steady shot in the beginning, but movement the third time it is shot.

MR. MITCHELL: I always thought the machine was warmed up before starting.

MR. POPOVICI: Perhaps; but there are two factors working against each other. In side-guiding the film isn't forced at all; the only pressure that acts comes from the springs that hold the film against the gate. Three sprocket teeth, instead of one pin, engage the film; hence the torque of the sprocket drum against the film is so much less than on a pilot pin movement. However, the motion is twice as fast, which balances it out, and still it is a little less than with the pilot pin.

HIGH-INTENSITY MERCURY AND SODIUM ARC LAMPS*

L. J. BUTTOLPH**

Summary.—*Characteristics of the sodium and high-intensity mercury arcs of interest to motion picture engineers are discussed, including starting, stability, regulation, power-factor, and multiple and series operation. Energy distribution as related to the sensitivity curves of photographic emulsions and to the use of filters is shown by graphs. Methods of controlling the light distribution and intensity are explained.*

The pioneer service of the Cooper Hewitt lamp in the motion picture field encourages thought of further service from the latest developments in gaseous conduction arcs. The new high-intensity mercury and sodium lamps differ from other Cooper Hewitt lamps in their relative compactness and increased brightness, in the simplicity of their auxiliary apparatus, and in the nature and quantity of their radiation. As these differences grew from the obvious limitations of the earlier lamps for studio use, they should be of immediate interest.

Instead of the gravity-controlled pool of mercury limiting the position of the familiar Cooper Hewitt lamp tube, the new lamps have oxide-coated cathodes, the characteristics of which have been described elsewhere.[1] It will suffice here to say that a fused coating of alkali earth oxide, notably barium oxide, on nickel or tungsten, at a temperature of about 900°C. produces a low-voltage cathode of a general type adaptable to use either in high-vacuum electron devices, such as radio tubes, or in gaseous conduction devices, such as mercury, sodium, or neon lamps, the functioning of the cathodes being largely independent of the nature of the surrounding gas. The one requirement for the proper operation of this type of cathode is the definite temperature already specified. Oxide-coated cathodes may be divided into two classes, depending upon whether their heating is solely that produced by the arc current and the voltage drop at the electrodes, or whether additional heating energy is sup-

* Presented at the Fall, 1934, Meeting at New York, N. Y.

** Engineering Department, General Electric Vapor Lamp Co., Hoboken, N. J.

plied to the cathode from an auxiliary device. The arc-heated type of cathode happens to be used in the high-intensity mercury arc, whereas the separately heated type is used in current models of the sodium arc. The use of either type of oxide-coated cathode at once removes restrictions as to operating position, and so permits the same flexibility of use possible with incandescent lamps.

The light-source length, or distance between the electrodes, of the new lamps is $^1/_6$ to $^1/_8$ that of standard Cooper Hewitt lamps, a fact that profoundly influences both their operating characteristics and their practical utilization. Electrically, the result is instantaneous starting when cold, without any such electrical or mechanical starting means as have usually characterized low-voltage arcs. The compactness results also in such a relatively high normal operating temperature and vapor pressure that the mercury arc does not restart until it has cooled for an interval, which can be shortened by using one of the arc-starting devices long in use with gaseous conduction lamps.

Although both the sodium and mercury arcs can be operated on direct current, the fact that the more efficient types are respectively lower and higher in operating voltage than the conventional direct-current sources has led to a standardization at present on a-c. models. It is outside the scope of this paper to detail methods of arc operation other than to point out the additional practical advantages of a-c. operation inherent in the voltage adjustment possible with transformers, the efficiency of reactive rather than resistive ballasting, and the combination of those two factors with safety in the insulating line transformer with high-leakage reactance.

In this connection, it should be noted that all arcs are inherently constant-current devices, and that arc-ballasting auxiliary devices are necessary only because constant-voltage rather than constant-current electrical distribution happens to be the practice. Series operation on constant-current lines is common in highway lighting practice and is being used with these new gaseous conduction arcs.

When operated on a more or less constant-voltage line with reactive ballasting the lamps have a power-factor of about 0.65, which may be corrected by condensers, in the usual manner, to over 0.90, this residual apparent power-factor being due to a distortion rather than a time displacement of the current wave.

The stability and regulation characteristics of gaseous conduction lamps can be made anything within reason, as they are fixed arbitrarily by the amount of ballasting used. Stability; persistence of the arc upon sudden decreases in line voltage, and regulation; changes in arc current or light, with changes in supply voltage; can be improved by increasing the ratio of the ballast voltage to the arc voltage drop—that is, by absorbing relatively more of the available voltage and energy in the ballast unit, with the obvious result of decreasing the over-all efficiency. A similar design compromise is involved in the lumen-per-watt rating of a given gaseous conduction lamp. The efficiency may be increased by taking a shorter operating life, or a longer life may be had by operating at a lower efficiency.

The complicated relation between arc-lamp stability and regula-

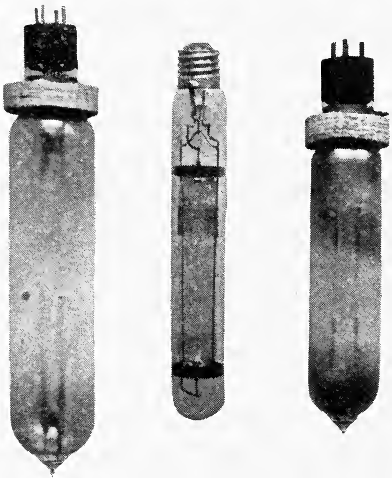

FIG. 1. Sodium and mercury arcs without vacuum jackets or auxiliary equipment. *Left:* 10,000-lumen sodium arc. *Center:* 14,000-lumen high-intensity mercury arc. *Right:* 6000-lumen sodium arc.

tion, over-all efficiency, and useful life has been discussed elsewhere.[2,3] It is to some extent true of incandescent lamps, but much more so of gaseous conduction lamps, that statements of either efficiency or life should always be in terms of the other factor and in terms of a stated or standardized method of operation.

Although many other types and sizes are in development, only two sodium arcs have been standardized for manufacture and sale in this country (Fig. 1). A 10,000-lumen lamp rated at 200 watts

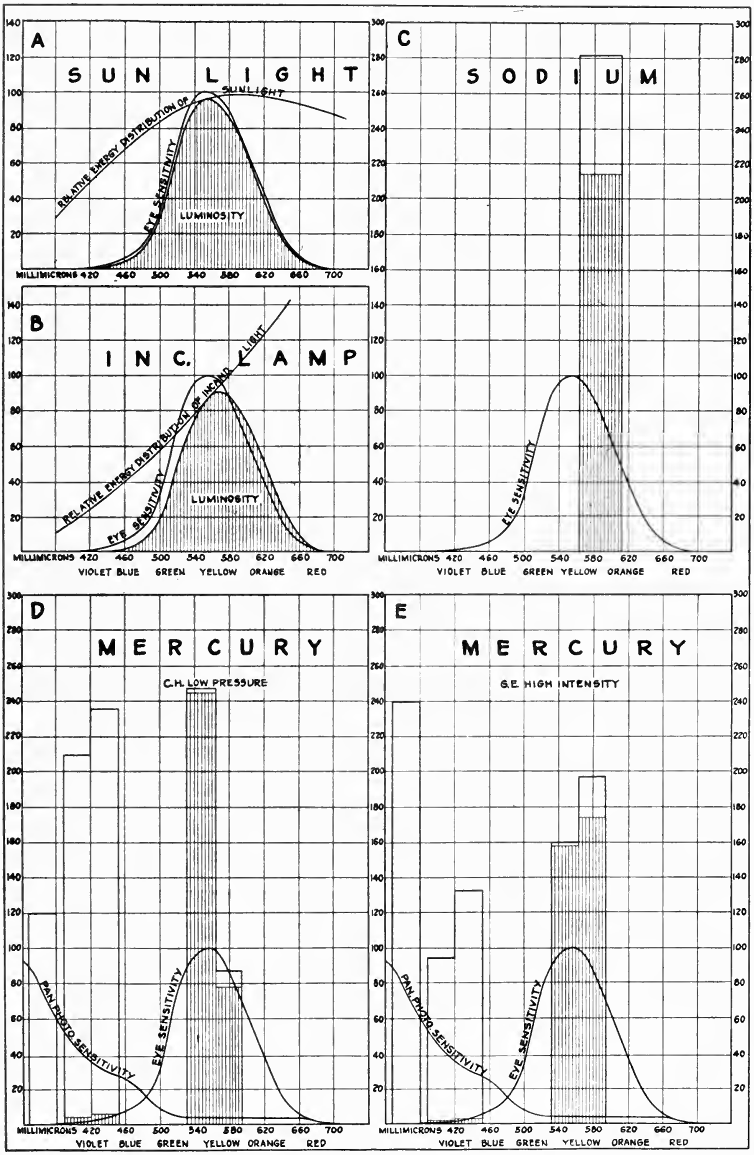

FIG. 2. Graphic indication of the energy required to produce comparable luminosities by light of various relative energy distributions.

in the arc and using about 25 watts in the auxiliary has an over-all efficiency rating of 45 lumens per watt when reactive ballasted for 30 per cent of the total voltage and rated for a useful life of 1350 hours. The light-source itself is 9 inches long and has an average brightness of 37 candles per square inch.

A 6000-lumen lamp rated at 150 watts in the arc and using about 15 watts in the auxiliary has an over-all efficiency rating of 36 lumens per watt when reactive ballasted for 30 per cent of the total voltage and rated for a useful life of 1350 hours. The light-source itself is 7 inches long and has an average brightness of 34 candles per square inch.

Both these sodium lamps must be enclosed in vacuum jackets to insure the temperature and sodium vapor pressure necessary for efficient operation. For the same reason an initial interval of about 20 minutes is required to attain an efficient operating temperature.

Although a smaller percentage of the total energy put into sodium lamps emerges as visible radiation, the pair of lines are fortunately so placed relatively to the visibility curve, Fig. 2, that the luminosity is more than three times that of incandescent light, and hence their efficiency is 2 to 2.5 times that of a 20-lumen-per-watt incandescent lamp.

This efficiency makes the lamp attractive for applications in which color values are of little importance, such as highway, flood, beacon, and spectacular lighting.

Instead of distorting colors, sodium light renders only a limited range of yellow, and that with so high a luminosity as greatly to reduce the apparent saturation. It has been suggested that this effect can be used to show visually the photographic black-and-white rendition of colored objects just as viewing filters are sometimes used. There is promise that the sodium lamp may be used for laboratory illumination in photographic processes using materials sensitive only to the blue and ultra-violet, but there seems to be little use for them as photographic studio light-sources with any of the photographic emulsions now in general use.

Although several sizes and types of high-intensity mercury and amalgam lamps are in actual development, only one, a high-pressure type of mercury arc, has been standardized for manufacture and sale. It is described as high-pressure because its normal mercury vapor pressure is about 1 atmosphere, or 1000 times that of the Cooper Hewitt lamp; and as high-intensity because the compactness and high vapor-pressure results in an increase in the intensity of the 577–

579 mμ lines relatively to the other lines, doubling the over-all arc efficiency, and a brightness 13 times that of the familiar Cooper Hewitt tube.

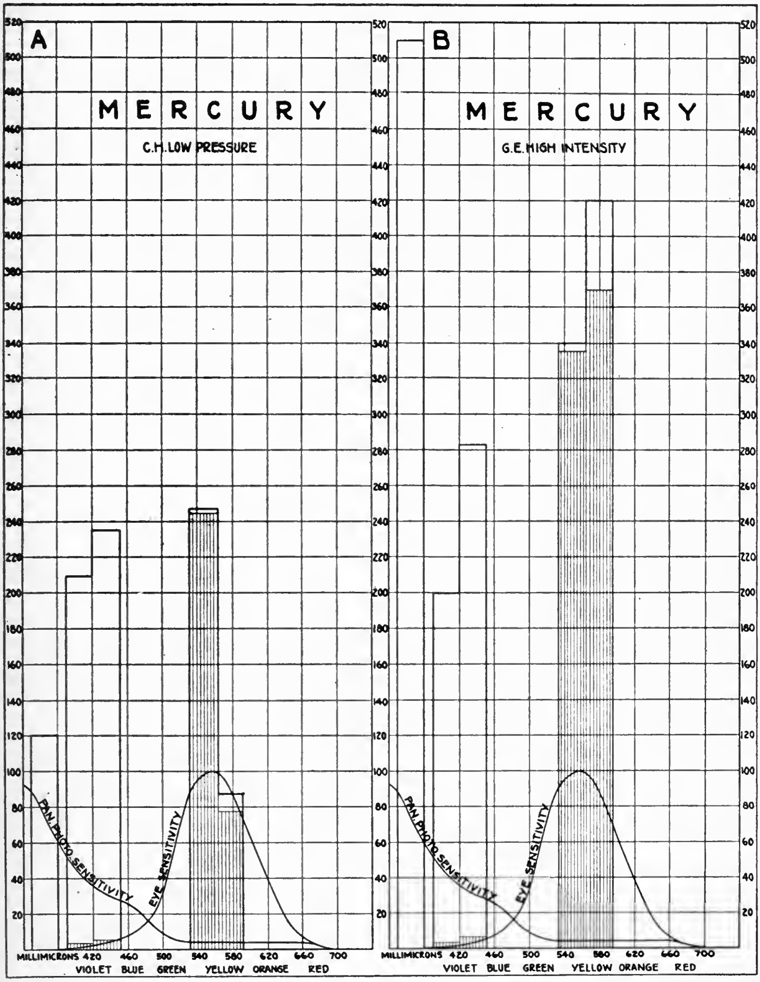

FIG. 3. Graphic comparison of total energies, the relative energy distributions, and the luminosities characteristic of a-c. Cooper Hewitt low-pressure and General Electric high-intensity mercury arcs.

This change in relative energy distribution with operating condition s shown graphically in Fig. 2 on the basis of equal luminosities, and in Fig. 3 on the basis of equal over-all wattages. In both figures, the total areas of the lines or blocks represent line energies, and the vertically ruled portions represent luminosities.

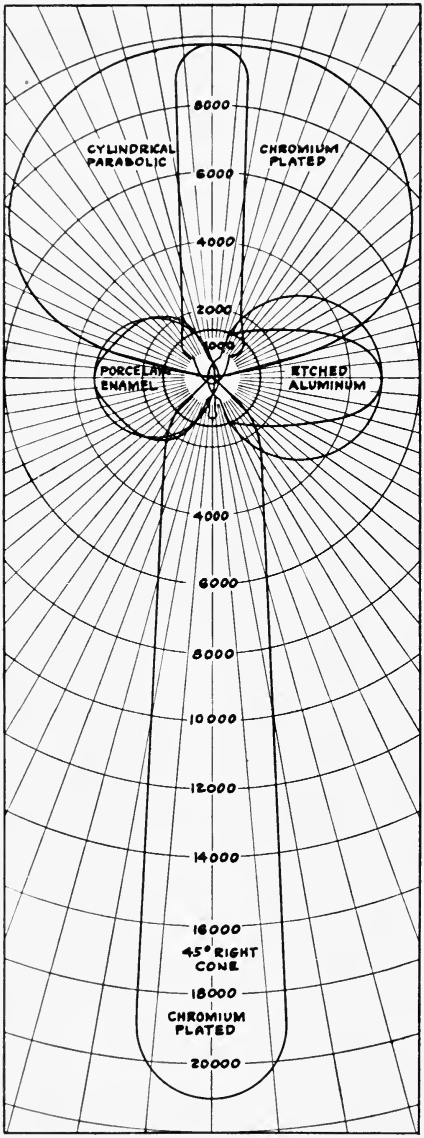

FIG. 4. Comparison of various types of reflectors, used with a 425-watt high-intensity mercury arc.

The increased intensity of the yellow lines is paralleled by a slightly greater increase in the 366 mμ group, as shown in Figs. 2 and 3, and a slightly smaller increase in the 405 and 435 mμ violet lines, so that the relation between foot-candles and photographic effects is about the same as for the Cooper Hewitt lamp.

In fact, the radiation characteristics of the high-intensity mercury arc are practically the same as those of certain older high-pressure quartz mercury arcs,[4] except that the glass enclosures intercept the ultra-violet or short wavelengths. The high-pressure type of arc is also similar to the quartz mercury arc in its electrical operating characteristics, except that it is made more thermally stable by an insulating enclosure in an integral outer bulb containing nitrogen at a pressure of $^1/_2$ atmosphere, and by using so limited a quantity of mercury as to assure complete vaporization at the normal operating temperature.

The 14,000-lumen high-intensity mercury arc now available may be operated on alternating current at 220 volts with a series reactor, or at any voltage with a reactive transformer. The power-factor of 65 per cent resulting from this manner of operation may be corrected to 92 per cent by using a condenser. The arc only is rated at 400 watts, and the reactor and transformer may take an additional 25 to 50 watts depending upon the design. The arc alone is rated at 35 lumens per arc watt, when ballasted for 30 per cent of the total voltage and rated for a useful life of 1500 hours.

The light-source tube is 6 inches long and $1^3/_8$ inches in diameter. It, in turn, is enclosed in a cylindrical tipless bulb 2 inches in diameter, which is, with its mogul screw base, 13 inches in over-all length. This compactness results in an average brightness for the

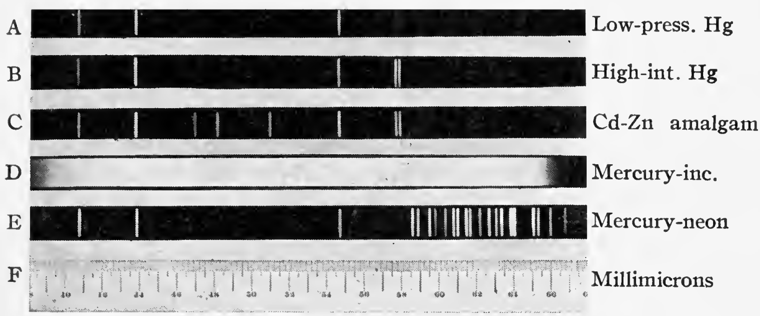

FIG. 5. Spectrograms of mercury light modified or augmented as indicated.

light-source itself of 175 candles per square inch. The unit is sufficiently compact for use with standard reflecting and diffusing equipment, and distribution curves possible with specially designed conical or cylindrical parabolic specular reflectors are shown in Fig. 4.

The high-intensity mercury arc operates at so high a temperature that additional spectral lines can be attained by introducing small amounts of cadmium and zinc. The relative energy distribution of the red and blue lines thus added has been such as to produce a light slightly bluer in subjective color than the unmodified high-intensity arc, but still containing enough red to give slightly improved color discrimination. This change in color quality is apparently attained only at a sacrifice of efficiency,[5] as has usually been the case in connection with amalgam lamps. Although spectrograms make only a qualitative comparison of spectra possible, those in Fig. 5 are a fair representation of the spectra obtainable from mercury and amalgam lamps. In this connection it should be noted that although it is not sufficient to show on the spectrograms of Fig. 5, the high-pressure high-intensity mercury arc contains enough red to make it noticeably better than the Cooper Hewitt low-pressure mercury arc in the discrimination of colors at the red end of the spectrum.

Both the sodium and the high-intensity mercury arc as now available operate as full-wave a-c. arcs having the flickering light characteristics of all full-wave a-c. arcs. The resulting stroboscopic effects in some applications may limit the use of the lamps, but there are still a large number of photographic processes in which it is no handicap. It is probable that high-intensity mercury arcs for d-c. operation will be available in case there is a definite need for their perfectly steady light.

The arguments for the light quality of incandescent lamps and carbon arcs are generally more applicable to color photography than to the ordinary black-and-white rendition of colored objects; and there is plenty of evidence that for the economical production of high-quality black-and-white pictures, the mercury spectrum is still of great value. The bulk of the light-source and the bulk and weight of the auxiliary equipment have probably been more important than any other factors in the recent decrease in the use of Cooper Hewitt lamps in studio lighting practice. It is believed that the high-intensity mercury arc with its increased efficiency, decreased bulk, and the possibility of light direction and control by compact reflectors, may find worth-while applications in modern studio lighting practice.

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DISCUSSION

PRESIDENT GOLDSMITH: What is the approximate life of the lamps, in normal operation?

MR. BUTTOLPH: The sodium lamps are rated at 1350 and the mercury lamps at 1500 hours. As stated in the paper, the rating involves a compromise with the efficiency at which the lamp is operated, and so is a tentative matter.

MEMBER: Where are the street lighting installations located?

MR. BUTTOLPH: One at Newton, Mass.; one at Revere Beach; one in New York City, at Jerome Avenue near Van Cortland Park; one in Pittsburgh, on Allegheny Boulevard. The largest I have heard of are being considered out on the West Coast.

MR. CRABTREE: How long does it take to reach maximum intensity?

MR. BUTTOLPH: A perfectly cold sodium lamp requires about twenty minutes.

MR. CRABTREE: What is the shape of the intensity curve with time?

MR. BUTTOLPH: Very low for the first five minutes; then it rises rapidly. This is a laboratory model, and the plate is a temporary support, you might say, for the vacuum jacket, or Dewar flask. You are seeing the sodium arc through three layers of glass. There is a bulb inside, and outside of it is a large Dewar flask similar to the unsilvered filler of a large-mouthed vacuum bottle. In the case of the mercury arc, the vacuum enclosure or the gas-filled enclosure is a part of the lamp structure.

PRESIDENT GOLDSMITH: Would the lamps be in any way applicable, for example, to the modern effects in lighting the fronts of theaters?

MR. BUTTOLPH: Yes, any place where the light may be used directly by reflectors, where you want a highly efficient production of spectacular color.

MR. CRABTREE: I can see a number of sun-spots in the bulb. What causes them?

MR. BUTTOLPH: If your eyes become sufficiently fatigued you can see certain clouded areas of metallic sodium condensed on the inner bulb. We never vaporize all of it; sodium is always distilling around from one place to another in the bulb.

MR. CRABTREE: How does the mercury lamp start?

MR. BUTTOLPH: Simply by applying the supply voltage; but it operates at such a very high pressure that it must cool for about ten minutes before it will restart. By adding a high-tension starting device, such as is used with the Cooper Hewitt lamps, it can be started much more quickly. For most applications the delay in starting is not serious. As a matter of fact, the street lighting units will involve combinations of this lamp with an incandescent, and the incandescent acts as a stand-by light source.

MR. POPOVICI: What is the percentage of the near-ultra-violet to the visible rays, from the photographic standpoint?

MR. BUTTOLPH: The actual energy is a little more than half that represented by the yellow and green light as shown graphically in Figs. 2 and 3.

MR. PALMER: In the early days of the motion picture industry the low-intensity mercury vapor lamp was used extensively for studio lighting and a number of studios relied on it exclusively for illumination. The Astoria studio of Paramount Publix (opened in 1918) was equipped with 1000 tubes distributed in 120 banks. Despite the great bulk of the equipment and its weight, the lamps were much used because of their high efficiency and the desirable actinicity of the light. The introduction of improved arc and incandescent units and the need for directional light-sources gradually caused the mercury lamps to be displaced.

The new high-intensity mercury lamps are more efficient than the old units and are more compact, and they undoubtedly have applications in the industry particularly for special problems. A recent application of these lamps was on a titling machine. The machine was equipped with a motor-driven camera running at 90 feet a minute, and the light-source consisted of two 35-ampere d-c. arcs placed about five feet away from the title board, one on each side. For these two arcs, taking a total of 7000 watts, four high-intensity a-c. mercury lamps having a total wattage of 1600 were substituted. It was found that the illumination from the mercury lamps was sufficient to produce the same photographic results as before, with a considerable saving in current and maintenance. The increase in efficiency was, of course, not entirely due to the difference in the two types of light sources; there was a gain due to the fact that the mercury lamps could be placed closer to the title board, placing more of the light where it is needed. Due to the fact that the current alternated 120 times a second, and the camera made 24 exposures a second, there was no appreciable flicker in the projected picture. The new lamps should be useful in cartoon work also, as the lighting set-up is very similar to that required for titles.

The mercury lamps, due to their high efficiency, produce very little heat as compared with other sources, and they are particularly suitable for under-water work or for work in enclosed spaces where good ventilation is not possible.

Mr. Crabtree: Is there any difference in behavior between the a-c. and d-c. lamps?

Mr. Palmer: The flicker can be seen in the a-c. lamp, of course. The d-c. lamp is perfectly steady, and no stroboscopic effect is noticed when you move your hand in front of it. The light has the same characteristics except that the a-c. arc flickers and the d-c. arc doesn't.

Mr. Crabtree: Is one of the lamps more apt to go out than the other?

Mr. Palmer: No; they remain lighted without any trouble.

President Goldsmith: Does the 20-minute period during which the light intensity rises mean a corresponding change in exposure?

Mr. Palmer: Before the cameraman starts to load up the magazine he turns on the light, and it warms up while he is getting ready to work. The current is so small that it would cost only a few cents to leave it on all night.

Mr. Hibben: Better actinic effects occur when there is proportionately a great deal more energy in the short wavelength region that affects the ordinary emulsion. Over-all efficiencies may improve with larger sizes. It seems possible, and perhaps desirable, to concentrate tremendous amounts of light at certain spots. When we began to develop filament sources we went to 5-kw., 10-kw., and even 50-kw. lights in order to get high concentration for shadows and for speed. If there is an industrial need for anything like that with mercury sources, it seems possible, and very feasible but requires time for development.

PIEZOELECTRIC LOUD SPEAKERS*

A. L. WILLIAMS**

Summary.—*Recent progress in piezoelectric loud speakers for theater use, including a new unit for upper registers, is described. Frequency-response characteristics of this unit alone and in combination are discussed and demonstrated.*

The character of the load upon the output circuit, and its effect upon the efficiency and the production of satisfactory response in the low and high registers, are discussed.

The loud speakers described and demonstrated in this paper all operate on the piezoelectric principle, using bimorph elements of Rochelle salt as the means of converting electrical into acoustical energy. The construction of these crystalline units has been described in earlier papers[1] which have shown that the bimorph or two-layer principle is utilized to attain a mechanical magnification of the movements of the crystal under an applied voltage, and to minimize the undesirable effects of saturation, hysteresis, and temperature. The bimorph principle has been further developed so that multiple-layer elements are now used.

Fig. 1 illustrates diagrammatically the construction of a typical general-purpose loud speaker operating on the piezoelectric principle. The motor consists of a double bimorph crystal element $2^1/_2$ inches square by $^1/_4$ inch thick, built up of four layers of Rochelle salt crystal slabs with electrodes attached to their surfaces. In the particular design illustrated, there is no electrode between the two inner slabs; therefore, as there is twice the thickness of material between the two inner electrodes compared with the outer layer, the electrical stress will be greater on the outside layers and will be commensurable with the mechanical motion. This mechanical and electrical stress equalization allows considerably more power to be handled than is possible with a two-ply unit.

The crystal unit is supported inside a water-tight steel case by being held at three corners between pads. The fourth corner is fitted with a metal cap, an extension of which is brought out through

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** Brush Development Co., Cleveland, Ohio.

a water-tight seal for driving the cone through a ratio-arm, the purpose of which is to match the mechanical impedance of the cone to that of the crystal unit. The capacity of one of these speakers is about 0.01 μf, and they operate well from a source of 8000 to 12,000 ohms. In fact, the response of the crystal is much better than that of the cone. Until that was realized there was a tendency to try to accommodate too wide a range of frequency on a single cone, and the advantage of using several units, each designed most efficiently for a particular portion of the audible spectrum, is now well recognized. This fact led to the design of the high-frequency electrophone, described by Ballantine,[2] which utilized a diaphragm composed of four

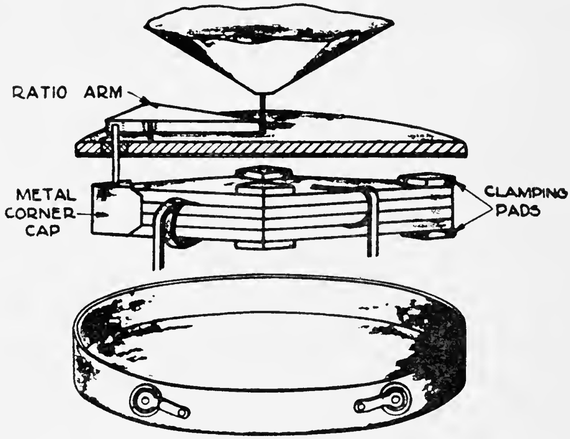

FIG. 1. Assembly of type *R95* Piezoelectric reproducer.

small bimorph units loaded by an exponential horn and designed to respond well up to 16,000 cycles.

It is possible also to construct a highly efficient reproducer for the higher frequencies without a horn. Such a unit is now available, and consists of a crystal unit driving a cone. The most important part of the cone is solid and, in the present models, made of wood. The object of such construction is to provide equal distances for the sound waves to travel outwardly before meeting the air; and to overcome the very rough response due to interference that is noticeable with single paper cones. A cross-section of such a speaker is shown in Fig. 2, and a theoretical response curve of a properly matched type *T-51* speaker and moving coil for theater combination in Fig. 3. The speakers are small, light, and relatively inexpensive to construct, and are shallow enough to be mounted at the center of a loud speaker designed for low-frequency response. In fact, due to the efficiency of response of the crystalline elements in the upper register, the type *T-51* speakers are produced at a cost sufficiently low that several units pointing in different directions may be very satisfactorily utilized in the same assembly to furnish a very uniformly distributed acoustic response at high frequencies.

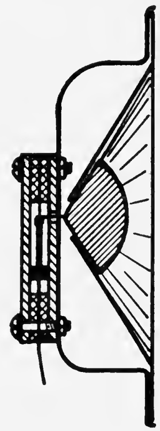

FIG. 2. *T-51* high-frequency reproducer.

They are designed to be used directly across the output circuit of an electron tube in the case of radio receivers, and with a transformer in theater installations where a low-impedance or 500-ohm line connects to the speakers. Due to the high efficiency of the reproducer, it will generally be found necessary to reduce the voltage so that the acoustical output of the high-frequency unit is the same as that of the low-frequency unit. If a volume control is inserted between the high-frequency and low-frequency speakers, it may be used as a very effective tone control. By such a method the response of the elements actually reproducing the upper frequencies is increased or decreased so as to render the tones at their proper intensities. The high efficiency of the units results in a reserve of power sufficiently great actually to emphasize the high-frequency response, when required, without overloading the speaker or reducing the output of the other speakers in the circuit.

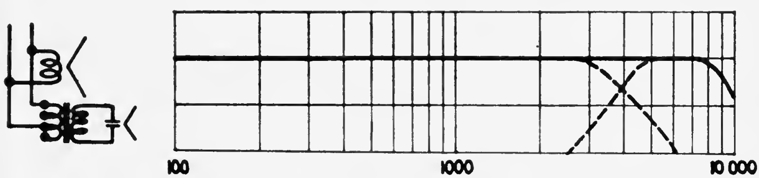

FIG. 3. Theoretical response curve of combined dynamic and type *T-51* theater speaker.

As the speaker has a negative reactance, a filter is not required when it is used in combination with an inductive reproducer of the usual moving-coil type. In fact, it not only supplies the upper register, thus permitting the magnetic speaker to be designed for maximum efficiency over a limited range, but also by its tendency to correct the power-factor of the dynamic speaker provides more efficient loading of the tube and circuit than would otherwise be obtained. The leading-current characteristic of the piezoelectric speaker makes it very desirable as an output load, especially if it is necessary to use a step-down transformer to reduce the amplifier output to some line level.

Carrying the idea of multiple speakers still further, a special theater speaker has been developed and is now available, built up from eight

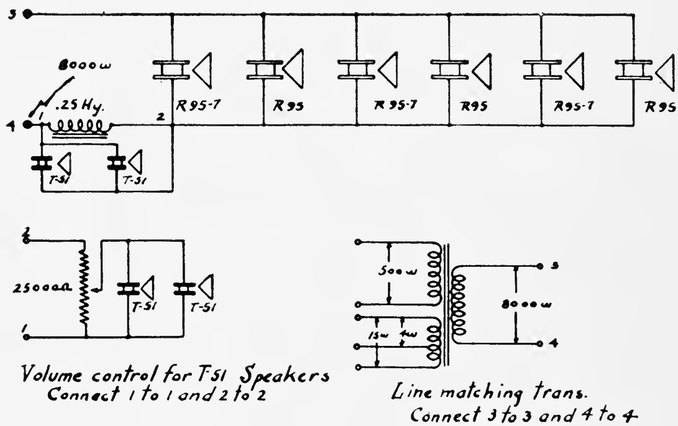

FIG. 4. Circuit diagram of type *8RT* theater reproducer.

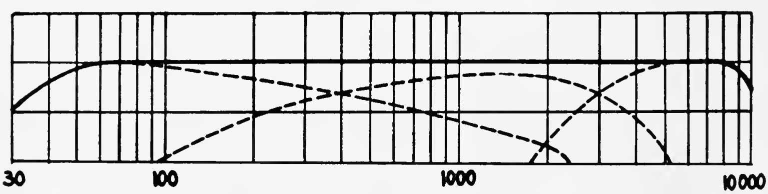

FIG. 5. Approximate distribution and total output of 8*RT* reproducer.

different speaker units designed to reproduce efficiently the whole acoustical range required for the new high-fidelity films. They are assembled in a single mounting and connected as shown in Fig. 4. The low- and middle-range speakers are connected in parallel, and are fed through a choke-coil across which are connected the high-frequency units. By properly designing the individual units and adjusting the value of the series inductance, it is possible to design a speaker with a very flat response over the range required, as illustrated in Fig. 5. This speaker presents an impedance load on the amplifier which is virtually constant over this range. No field excitation is required, and due to the fact that the load is mostly capacitive, a high-impedance line may be used without fear of losing the higher frequencies. The speakers are designed to operate across the plates of standard amplifier tubes. Where low-impedance lines already exist between the projection room and the stage, a step-up transformer may be used to match the impedance of the speakers to the line impedance. Two to four of these speakers may be used in the average size theater.

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DISCUSSION

MR. MITCHELL: I have been informed that in some of these piezoelectric crystals there is a fatigue characteristic after they have been in operation for some time. Is that so?

MR. WILLIAMS: We have had no sign of fatigue at all. We operated some speakers, in which a large piece of crystal was used, having a wooden arm attached to them to which a cone was fastened, for more than two years on 220 volts, 60 cycles, in a little wooden shed where the humidity and temperature varied winter and summer, and there was absolutely no sign of deterioration of the crystals. Installations of the earlier type of speaker have been operating in Severance Hall, the home of the Cleveland Orchestra, for five years, without a service call, either for microphone or speakers. The crystal must be enclosed however, otherwise in very hot, dry atmospheres there will be a tendency toward dehydration.

MR. HICKMAN: What is the amplitude of the speaker cone?

MR. WILLIAMS: The maximum amplitude so far attained is about an eighth of an inch. As used in the theater speaker, in which a number of units are used in a single baffle, each speaker loads the other, and the amplitude is reduced very greatly, thus enabling the speakers to handle considerably more power. The groups of eight will handle 20 watts safely, but 5 watts are recommended as a working maximum. The individual loading between the cones restricts the motion and, incidentally, due to the back emf., raises the impedance quite considerably.

REFLECTING SURFACES OF ALUMINUM*

J. D. EDWARDS**

Summary.—*Aluminum is inherently a good reflector of radiation in the ultraviolet, visible, and infra-red portions of the spectrum. Means of developing and maintaining this high reflectivity in commercial reflectors are described. The new Alzak process of electrolytic brightening and oxide coating makes available aluminum reflectors, both specular and diffuse, having reflection factors up to about 85 per cent. The Alzak reflectors have a hard, abrasion resisting coating of clear transparent aluminum oxide on the surface which makes them weather-resistant and easily cleaned.*

Aluminum, the metal, is intrinsically bright. To make a good practical reflector from aluminum requires the solution of two problems: first, to develop suitable methods for bringing out or developing the inherent brightness of the metal; second, maintain the brightness of the reflecting surface under service conditions.

For brightening a metal surface, the obvious and time-honored expedient is to polish it. Where a specular surface is required this operation may be necessary, but it has certain limitations. With commercial aluminum sheet, about the best reflectivity that can be attained by polishing is of the order of 65 to 75 per cent. It is true that higher reflectivities, even up to 89 per cent, have been achieved by polishing some of the hardest aluminum alloys by a special technic, but such a reflecting surface can have only very limited application.

Where a diffusing surface is satisfactory, chemical etching methods are very effective in bringing out the high reflecting power of aluminum.[1] One such etching medium is an aqueous solution containing about 5 per cent sodium hydroxide and 4 per cent sodium fluoride. The surface is etched and brightened by immersion in this solution at a temperature of about 90°C. A final dip is given in a cold solution of nitric acid containing equal parts of concentrated nitric acid and water. Using this method of etching, aluminum diffuse reflecting surfaces are being commercially produced, which have a reflection factor for visible light ranging from 82 to 87 per cent, and for

* Presented at the Fall, 1934, Meeting at New York, N. Y.

** Aluminum Research Laboratories, New Kensington, Pa.

ultra-violet radiation at a wavelength of 296.7 mμ of 81 to 82 per cent.

Fig. 1 shows a curve of the reflectivity of aluminum for wavelengths ranging from 0.2 to about 12 μ.[2] This curve represents values that are practically attainable, and is interesting for a number of reasons. Aluminum, it will be seen, is an excellent reflector of ultra-violet radiation; it is unexcelled in this respect by any other metal. This characteristic is of special significance in the photographic art, because of the sensitivity of photographic film to short-wave radiation. The reflectivity of aluminum is nearly 90 per cent in the visible range, and attains values as great as 97p er cent in the infra-red range.

Having produced a surface of high reflectivity by the etching pro-

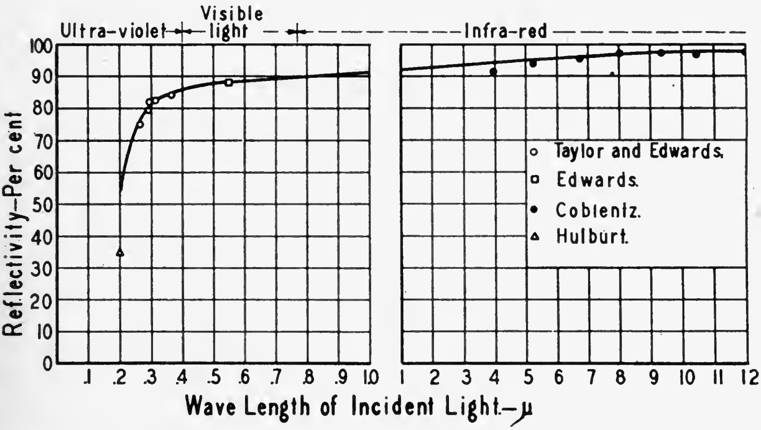

FIG. 1. Reflectivity of aluminum for radiations of various wavelengths.

cedure just outlined, the problem remains of maintaining the surface against depreciation under severe service conditions. Indoors, where frequent cleaning is not required, etched reflectors of this type have proved highly satisfactory. Where they collect dust and dirt rapidly, however, or where they are subject to weathering, such a surface is not as readily cleanable as might be desired, and may show considerable surface attack when exposed continuously. The surface can be protected with a clear, colorless lacquer, but only at a sacrifice of some 10 per cent in reflection. Outdoors, of course, the lacquer protection is relatively short-lived, and may become yellow and discolored if not carefully selected.

Another type of protection that is available is oxide coating of the aluminum surface. Electrolytic or anodic oxidation of aluminum, as typified by the *Alumilite* process, is a means of providing aluminum with a hard and abrasion-resisting coating of aluminum oxide. This coating is likewise highly impervious to moisture and is protective against weathering. An oxide coating, however, that is thick enough to confer all these properties in the desired degree decreases the reflectivity of the surface from about 10 to 20 per cent, and leaves the metal with a rather opaque and milky surface finish which naturally detracts from its value as a reflector.

A discovery of R. B. Mason of Aluminum Research Laboratories has solved in a highly satisfactory way the problem of producing bright aluminum surfaces and maintaining them under service conditions. The method is that of electrolytically brightening aluminum so as to bring out its maximum reflectivity. In this process, the aluminum reflector, formed to final size and shape, is made the anode in an electrolyte of novel composition, acting in which capacity the reflector is brightened by the electrolytic removal of impurities, both metallic and non-metallic, from the surface of the metal. This process is unique in that the brightening is effected without any etching or roughening of the surface; thus, a highly polished reflector can be electrolytically brightened without appreciable loss of specularity. For example, a polished aluminum reflector having a reflection factor of 74 per cent, after being subjected to this electrolytic brightening treatment, had a reflection factor of 87 per cent. A very thin protective oxide film is formed upon the surface, but it is too thin to withstand many service conditions satisfactorily. Very fortunately, however, the electrolytically brightened surface can be further oxidized by the Alumilite process to give it a substantial protective coating of oxide without any important loss in reflectivity. Specular reflectors having reflectivities of 80 to 85 per cent are being commercially produced by this process. Application of the final oxide film appears to cause a somewhat greater loss of reflection for ultra-violet and infra-red radiation than for visible light.

The trade-name *Alzak* has been applied to this process and to reflectors made by it. The process in outline consists first in preparing the surface by polishing or etching, depending upon whether a specular or diffusing surface is required. The surface is then electrolytically brightened and oxidized, whereupon it becomes a bright reflector having a clear, transparent oxide coat upon its surface. As a final treatment, the oxide-coated reflector is "sealed" so as to make the oxide coat impervious and resistant to staining or marking by handling or in service. For the best results, aluminum sheet of special type and composition is selected for reflectors to be finished by the Alzak process. The Alzak reflectors have a smooth, hard, glassy surface which does not collect dirt and which can be readily cleaned by washing with soap and water. If a more thorough cleaning is necessary, the use of a mild abrasive such as *Bon-Ami* is satisfactory and cleans without injury to the surface.

During the past year there has been an unusual interest in aluminum reflectors, both because of the development of the Alzak process and also because of the application of evaporated aluminum films to telescope reflectors. In this latter application, instead of preparing a highly reflecting surface upon aluminum, a very thin film of aluminum is deposited upon the glass or metal surface to be used as the reflector, producing what is known as a "first-surface mirror." Aluminum normally has a boiling point at atmospheric pressure of about 1800°C. If, however, the pressure is reduced to a very low value, the boiling point is correspondingly reduced. For example, at a pressure of about 0.001 mm. of mercury the boiling point of aluminum is about 730°C, and at a pressure of 0.1 mm. is about 950°C. If, therefore, an object to be coated is suspended in a highly evacuated chamber, and aluminum contained therein is electrically heated to its boiling point, the aluminum will evaporate and be deposited as a bright metallic film upon any surface in the path of the stream of aluminum vapor. Such films are apparently highly satisfactory for telescope reflectors because of their high reflectivity for the photosensitive ultra-violet radiation and also because of their non-tarnishing characteristics. Such films are not, however, able to withstand the handling or cleaning to which Alzak reflectors can be subjected nor are they weather-resistant.

Aluminum paint is another medium by which bright reflecting surfaces may be produced. It has been extensively used for motion picture projection screens. The reflection factors of aluminum-painted surfaces will vary from 60 to 75 per cent, depending upon the vehicle and upon the grade of aluminum bronze power employed. The smoothness of surface and diffusiveness can be controlled to some extent by proper formulation of the paint. Aluminum bronze powder is also available in the form of a paste, which, with a suitable vehicle, gives a bright and uniformly diffusing surface. The luster of an aluminum-painted screen adds "life" to the projected picture.

An important application of the Alzak process is in the production of lighting reflectors. The Alzak reflector has the advantages of lightness and non-breakability in addition to its high reflectivity and non-tarnishing characteristics. Aluminum reflectors can also be formed to the required shape, with the high precision that is necessary in some forms of projectors. Tests are under way to develop the possibilities of this process in preparing optically accurate reflecting surfaces, both small and large. It is too early, however, to make any prophecies as to what can be done in this very exacting field.

Another potential application of the Alzak process is in the production of small projection screens for home use. The bright aluminum surface made suitably diffusing presents an attractive background for the picture, and its lightness and ready washability are additional desirable characteristics. Other applications of bright metal trim and surfaces naturally suggest themselves. It is apparent that the motion picture industry may find many uses for these new products.

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DISCUSSION

MR. SANDVIK: What methods are used for polishing aluminum surfaces?

MR. EDWARDS: Aluminum reflectors are usually finished by buffing with "white diamond" or similar polishing compounds.

PRESIDENT GOLDSMITH: Do these two samples differ in their resistance to finger-marking, for example?

MR. EDWARDS: One is finished by buffing and the other is oxide-coated. The buffed sample will finger-mark readily. The other may show finger-marks, but they will wipe or wash off. You can not satisfactorily remove them from the first reflector except by rebuffing.

PRESIDENT GOLDSMITH: The same distinction holds as well for the two etched reflectors?

MR. EDWARDS: Yes. You can tell the difference at once by running your finger over the surfaces; the oxide-coated surface has a smooth, glassy feeling.

MR. CRABTREE: What is the effect of gases present in the air, such as sulfur dioxide, sulfuric acid, hydrogen sulfide?

MR. EDWARDS: The oxide coatings are not resistant to high concentrations of many chemical reagents. We have had reflectors with the Alzak surface exposed to the New Kensington industrial atmosphere for a period of over a year with no loss of reflection factor. When brought into the laboratory and washed, they exhibited their original reflection. They will, of course, collect dirt.

MR. CRABTREE: How does the reflection factor of a lamp reflector fall off under practical conditions without cleaning? Is the loss of reflective power due entirely to dirt?

MR. EDWARDS: In the case of the Alzak aluminum reflector it is due almost entirely to dirt. In one case I know of, measurements were made on a silver-plated reflector and an Alzak reflector; the silver-plated reflector had been plated and polished three or four days before. Measurements were made of the two, and they were then cleaned and re-measured. There was no increase or decrease in reflection of the Alzak reflector, but cleaning increased that of the silver-plated reflector by 5 or 6 per cent, showing the depreciation that had taken place in a matter of three or four days. Aluminum is not darkened by sulfides as is silver.

MR. FRIED: In the production of motion picture screens, can you control the diffusion characteristics very accurately?

MR. EDWARDS: Only approximately.

MR. JOY: How high a temperature can the reflector withstand without becoming discolored?

MR. EDWARDS: In some of our experimental work the temperature of the reflector surface was about 320°F. over quite an extended period. There was no depreciation.

MR. JOY: Have you done any work at, say, 200°C.?

MR. EDWARDS: Some experiments have been reported in which Alzak reflectors were heated in an oven for 500 hours at 250°C. with only a small loss of reflectivity.

MR. DAY: How large sheets can you handle now, particularly in the anodic treatment?

MR. EDWARDS: We have only a small plant at New Kensington for the Alzak process, but we have coated sheets about three feet square.

MR. DAY: Have you attempted 10 × 12 feet?

MR. EDWARDS: Not yet; but it is possible if you have the tank equipment for it.

MR. PALMER: Can you make as good a reflector by the vaporization process as you can by the anodic process?

MR. EDWARDS: My knowledge of the vaporization process is second-hand, but I have a reflector made on glass that has a reflection factor of 90 per cent. I have seen what I thought were reliable measurements going even above that, say, 92 per cent. You can make a better reflecting surface by that process than by the Alzak process. However, it will not withstand the service conditions that this Alzak reflector will, because of the thin, necessarily soft, film of aluminum. But it is very serviceable on the reflector of an astronomical telescope. This surface would be of particular value in stellar photography where you have the high reflection factor of aluminum for ultra-violet light, giving an increased sensitivity in photographically recording the light from stars.

MR. RAVEN: Have tests been made showing the reflection factor and diffusion characteristics of this finish on flat sheets? If so, how does it compare with the surfaces we now use for motion picture screens? Also, would it be difficult to keep a screen with this finish clean and efficient?

MR. EDWARDS: Maintenance would be relatively easy. Any ordinary kind of dirt is readily removed by washing with soap and water, and the surface will dry free from water-marks.

MR. RAVEN: In other words, ordinary washing would restore the surface to practically its original condition?

MR. EDWARDS: There would be no difficulty whatever.

MR. GAGE: I have had the good fortune to see this process of evaporating aluminum on glass. It is done at the Physical Laboratory of Cornell University by Robley C. Williams. If you start with a good, smooth glass surface, you can get a most excellent coat of aluminum. However, there is no advantage in coating the aluminum so thickly that you can not see the filament of an incandescent lamp through it. The coating can be made so permanent that you can scrub the aluminum coat with cheese cloth, for perhaps 500 times, just as hard as possible, without apparently injuring the surface. This extra durability is secured by first evaporating a thin layer of chromium on hard Corning borosilicate glass followed immediately by a layer of aluminum evaporated from another filament. When removed from the vacuum the aluminum is hardened by washing in tap water, alcohol, or by condensed breath moisture.

How much heat can the all-aluminum reflectors withstand? That is probably a matter that is exciting considerable interest at the present time among the projection engineers. As we know, the back-surface silvered glass reflector will not stand heat above a temperature at which the backing breaks down. We shellac the surface and gain a certain resistance to heat, which is small. If the back of the silver is copper-plated and we use a high-grade varnish, then we can use higher temperatures.

What particularly interests the projection engineer is whether the specular aluminum surface, as treated, can stand a temperature comparable with that withstood by a silvered reflector backed with a good enamel.

MR. EDWARDS: I can not say just what temperature can be withstood without depreciation. The aluminum oxide on the surface is not easily discolored by heat. When the metal and oxide have been stretched sufficiently by thermal expansion, hairline cracks appear. They do not injure the reflection efficiency of the surface appreciably, and are so fine that they can not be seen when viewed directly. The light must be almost at the angle of grazing incidence in order to see them. Our hopes, at least, are that reflectors of this type will stand reasonably high operating temperatures, and do so very satisfactorily.

MR. MITCHELL: Have you any comparative data on the reflection characteristics of chromium, for instance, and this new finish?

MR. EDWARDS: The data I have seen from Nela Park indicate that chrome-plate has a reflection factor of the order of 60 to 65 per cent; with the new finish the reflection may be 80 to 85 per cent.

SIMPLE THEORY OF THE THREE-ELECTRODE VACUUM TUBE*

H. A. PIDGEON**

Summary.—*The physical principles upon which the operation of the three-element vacuum tube depends are presented in simple form and the terms usually applied to the tube, its operation as an amplifier, and a simple approximate method for computing the power output and percentage of distortion are explained.*

No new material is presented in the paper although some of it is presented from a somewhat different point of view from that usually found in the literature. An effort has been made to present in reasonably compact form the essential features of the subject most useful to engineers interested in vacuum-tube applications.

The subjects discussed include: the portion of electron theory upon which the fundamental principles of vacuum-tube operation are based; space charge, the three-halves power law, temperature and voltage saturation; characteristics of the three-element tube; definition and physical significance of the terms plate resistance, transconductance, and amplification factor; dynamic characteristics, power output, and distortion; various means of coupling the vacuum tube to its associated circuits; and means for testing vacuum tubes for adequate thermionic emission.

Vacuum tubes depend for their operation upon the flow of a stream of *electrons* through the evacuated space between the electrodes of the tube. To produce such a flow of electrons, which constitutes an electrical current, two things are necessary: First, there must be a continuous source of supply for the electrode producing the flow of current. The electrode producing this continuous supply of electrons is designated the *cathode.* It must be maintained at an elevated temperature necessary for the liberation of electrons from it. Second, to produce a continuous flow of the electrons, some force must be supplied to propel them. Since they are very small negative charges of electricity, they are attracted by a positively charged body and repelled by a negatively charged body. Consequently, if a second electrode within the vacuum tube be maintained at a positive potential with respect to the cathode, it attracts the negatively charged electrons to it at a rate depending upon the rate at which they are

* Presented at the Spring, 1934, Meeting at Atlantic City, N. J.

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

supplied by the cathode, or upon other factors which will be discussed later. Such an electrode, maintained at a positive potential and acting as a collector of electrons, is designated the *anode* or *plate.*

It is necessary that the electrodes be inclosed within an evacuated envelope, because the presence of air or other gases, even at low pressures, seriously interferes with the performance of the vacuum tube. Such a vacuum tube as we have described, consisting of an evacuated envelope containing two electrodes, a cathode acting as an emitter of electrons, and a positively charged anode or plate acting as a collector of electrons, is called a *diode* or *two-electrode* vacuum tube. Obviously, when the plate of such a tube is maintained at a negative potential with respect to the cathode, it becomes negatively charged, and consequently repels the electrons so that it ceases to collect them and no current flows. The electron current flow in such a tube is, then, unidirectional; that is, it flows only from the cathode to the anode, and only when the potential of the anode is positive with respect to the cathode. If an alternating voltage, or one that periodically changes from positive to negative values and *vice versa,* be applied between the electrodes of such a tube, current will flow in the tube only during the portion of the cycle when the plate is positive with respect to the cathode. Such a device is capable, then, of converting alternating current into unidirectional or direct current. This function is performed by the rectifier tubes employed in all modern radio receivers designed to operate on alternating-current supply.

Furthermore, in such tubes resistance is offered to the flow of electrons, the nature of which will be discussed more fully later. It will suffice to state here that its origin is in the electrical field set up in the space between the cathode and anode by the negative electrons, and that its magnitude depends upon the size, shape, and spacing of the electrodes. If the rate of supply of electrons by the cathode is sufficiently large, this resistance limits the magnitude of the current that may flow at any given anode potential. The current increases with increasing positive plate potential and, consequently, in such a tube it can be varied by varying the potential of the plate.

What is desired in most applications of vacuum tubes, however, particularly in amplifiers, is some means of controlling the flow of electrons to the anode in accordance with variations of an input signal. It is further desired to accomplish these variations in current to the anode with the expenditure of the least possible amount of energy, so that it will be possible for very weak signals to perform this control function.

Such a means of control is found by the insertion of a *grid* or mesh structure between the cathode and anode of the two-electrode tube described above. By maintaining the grid at some appropriate negative potential, it will repel electrons and will in part, but not wholly, neutralize the positive or attractive force exerted upon them by the positive plate. Consequently, an electron stream will still flow through the grid to the plate, but it will be smaller than it would be if the negative grid were not present. By making the grid less negative, its repelling effect will be reduced and a larger current will flow through it to the plate. In a similar manner, if the grid is made more negative, its effect will be increased and the current to the plate will be correspondingly reduced. If the potential of the grid be made to vary about some mean value in accordance with some desired signal, the plate current will vary in a corresponding manner. Since the grid is assumed at all times to be at a negative potential with respect to the cathode, it can not collect electrons, and so, a very minute amount of energy will suffice to vary its potential in accordance with the input signal.

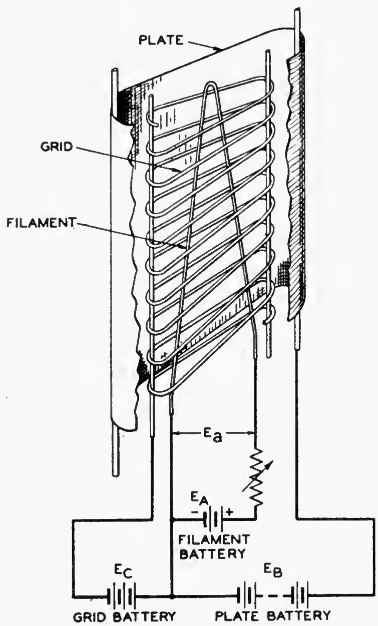

FIG. 1. Schematic diagram of a triode, showing battery connections.

Since such a vacuum tube has three electrodes, *viz.*, cathode, anode, or plate, and grid, it is commonly referred to as a *triode* or three-electrode vacuum tube. The arrangement of the electrodes in a three-electrode tube is shown in Fig. 1. To maintain the electrodes of such a tube in an operating condition and at the proper potentials requires three sources of energy or potential as follows:

To maintain the cathode at the high temperature necessary for the liberation of electrons from it requires energy to be supplied to it.

If the cathode is in the form of a wire or ribbon filament heated by passing current through it, the source of electrical energy, if it be a battery, is referred to as the filament battery. The arrangement of such a battery is shown in Fig. 1. The voltage applied to the filament terminals is designated by E_a. Similarly, batteries supplying the positive plate potential and the negative grid potential, or *grid bias*, are referred to as the plate battery and grid battery, respectively. The arrangement of these batteries is shown also in Fig. 1. Having briefly described the elements of the triode and outlined its essential fundamental principles, we shall next proceed to describe these features in more detail and then show how the device operates as an amplifier.

ELECTRONS

All matter is made up of submicroscopic particles. These particles, which are the smallest into which matter can be subdivided and still retain the properties of the original substance, are called *molecules*. Molecules of different substances vary greatly in complexity, ranging from extreme simplicity in some substances to very great complexity in others. Ultimately, however, all molecules may be broken up into simpler constituents called *atoms*. Of these there are about ninety distinct kinds known, each representing one of the chemical *elements* from which all matter is constructed. Only a few elements, however, appear in the molecules of any one of even the most complex substances. An element, then, is a fundamental substance composed of only one kind of atom. In some elements, the molecules are composed of single atoms; in other elements, two or more like atoms are associated together to form the molecule. Some of the more common elements are hydrogen, oxygen, nitrogen, carbon, iron, nickel, copper, *etc.*

Carrying the analysis further, atoms are well known to have complex structures. According to the most widely accepted modern physical picture of the atom, it corresponds roughly to a miniature solar system. Corresponding to the sun in our solar system is the *nucleus* of the atom which, in general, is a very small, compact structure composed of a combination of extremely minute particles called protons, neutrons, positrons, and electrons. The *proton*, whose mass may be taken as the unit of atomic weight has a positive charge equal in magnitude, but opposite in sign, to that of the electron. Its mass is very large compared with that of the electron or of the positron. The *neutron* has very nearly the same mass as the proton, but is uncharged. The *positron* may be regarded as the ultimate unit of positive charge just as the electron is the ultimate unit of negative charge. The positron has the same magnitude of charge as the electron and very nearly (at least) the same mass. Practically all the mass of the atom is associated with the small, dense nucleus. Revolving about the nucleus in orbits at relatively large distances from it, are one or more electrons.

The simplest of all atoms is that of hydrogen, whose nucleus consists of a single proton with a single electron revolving about it. The mass of the nucleus in this case is 1840 times that of the electron. The next atom in simplicity is that of helium, whose nucleus consists of four protons and two electrons bound together in a compact central core of great electrical stability. Revolving about this compact nucleus are two electrons.

The atoms of the other elements become increasingly more complex by the successive addition of one electron to those revolving about the nuclei, and with the progressive addition of protons, neutrons, positrons, and electrons to the nuclei. In every case the normal atom has an exactly equal number of positive and negative elementary charges, so that the atom as a whole is neutral; that is, it behaves toward electrified bodies at some distance from it as though it had no charge at all.

CONDUCTION

From the standpoint of this discussion, the atoms of certain substances, known as *conductors*, exhibit a very important property. This is particularly true of the metals—copper, aluminum, silver, platinum, iron, nickel, *etc.* The outermost electrons in the atoms of these materials are so loosely attached to the atoms that they actually escape and wander from atom to atom. These wandering electrons are called *free* electrons, although the individual unattached electrons probably remain so for only very short intervals. However, in the aggregate the free electrons per cubic centimeter at any instant amount to an extremely large number. They are in a state of continual rapid motion, or *thermal agitation.* The situation is analogous to that in a gas where it is known that the molecules, according to the kinetic theory, are in a state of rapid motion, with a random distribution of velocity. Now, if it were possible at a given instant to examine the individual molecules or electrons, it would be found that their velocities vary enormously (theoretically they vary from zero to infinite velocity), but that the average kinetic energy of the molecules or electrons is constant for a given temperature, and that it varies with the temperature, being in fact directly proportional to the absolute temperature.

If a conductor, let us say a copper wire, is placed in an electrical field—that is, if the ends of the wire are maintained at different potentials by means of a battery—there is a slow drift of the "atmosphere" of free electrons along the wire toward the end at the higher potential. This slow average drift, which is superimposed upon the relatively very rapid random motion of the individual electrons due to thermal agitation, accounts for the usual conduction currents observed in conductors.

THERMIONIC EMISSION

Another important phenomenon that depends upon the free electrons in conductors is *thermionic emission.* This is the passage of an extremely small fraction of the free electrons through the walls of the conductor into the space outside. Since the free electrons have high average velocities, they would escape in large numbers even at ordinary room temperatures were it not for the fact that at the surface of metals there are very strong forces tending to pull the electrons back into the interior. The situation may be illustrated by the following rough analogy: Suppose that we have a rather deep box open at the top and partially filled with small rubber balls. If the balls are kept in a state of agitation, let us say by shaking the box, an occasional ball will acquire enough velocity, in the proper direction, to escape from the box. That is, by a particularly favorable series of collisions with other balls, it acquires enough kinetic energy so that it may perform the definite amount of work required to lift itself over the walls and escape. If the balls are more and more vigorously agitated, correspondingly more of them will acquire enough energy to escape.

Just as the height of the walls of the box represents a definite amount of work the rubber balls must do to escape, so, too, the surface forces in a conductor represent a definite amount of work an electron must perform to escape from the conductor. This work is known as the *thermionic work-function.* It is sometimes expressed in terms of the equivalent number of volts; that is, the potential difference, in volts, through which an electron must fall to acquire a value of kinetic energy equal to the work-function. It is different for different substances. For example, in tungsten it is 4.52 volts.

In all known substances the work-function is so large that substantially no electrons can escape at ordinary temperatures. However, as the temperature is raised the average kinetic energy of the free electrons is increased proportionally until finally a temperature is reached at which an appreciable number of electrons begin to escape. In pure metals this temperature varies from 1600° to 1800°K. The rate of emission of electrons per unit area (sq. cm.) as a function

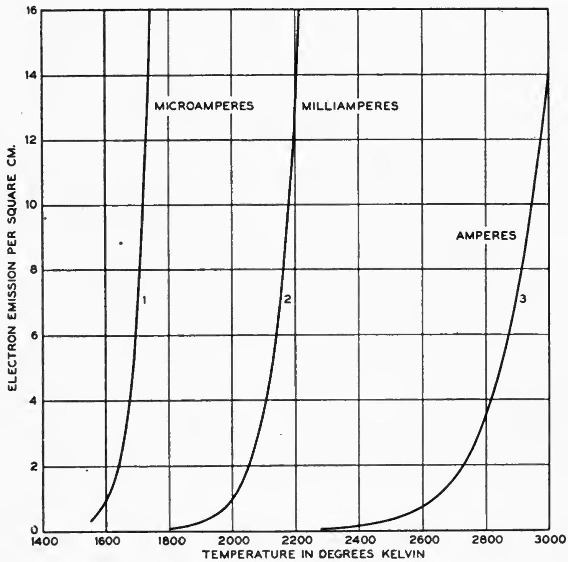

FIG. 2. Electron emission from one square centimeter of pure tungsten as a function of temperature. Curves *1*, *2*, and *3* show the emission current in microamperes, milliamperes, and amperes, respectively.

of temperature follows a law given by what is known as Richardson's equation. It is*

$$I_s = AT^{1/2}\epsilon^{-\varphi e/kT} \qquad (1)$$

* W. O. Richardson, S. Dushman, and others have derived a slightly different expression for electron emission. It is:

$$I_s = A_0T^2\epsilon^{-\varphi_0 e/kT}$$

in which A_0 theoretically has the same value for all metals. Either equation may be taken as a satisfactory expression for electron emission. In fact, it is very difficult to obtain emission data with sufficient precision to distinguish between the two equations.

in which I_s is the emission current in amperes per square centimeter, ϵ is the Napierian logarithmic base, k is the so-called Boltzmann constant (1.37×10^{-23} joules per degree), A is a constant depending upon the emitting substance, φ is the work-function (in volts), e is the charge of the electron (1.59×10^{-19} coulombs), and T is the temperature (°K.).

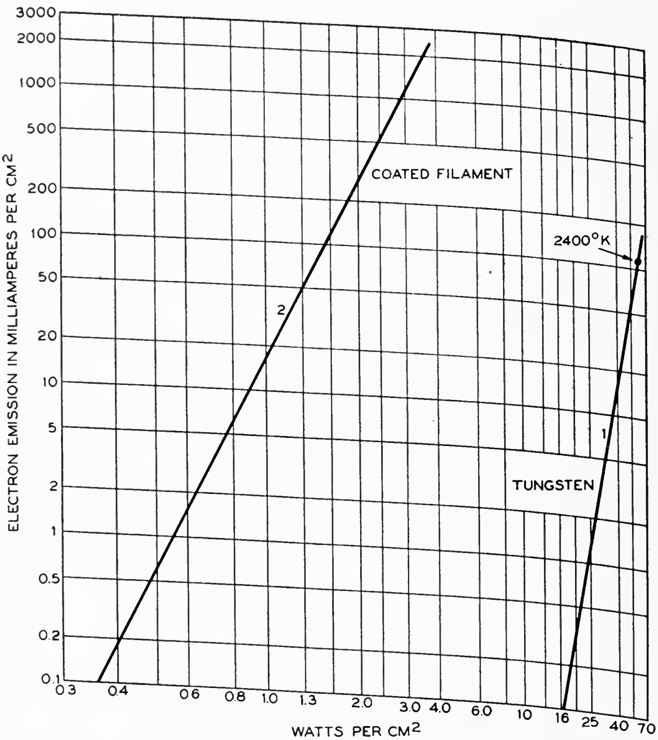

FIG. 3. Electron emission from one square centimeter of tungsten and oxide-coated filament, as a function of the heating energy in watts per square centimeter.

The emission from one square centimeter of pure tungsten is shown by the curves of Fig. 2. Curves *1*, *2*, and *3* give the current in microamperes, milliamperes, and amperes, respectively. They show how extremely rapidly the emission increases with temperature.

Since the energy required to heat a thermionic emitter or cathode is dissipated by radiation from the surface, excepting what is lost by conduction through the leads, it is convenient to express the emission as a function of the number of watts dissipated per unit area of the surface. Curve *1* of Fig. 3 shows the emission from one square centimeter of tungsten plotted in this manner. The coördinates are so chosen that emission data following Richardson's equation give a straight line.

Certain oxides, such as barium and strontium oxides or a combination of the two, when applied to the surface of a metal, have the property of enormously increasing the electron emission at a given

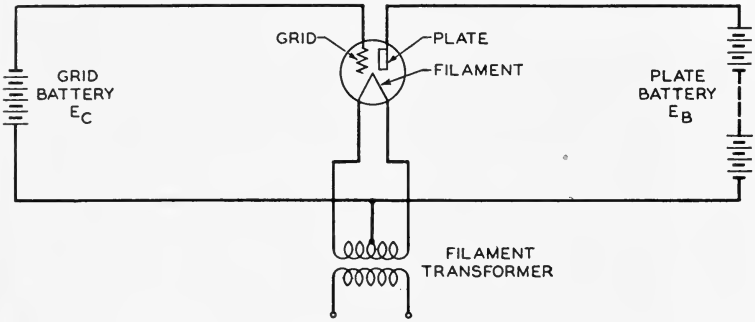

FIG. 4. Schematic diagram of circuit connections to a triode employing a filament transformer.

temperature. This is due to a very material decrease in the work-function. For example, the work-function is equivalent to about 4.52 volts for pure tungsten, and to 1.0 volt or less for oxide-coated filaments. The emission from such filaments varies widely, but curve *2* of Fig. 3 may be taken as a typical illustration of emission lines obtained for one square centimeter of coated filament. The great difference between it and tungsten is at once apparent.

For example: Tungsten operating at 2400°K. emits 116 milliamperes per square centimeter of surface and requires about 58 watts per square centimeter to heat it. The emission is, then, 2 milliamperes per watt. On the other hand, oxide-coated filaments operate within the range 950° to 1125°K., with a power dissipation of 2.0 to 5.0 watts per square centimeter, and an emission of 75 milliamperes or more per watt.

However, as stated, the emission from oxide-coated cathodes varies greatly, depending upon the core and coating materials, coating and exhaust technic, *etc.* Furthermore, the life of cathodes depends also upon this technic and may vary greatly with it.

PRACTICAL CATHODES

Cathodes in vacuum tubes are universally heated electrically. The simplest type is in the form of a wire or ribbon, heated directly by passing a current through it. Vacuum tubes having such filaments for cathodes are sometimes called *filamentary* tubes to distinguish them from tubes having *indirectly heated* cathodes. The filament current may be supplied by a battery, as shown in Fig. 1, or by a generator or transformer in case alternating current is employed. One disadvantage of using alternating current for the filaments of tubes used in audio-frequency circuits is that it introduces objectionable hum in the output. The hum can be minimized by connecting the plate and grid circuits to the mid-point of the secondary of the transformer, as shown in Fig. 4, but in general it is not possible to apply alternating current to the filaments of vacuum tubes used in the early stages of high-gain amplifiers.

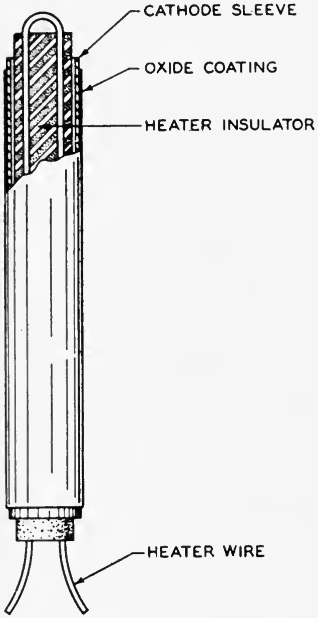

FIG. 5. Schematic diagram of an indirectly heated cathode.

This difficulty is overcome in a large measure by using indirectly heated cathodes. One common arrangement is shown in Fig. 5. The cathode consists of a metallic cylindrical sleeve, usually of nickel, coated with a mixture of barium and strontium oxides. A lead-wire from the cathode sheath is carried out to an external tube terminal so that the cathode may be maintained at any desired potential.

The heater wire is usually of tungsten, and may be in the form of a spiral or, as in the illustration, in the form of a hair-pin threaded through parallel tubular holes in a ceramic insulator. Vacuum tubes having cathodes of this type are referred to as *heater type* tubes; or, since the cathode sheath is at a uniform potential, they are often referred to as *unipotential* or *equipotential cathode* tubes to distinguish them from filamentary tubes. The heaters may be operated on either direct or alternating current. When the latter is used, although the hum is reduced to a much lower level than in filamentary tubes, it is not entirely eliminated, for reasons beyond the scope of this paper to discuss. The usual circuit arrangement is shown in Fig. 6. Con-

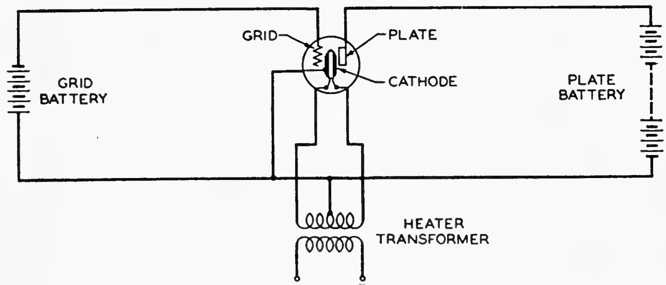

FIG. 6. Schematic diagram of circuit connections to a triode with indirectly heated cathode.

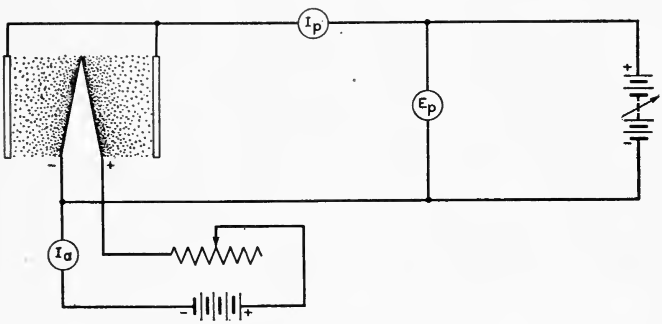

FIG. 7. Schematic diagram of circuit connections to a diode whose characteristics are shown in FIG. 8.

necting the mid-point of the secondary winding of the transformer to the cathode usually reduces the residual hum observed even in heater type tubes.

VACUUM-TUBE CHARACTERISTICS

Let us next consider the characteristics of a vacuum tube containing a filamentary cathode and a plate or anode, as shown in Fig. 7. We shall assume that the filament current, I_a, is held at some fixed value such that the filament operates at a temperature sufficiently high to emit a copious number of electrons. Let the plate be connected to the positive terminal of the plate battery, whose negative terminal is connected to the negative filament terminal as shown. We shall assume that the potential of this battery can be varied at will to any desired value. The potential of the plate, with respect to the negative filament terminal, is measured by the voltmeter, E_p; and the electron stream to the plate, called the plate current or space current, I_p, is measured by the I_p meter. Let us assume that the

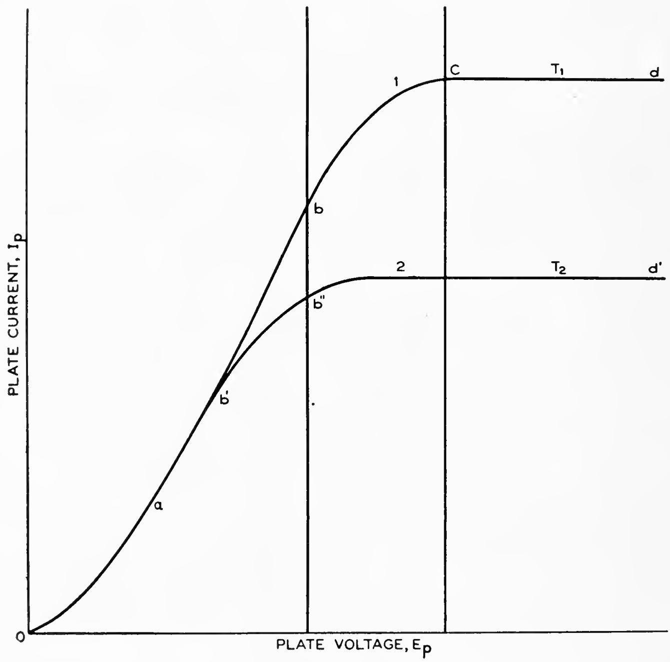

FIG. 8. Plate current-plate voltage characteristics of a diode.

plate potential, E_p, is varied gradually from zero to greater and greater positive values. The corresponding values of the plate current, I_p, are measured by the I_p meter. If the corresponding values of I_p and E_p are plotted, a curve is obtained as indicated by *o*, *a*, *b*, *c*, *d* in Fig. 8, showing that the current increases slowly at first as the plate potential is increased from zero, then more and more rapidly. Later it increases more slowly and finally becomes quite constant, increasing scarcely at all with further increase in plate voltage. The interpretation of the curve is as follows: At *c* the plate potential becomes sufficiently high to draw to the plate substantially all the electrons emitted by the filament and, consequently, there can be no appreciable further increase in current with further increase in plate voltage. In the region from *c* to *d*, then, the plate current is substantially independent of the plate voltage and the tube is in a condition of *voltage saturation*. The current is determined only by the temperature of the filament, designated by T_1. Now, at this point the question naturally arises: Since the plate, at any positive potential, exerts an attractive force upon all the negative electrons, why does it not when at some lower potential, such as at *a*, for example, attract all the electrons to it? The answer is that it does not because the evacuated space between the cathode and the plate offers resistance to the flow of the electron stream. The origin of this resistance is found in the presence of *space-charge*.

Since the electrons are, in fact, minute negative charges of electricity, there is at every point in the space between the cathode and the plate a negative charge whose density is proportional to the number of electrons per unit volume at that point. This charge is designated space-charge. Although it extends throughout the interelectrode space, its density is relatively so much greater at points very near the cathode surface, where the velocity of the electrons is low, that for all practical purposes we may regard it as confined to a sheath about the cathode (in this case a filament) varying from a few thousandths to a few hundredths of a centimeter in thickness. The situation is somewhat as pictured roughly in Fig. 7. As a matter of fact, the space-charge is relatively much more dense at points close to the cathode than it is possible to indicate in such a picture.

Now, this cloud of negative electrons produces an electrical field near the surface of the cathode which opposes the escape of electrons from it. This field is opposite in direction to that produced by the anode maintained at a positive potential. The resistance to the flow of electrons produced by the space-charge is such that if the cathode surface were at a uniform potential and if the electrons were emitted with zero velocity (which is not quite true), it can be shown from theoretical considerations that the plate current should increase proportionally to the three-halves power of the plate voltage. That is,

$$I_p = KE_p^{3/2} \tag{2}$$

in which K is a constant depending upon the geometrical dimensions of the electrodes and upon their spacing. The plate current, then, from o to some point b, in Fig. 8 follows this three-halves power law, being limited by the resistance produced by the space-charge. In this region the plate current is independent of the temperature of the filament and, consequently, it is said to be in *temperature saturation*.

If the temperature of the filament is lowered to some value T_2, the plate current-plate voltage characteristic is changed as indicated by the curve $o\ a\ b'\ c'\ d'$, the height of the flat portion $c'd'$ again being determined by the lower temperature, T_2, of the filament.

Now, in the operation of vacuum tubes it is impracticable to maintain the cathodes at a precisely constant temperature. Economic considerations require that certain tolerances be allowed in the range of operating filament current and temperature. On the other hand, it is highly undesirable to have the plate current and, consequently, the operating performance of the tube vary with such fluctuations in filament current. For this reason vacuum tubes must be limited in their range of operation to the region of reasonably good temperature saturation. That is, in curve *1* of Fig. 8, the operating range is limited to the region $o\ a\ b$. If the temperature of the cathode in this particular tube should fall to T_2, the characteristic would change from $o\ a\ b$ to $o\ a\ b'\ b''$ which would perhaps be too great a change to be tolerated. This subject will be discussed further after we have considered the characteristics of three-electrode tubes.

THE THREE-ELECTRODE VACUUM TUBE

Suppose we modify the tube structure shown diagrammatically in Fig. 7, and whose characteristics are shown in Fig. 8, by inserting a grid between the plate and the cathode. Grids are usually spirals of fine wire held rigidly in place by welding them to heavier supporting wires. The modified structure typical of a three-electrode tube or triode is shown diagrammatically in Figs. 1 and 9. Let the filament and plate circuits be identical to those previously considered in Fig. 7. Let the grid be connected, as shown in Fig. 9, to the negative terminal of the grid battery, the positive end of which is connected to the negative filament terminal. Let us assume that the grid voltage, E_g, is variable at will from zero to any desired negative value, and that it can be measured by the voltmeter shown.

Now, with the grid interposed between the cathode and the plate, we should expect it to shield the cathode from the plate more or less, and so render the latter less effective in drawing electrons away from the cathode. Consequently, the plate current is smaller than before. Particularly, if the grid is held at some negative potential, it produces a negative field at the cathode which partially neutralizes the positive field produced by the plate, thus reducing the power of the latter to pull electrons through the space-charge region.

Let us first assume that the grid is held at zero potential with respect to the filament, and that the plate voltage is varied as before, reading the corresponding values of plate current, I_p, for given values of E_p. The results are represented by curve *1* of Fig. 10.

Let us next assume that the grid is held at some fixed negative

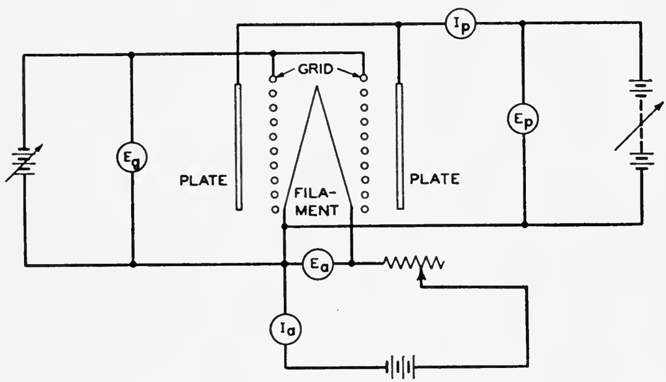

FIG. 9. Schematic diagram of circuit connections to a triode whose characteristics are shown in Figs. 10 and 11.

potential, say, −3 volts, and the process repeated. The results are shown by curve *2*. Let the process be repeated for $E_g = -6, -9, -12$, and −15 volts. The results are given by curves *3*, *4*, *5*, and *6*. We see that all the curves of this family of characteristics have approximately the same shape, and that they are approximately equally spaced. The approximate effect, then, of increasing the negative grid voltage by equal steps of 3 volts is to move the characteristic to the right by equal increments along the voltage axis. These curves will also be found to follow a three-halves power law approximately, if due regard is given to the transfer of the origin along the plate voltage axis.

Now, let us assume that the plate is held at some fixed potential, say, 90 volts, and that values of the plate current are obtained as the grid bias is varied from zero to such a negative voltage that it completely neutralizes the effect of the plate, thus reducing the plate current to zero. This characteristic is represented by curve *1* of Fig. 11. Let this process be repeated with the plate held at 120, 150, 180, 210, and 240 volts. The results are given by curves *2*, *3*, *4*, *5*, and *6*. Again we obtain a family of similarly shaped curves spaced at approximately equal distances. Furthermore, the curves have approximately the same shape as the family shown in Fig. 10

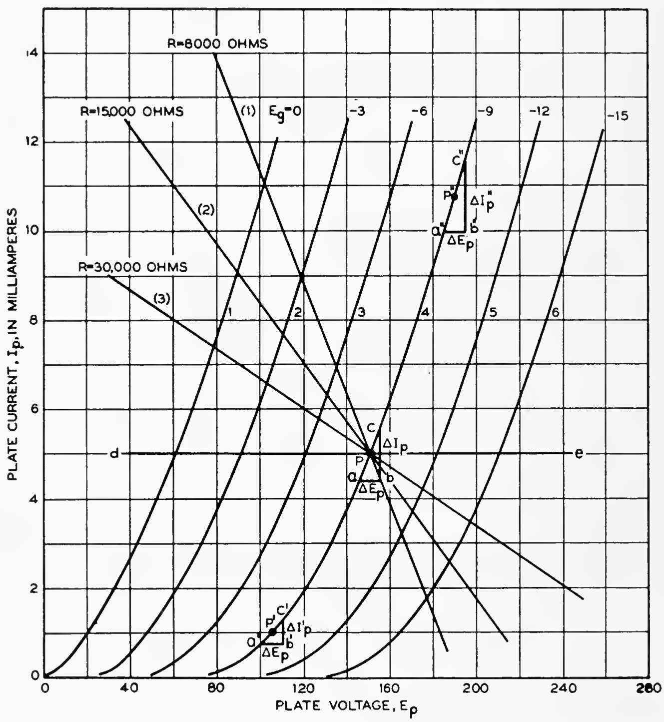

FIG. 10. Plate current-plate voltage characteristics of a triode.

and, in fact, they do follow the same law with certain necessary modifications. As an approximate equation for the entire family of characteristics of a three-electrode tube we may write,

$$I_p = K(E_p + \mu E_g)^{3/2} \tag{3}$$

in which μ is the amplification factor (discussed later) and K is a function of the geometrical dimensions of the tube elements and the amplification factor μ. Both K and μ are commonly referred to as *tube constants,* although they do vary somewhat over the usual range of operation. In most cases, particularly in tubes having filamentary cathodes, an exponent differing somewhat from $^3/_2$ will be found to fit the characteristics best. Among the more important factors contributing to departure from the ideal three-halves power law are: potential drop along the filament, variations in the magnitude of the amplification factor, μ, and the effect of the initial velocity

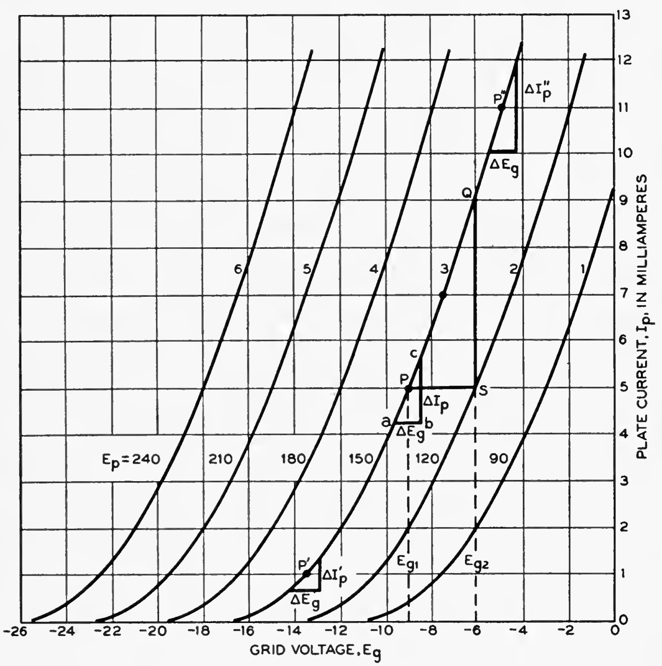

FIG. 11. Plate current-grid voltage characteristics of a triode.

with which the electrons are emitted from the filament. It is beyond the scope of this paper to discuss these factors in detail.

It is readily seen from consideration of equation 3 that if K and μ were constant, all the curves of any family of characteristics, such as those shown in Fig. 10 or Fig. 11, would have exactly the same shape and would also have exactly the same horizontal voltage intercept between them at all points. For, if E_g be changed by successive equal increments and if E_p is changed at the same time in the opposite sense by successive equal increments μ times as large as the increments in E_g, the plate current, I_p, will remain unchanged. This is true regardless of the value of I_p. Hence, all the characteristic curves in the families shown in Fig. 10 or Fig. 11 could be obtained by a simple translation of any one of the curves by successive equal steps in the direction of the voltage axis.

In both the families of characteristics shown in Figs. 10 and 11 we have assumed that the total electron emission is sufficiently great that at all points the plate current is limited by the space charge. In other words, we are assuming that the total emission from the filament is at least several times the maximum values of the indicated plate current, so that the tube operates in a condition approximating temperature saturation. Consequently, the curves do not show any appreciable flattening out at the tops, such as shown in Fig. 8.

From the families of characteristics shown in Figs. 10 and 11 it is apparent that under conditions of filament temperature saturation, the plate current in a triode is determined by both the plate and grid voltages. Since these voltages may be varied independently of each other, they may be chosen in pairs to determine an indefinitely large number of operating points extending throughout the permissible operating range of the tube. Each operating point (that is, each point in the diagram of Fig. 10 or Fig. 11) determines fixed values of plate voltage, grid voltage, and plate current. One such operating point is at P in Figs. 10 and 11, at which the plate voltage is 150 volts, the grid voltage is -9 volts, and the plate current is 5 milliamperes.

Let us consider further the operating point P. If the grid voltage is varied about this point by the small amount, ΔE_g (Fig. 11), indicated by the base of the small triangle *abc*, the plate current will at every instant be given by the corresponding points on the characteristic between the points *a* and *c*, and will vary through the range given by ΔI_p which is the altitude of the small triangle *abc*. The ratio of this change in plate current to the change in grid voltage, with the plate voltage remaining constant, is called the *mutual conductance* or *transconductance* of the tube. That is,

$$\text{Transconductance} = S_m = \frac{\Delta I_p}{\Delta E_g} \qquad (4)$$

when ΔI_p and ΔE_g are made infinitesimally small.

Physically, the transconductance at any given operating point is the rate of change of plate current with variations in the grid voltage; that is, it is the slope of the plate current-grid voltage characteristic at constant plate voltage. It is usually measured in microamperes per volt or in micromhos. Numerically, it is the change of plate current in microamperes per volt change in grid voltage, the plate voltage remaining constant.

Obviously, the transconductance is not the same at all operating points for a given tube. For example, if the operating point is chosen at P' (Fig. 11) and the same small change in voltage applied to the grid, the change in the plate current, $\Delta I_p'$, will be less than at P, because the characteristic curve is flatter at P' than at P. Consequently, the transconductance at P' is smaller than at P. At P'' it is larger than at P for a similar reason.

Transconductance varies greatly in different types of tubes. It is beyond the scope of this paper to discuss in detail the factors determining its magnitude, but it will suffice to state that, in general, it increases with the size of tubes, with the plate voltage and plate current at which they operate, and also increases with decrease in the electrode spacings, particularly that between the cathode and grid. The transconductance is a useful criterion of performance, or figure of merit of vacuum tubes, since it determines the magnitude of output current for a given input voltage applied to the grid.

Referring again to Fig. 11, suppose we start at the operating point P and change the grid voltage to E_{g2} with the plate potential held constant at 150 volts. This change from E_{g1} to E_{g2} is equal to the horizontal intercept PS, between the 150- and 120-volt characteristics. The plate current rises to the value given by the point Q on the 150-volt characteristic. Next, let the plate voltage be changed from 150 volts to 120 volts, maintaining the grid voltage constant at E_{g2}. The operating point is now at S, and the plate current is exactly the same as it was at the original operating point P. We thus see that the effect upon plate current of reducing the plate voltage from 150 to 120 volts is exactly equal and opposite to that produced by changing the negative grid voltage from $E_{g1} = -9$ volts to $E_{g2} = -6$ volts, because the two operations leave the current unchanged from its original value. The ratio of the plate voltage change to the grid voltage change producing equal and opposite changes in the plate current gives us the magnitude of another electrical parameter of the tube, known as the *amplification factor*, μ. Thus, in this case,

$$u = -\frac{E_{p1} - E_{p2}}{E_{g1} - E_{g2}} = \frac{150 - 120}{9 - 6} = 10 \qquad (5)$$

We see from this argument that to produce equal and opposite changes in the plate current (thus leaving its final value unchanged), the change in plate voltage must be μ times the change in grid voltage. In other words, we may describe the amplification factor as a measure of the relative effectiveness of small changes in grid voltage to similar changes in plate voltage in changing the plate current. The amplification factor is a very useful tube parameter since, in conjunction with the plate resistance, it at once gives a measure of the amplification to be attained with any given external load resistance.

Let us next consider the operating point P in Fig. 10. It corresponds exactly to the operating point P in Fig. 11, since it defines the same plate voltage, grid voltage, and plate current. Now let the plate voltage be varied about this point by the small amount ΔE_p, equal to the base of the small triangle *abc*. The operating point will simultaneously move along the characteristic from a to c, since the grid voltage is not changed. The corresponding change in the plate current is ΔI_p which is equal to the height bc of the small triangle *abc*. Now, since a change in plate voltage, ΔE_p, produces a change in current, ΔI_p, the quotient obtained by dividing ΔE_p by ΔI_p gives the resistance the tube offers to this change. This resistance is called the *plate resistance*, R_p, of the tube at the operating point P. Thus,

$$R_p = \frac{\Delta E_p}{\Delta I_p} \quad (6)$$

when ΔE_p and ΔI_p are made infinitesimally small. That is, R_p is the reciprocal of the slope of the plate current-plate voltage characteristic at constant grid voltage. At the point P in Fig. 10,

$$R_p = \frac{10}{1.25 \times 10^{-3}} = 8000 \text{ ohms}$$

By an argument precisely similar to that used in the case of the transconductance, it can be shown that the plate resistance at P' is larger than at P, and at P'' it is smaller than at P. For all points along the line *de*, for which the current is constant, the plate resistance remains practically constant.

We have just discussed three of the more important electrical parameters of the three-electrode vacuum tube, *viz.:* the transconductance, S_m, the amplification factor, μ, and the plate resistance R_p. Both S_m and R_p vary widely with variations in plate current, and vary in an approximately inverse manner with respect to each other. The amplification factor, μ, is often referred to as the *amplification constant* and, while it is not a constant, it does not vary greatly over the usual operating range.

These three tube parameters are not independent of each other and, in fact, we should not expect them to be, for the argument used in obtaining the value of μ indicates that some relation exists between μ, S_m, and R_p. In fact, simply expressing the definition previously given for the amplification factor in mathematical form gives

$$\mu = \frac{\dfrac{\Delta I_p}{\Delta E_g}}{\dfrac{\Delta I_p}{\Delta E_p}} \qquad (7)$$

If ΔE_g and ΔE_p be so chosen that I_p remains constant—that is, such that the values of ΔI_p in the numerator and denominator of equation (7) are equal in magnitude and opposite in sign—then

$$\mu = - \left.\frac{\Delta E_p}{\Delta E_g}\right]_{I_p = \text{constant}} \qquad (8)$$

Equation (8) is equivalent to equation (5), and precisely defines the value of μ when ΔE_p and ΔE_g are infinitesimally small.

Combining equations (4) and (6) with (7) gives:

$$\mu = S_m R_p$$

from which

$$S_m = \frac{\mu}{R_p} \qquad (9)$$

In the illustration given above,

$$S_m = \frac{10}{8000} = 1250 \times 10^{-6} \text{ amperes per volt} = 1250 \text{ micromhos}$$

at the point P.

DYNAMIC CHARACTERISTICS

Thus far we have considered only what are usually called the *static characteristics* of the three-electrode tube. That is, we have considered the plate current as a function of voltages applied directly between the plate and cathode and between the grid and cathode without any external impedance between the measured potential sources and the tube elements. In the practical applications of vacuum tubes it is necessary to have such external impedances in the plate and grid circuits. For in any such application, the input signal is applied to the grid as a control element; that is, the potential of the grid is made to vary with time in accordance with variations in the signal intensity. Since, as we have seen, the plate current varies with the grid potential, it also must vary in accordance with the signal input on the grid. Obviously, if the tube is to serve any useful purpose, its fluctuating plate current must be made to operate some receiving device such as a telephone receiver or a loud speaker, or to provide varying potentials to the grid of the following tube if an amplifier of more than one stage is employed. Since any such device must have impedance (that is, resistance), it necessarily results in the introduction of an external impedance into the plate

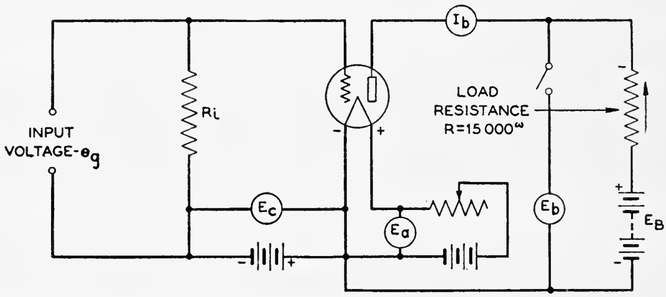

FIG. 12. Schematic diagram of circuit connections to a triode, with external load resistance and input resistance in the circuit.

circuit of the tube. An exactly similar argument applies to the grid circuit. To apply an input signal to the grid requires the insertion of the input signal device in the grid circuit, with its given impedance.

Let us next consider such an arrangement and the effect it has upon the operating characteristic of the tube. The circuit arrangement, in a simple form, is shown in Fig. 12. R is the resistance of the receiving device in the plate circuit. It is called the *output* or *load resistance* since it is the resistance into which the useful power is delivered. R_i is the impedance of the input signal device which applies an input voltage, e_g, to the grid of the tube. Let us assume that we can vary this input voltage, e_g, at will, and that for the present it is zero. We shall further assume that the grid is negative in potential with respect to the filament at all times so that it can not collect electrons. Since there is no current flowing in the grid circuit, the potential drop across R_i is zero, and thus the operating potential of the grid with respect to the filament is E_c, which we shall assume to be -9 volts. This voltage is indicated by the voltmeter, E_c.

In the plate circuit, let the plate battery voltage E_B be adjusted to give a potential between the plate and filament of 150 volts, as indicated by the voltmeter, E_b. The plate and grid voltages are now

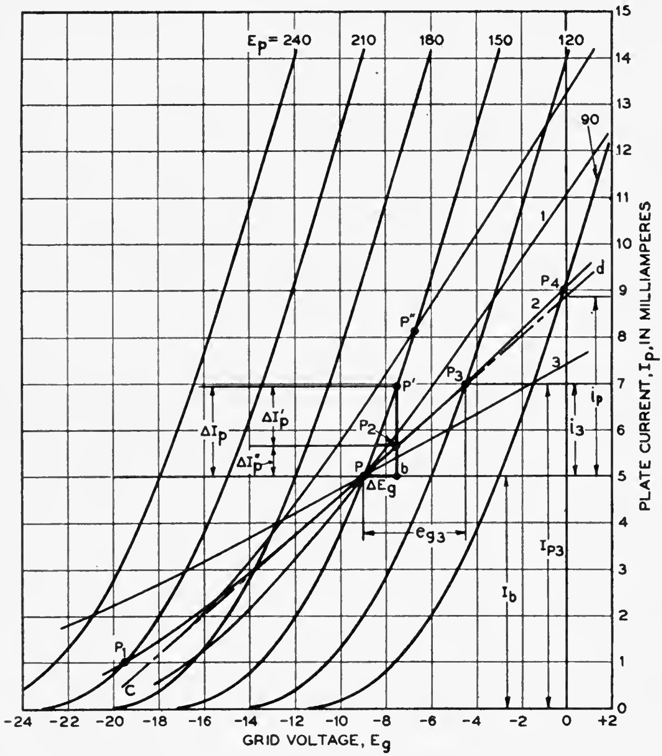

FIG. 13. Dynamic or load characteristics of a triode obtained with the circuit shown in Fig. 12, and with load resistances of 8000, 15,000, and 30,000 ohms.

adjusted to the values giving the operating point P in Fig. 11. Hence the operating plate current, I_b, has the value 5 milliamperes determined by that point. For the sake of clarity the curves of Fig. 11 with the operating point P are reproduced in Fig. 13.

It should be observed that with the operating plate potential, E_b, adjusted to 150 volts, the plate battery voltage, E_B, must be higher than 150 volts. For, since the plate current, I_b, flows through the load resistance, R, it produces a potential drop in the direction of the arrow.* This potential drop subtracted from the battery voltage E_B, gives the operating potential difference E_b between plate and filament. That is

$$E_b = E_B - I_b R \tag{10}$$

Starting at the operating point P in Fig. 13, let us vary the grid potential, maintaining the plate battery voltage, E_B, constant, and see what happens. Since we have assumed that we can vary e_g at will, let us adjust its value to 1.5 volts in such a direction as to reduce the grid bias from -9 to -7.5 volts. If the plate voltage were to remain constant at 150 volts, the operating point would be moved to P' on the 150-volt characteristic. The plate potential does not remain constant, however, for as the plate current increases the potential drop through R increases, and the plate potential falls an equal amount (since E_B is constant). Hence, the operating point must move to some point P_2 at a lower plate potential and lower plate current than at P'. Continuing this procedure by adding further positive increments to the input voltage, e_g, we obtain additional points through which the curve P, P_2, P_3, P_4 is drawn. By choosing various negative values of e_g, the curve is extended in the opposite direction from the original operating point P. This curve, P_1, P, P_4, is called the *dynamic characteristic* of the tube through the operating point P. It is easy to determine the point of intersection of this curve with any static characteristic at constant plate voltage. For example, consider the point P_3, at which it intersects the 120-volt characteristic. At this point the plate potential has dropped 30 volts from its original value at P. This potential drop is caused by the increased potential drop across the load resistance, R, due to the

* In the conventional sense, the current in the plate circuit flows from the positive terminal of the battery E_B through the resistance R, thus producing a potential drop I_bR in the direction of the current flow. The current then flows from the plate to the filament and back to the negative terminal of the plate battery E_B. Heretofore, we have referred to the electron current flow being from the filament to the plate. The reason for this seeming discrepancy is that the conventional direction of current flow is that which would be taken by a positive charge; whereas the electron, being an actual negative charge, moves in the opposite direction.

plate current increasing from I_b to I_{p3}, that is, by an increment, i_3. We have then, assuming that $R = 15{,}000$ ohms.

$$i_3 = \frac{150 - 120}{R} = \frac{150 - 120}{15{,}000} = 2.0 \text{ milliamperes}$$

and
$$I_{p3} = I_b + i_3$$
$$= 5.0 + 2.0 = 7.0 \text{ milliamperes.}$$

Thus, the dynamic characteristic intersects the 120-volt characteristic at a plate current of 7 milliamperes. The dynamic characteristic may be defined as the locus of points determining the plate current of the tube as the grid potential varies, with a given load resistance in the plate circuit.

The slope of the dynamic characteristic P_1PP_4 at the point P may be derived readily as follows: Consider the two small triangles $PP'b$ and PP_2b in Fig. 13, with the common base ΔE_g, and whose altitudes are given by ΔI_p and $\Delta I_p''$, respectively. These triangles are assumed to be so small that the static and dynamic characteristics are essentially linear throughout the range considered. The slope of the dynamic characteristic, which we shall call S_{md}, is given by

$$S_{md} = \frac{\Delta I_p''}{\Delta E_g} \tag{11}$$

$$\Delta I_p'' = \Delta I_p - \Delta I_p' \tag{12}$$

We shall assume that the operating point moves from P to P_2 on the dynamic characteristic in two successive steps. In the first step the plate voltage remains constant and the grid voltage is changed by the amount ΔE_g. The operating point moves from P to P' on the 150-volt static characteristic. The resulting change in plate current ΔI_p, is given by

$$\Delta I_p = S_m \Delta E_g = \frac{\mu}{R_p} \Delta E_g \tag{13}$$

In the second step, the grid voltage remains constant and the plate voltage is changed by the amount ΔE_p, during which the operating point moves along the vertical line from P' to P_2, the plate current changing by the amount $\Delta I_p'$. From the definition of plate resistance, E_g, remaining constant,

$$\Delta I_p' = \frac{\Delta E_p}{R_p} \tag{14}$$

But this change in plate voltage is produced by the increased potential drop through the load resistance, R, due to the plate current increasing by the amount $\Delta I''_p$; therefore,

$$\Delta E_p = \Delta I_p'' R \tag{15}$$

Hence,

$$\Delta I_p' = \frac{R}{R_p} \Delta I_p'' \tag{16}$$

Substituting the values of ΔI_p and $\Delta I_p'$ given by equations (13) and (16) in (12)

$$\Delta I_p'' = \frac{\mu}{R_p} \Delta E_g - \frac{R}{R_p} \Delta I_p''$$

or

$$\Delta I_p'' = \frac{\mu}{R_p + R} \cdot \Delta E_g \tag{17}$$

Finally, substituting in equation (11)*

$$S_{md} = \frac{\mu}{R_p + R} \tag{18}$$

Equation (18) expresses the slope of the straight line *cd* in Fig. 13, which is tangent to the dynamic characteristic at the operating point P. If the dynamic characteristic were linear, that is, if it coincided with the straight line *cd* at all points, the output current, i_3, at any point P_3 would be exactly proportional to the input voltage, e_{g3},

* To those familiar with calculus operations, it will be apparent that the above procedure is equivalent to a simple process in differential calculus.
For, let

$$I_p = f(E_p, E_g) \tag{19}$$

Then

$$dI_p = \frac{\delta I_p}{\delta E_p} dE_p + \frac{\delta I_p}{\delta E_g} dE_g \tag{20}$$

Which, from the definitions of transconductance and plate resistance, may be written,

$$dI_p = \frac{1}{R_p} \cdot dE_p + \frac{\mu}{R_p} \cdot dE_g \tag{21}$$

Also for points on the dynamic characteristic,

$$dE_p = - dI_p \cdot R \tag{22}$$

Substituting in the preceding equation,

$$dI_p = - \frac{R}{R_p} dI_p + \frac{\mu}{R_p} dE_g \tag{23}$$

From which

$$S_md = \frac{dI_p}{dE_g} = \frac{\mu}{R_p + R} \tag{24}$$

and its value would at once be obtained by multiplying equation (18) by the input voltage, e_{g3}. Thus,

$$i_3 = \frac{\mu}{R_p + R} \cdot e_{g3} \qquad (25)$$

For any signal input, the output current and the resulting variation in potential across the load resistance, R, would be an exact replica of the signal voltage in magnified form. But as the dynamic characteristic is not exactly linear, the output is not quite proportional to the input. There results what is known as distortion in the output, a subject that will be discussed more fully later.

For very small inputs, the dynamic characteristic practically coincides with the straight line cd and, consequently, the output current is given quite accurately by equation (25). For larger signal inputs, it can be shown that the fundamental components of the output, that is, that portion of the output that is a replica of the input, is given to a fairly close approximation by equation (25).

As a further illustration of the foregoing argument, let us assume that a very simple signal, which varies with time, is applied to the grid. We shall assume that, before this signal is applied, the plate voltage impressed upon the tube as measured by the voltmeter, E_b, is 150 volts, and the grid bias voltage as measured by the voltmeter, E_c (Fig. 12), is -9 volts. The operating point of the tube is now given, as before, by the point P in Fig. 13. To avoid confusion, these curves are reproduced in Fig. 14. Now, let us assume that an input voltage which is sinusoidal in form is applied in the grid circuit. The form of such a voltage wave is shown by curve A in Fig. 14. Time is measured downward from the point O on the vertical axis through the point P. The input voltage at any time T_1 is given by the horizontal displacement of the corresponding point Q_1 on the curve. It will be seen that as time progresses from O, the input voltage increases toward the right or positive direction until at time T_2 it reaches a maximum value, e_g, at Q_2; then recedes to zero at T_3; increases to an equal maximum distance, e_g, in the negative direction (left); and again returns to zero at time T_5. The voltage is assumed to repeat this cycle continuously in periods of time equal to T_5.

Let us now inquire what is the character of the output of this tube with such an input voltage applied. It is given by curve $B(O'Q_2'Q_4')$, in which time is now measured in the horizontal direction toward the right from the point O', and the current is given by the ordinates.

This may be readily verified point by point. For example, consider point Q_1 on curve A. Projecting this point vertically upward shows that it corresponds to a grid voltage of −2.6 volts and to a plate current of 7.86 milliamperes at point Q_1'' on the dynamic characteristic. Projecting this point horizontally to the right gives the point Q_1', at time T_1, on curve B. Other points on curve B may be obtained from curve A in the same manner.

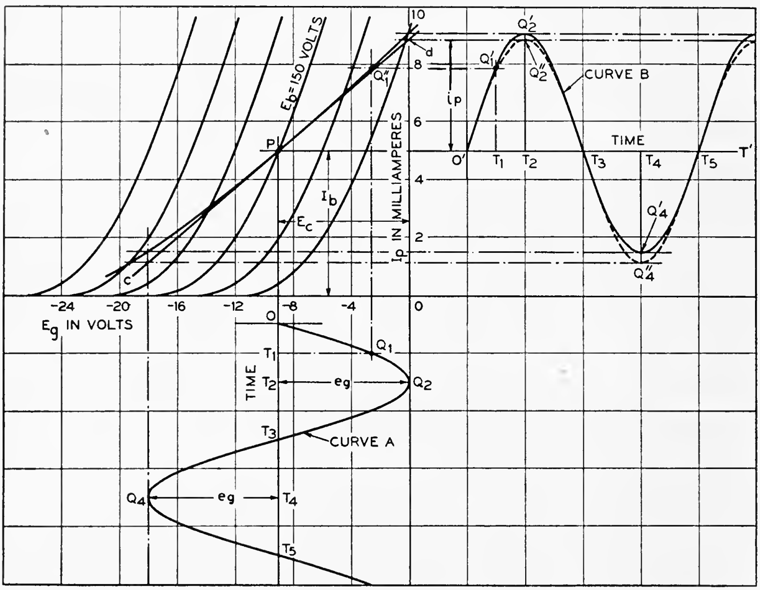

Fig. 14. Output current of a triode with a sinusoidal input voltage applied to the grid.

Curve B, showing the variation of the output current about the time axis $O'T'$, is almost, although not quite, exactly similar to the input voltage curve A. The positive lobes above the axis $O'T'$ are somewhat higher than those below this axis. This distortion is due to the curvature of the dynamic characteristic as previously discussed. If the dynamic characteristic were the straight line cPd, then the output current would be exactly given by the dashed curve $O'Q_2''Q_4''$, and the output current would also be sinusoidal and of exactly the same form as the input wave.

From equation (18) it is apparent that the slope of the dynamic characteristic decreases with increasing values of the load resistance,

R. If the load resistance is made equal to the plate resistance at point P in Fig. 13, that is, $R = 8000$ ohms, the dynamic characteristic is given by curve *1*. If the load resistance is changed to 30,000 ohms, the dynamic characteristic is given by curve *3*. Increasing the load resistance not only decreases the slope of the dynamic characteristic but it also decreases the curvature, making the characteristic more nearly linear. This reduces the distortion, although at the same time it reduces the power output when R becomes larger than R_p, since it can be readily shown that for a given grid swing, the maximum power is obtained from a vacuum tube when the external load resistance is made equal to the plate resistance.

In vacuum tubes associated with telephone transmission lines, it is desirable or even necessary to operate them into matched impedances in order to minimize disturbing effects due to reflection. However, in many applications where this restriction does not apply and where distortion is a criterion of the useful power obtainable, it is advantageous to operate a three-electrode tube into a load resistance larger than the plate resistance, at the same time choosing an optimum point on the plate current-plate voltage characteristic such as to give the maximum permissible plate-voltage and plate-current swings. This will be illustrated after we have discussed a simple method for the approximate computation of the percentage of distortion.

It is sometimes advantageous to work with dynamic characteristics plotted on the plate current-plate voltage family of characteristics. Dynamic characteristics, commonly called *load lines*, corresponding to curves *1*, *2*, and *3* of Fig. 13, are shown in Fig. 10. Each dynamic characteristic or load line so plotted is a straight line whose slope is equal to the reciprocal of the load resistance. This follows from the fact that at all points on any dynamic characteristic the variations in plate potential are equal to the variations in the potential drop across the load resistance, which in turn are directly proportional to the variations in the plate current.

AMPLIFICATION

The final objective in an amplifier tube is, of course, not only to have the output as nearly identical to the input in wave-form as possible, but also to have it as much larger as possible as measured by its current, voltage, or power.

As an illustration, let us compute the amplification obtained in the example previously considered with a sinusoidal input applied to the grid. The amplitude or peak value of the input voltage is given by the line T_2Q_2 in curve A of Fig. 14, which we shall call e_g. For reasons previously given, we may take as a close approximation the ordinate T_2Q_2'' of curve B, which we shall call i_p, as the peak value of that component of the putput which is an exact replica of the input wave. Then i_p is at once obtained by multiplying the dynamic transconductance, given by equation (18), by e_g. That is,

$$i_p = \frac{\mu}{R_p + R} e_g \tag{26}$$

The peak value of the output voltage wave, e_p, across the load resistance is obtained by multiplying i_p by R. Whence,

$$e_p = \frac{\mu e_g}{R_p + R} \cdot R \tag{27}$$

The voltage amplification, A_v, is given by the ratio of e_p to e_g; that is,

$$A_v = \frac{e_p}{e_g} = \frac{R}{R_p + R} \cdot \mu \tag{28}$$

In this case, $R = 15{,}000$ ohms, $R_p = 8000$ ohms, and $\mu = 10$. Hence,

$$A_v = \frac{15{,}000}{8000 + 15{,}000} \mu = \frac{15}{23} \mu = 6.52$$

Thus, in this simple case the output voltage is 6.52 times the input voltage.

The power amplification is also readily computed. The average power dissipated in the load resistance, with a sinusoidal current flowing through it, is given by one-half the product of the peak current by the peak voltage across its terminals. That is,

$$W_0 = \frac{1}{2} i_p \times e_p = \frac{1}{2} \frac{\mu e_g}{R_p + R} \times \frac{\mu e_g}{R_p + R} R = \frac{1}{2} \left(\frac{\mu e_g}{R_p + R}\right)^2 R \tag{29}$$

In the input circuit the grid draws no current, as previously discussed, so that the only power dissipated is in the resistance, R_i, due to the input voltage, e_g, across it. The peak current through R_i is given by

$$= \frac{e_g}{R_i} \tag{30}$$

The power dissipated in R_i is given by one-half the product of the peak current and peak potential drop· that is,

$$W_i = \frac{1}{2} i_g \times e_g = \frac{1}{2} \frac{e_g^2}{R_i} \tag{31}$$

The power amplification is then given by

$$A_\omega = \frac{W_0}{W_i} = \frac{\mu^2}{(R_p + R)^2} \cdot R\,R_i \tag{32}$$

If $R_i = 600{,}000$ ohms,

$$A_\omega = \frac{100}{(8000 + 15{,}000)^2} \cdot \times 15{,}000 \times 600{,}000 = 1701\text{-fold amplification}$$

In many applications it is convenient to express the amplification in logarithmic form. It is commonly expressed in terms of ten times the logarithm to the base ten of the power amplification. The amplification expressed in this manner is called the *gain* of the tube, and the unit of measurement is the decibel, indicated by *db*. Thus, gain in the above example is given by

$$G = 10 \log_{10} \frac{W_0}{W_i} \tag{33}$$

$$= 10 \log_{10} \left[\frac{\mu^2}{(R_p + R)^2} RR_i \right] \tag{34}$$

$$= 20 \log_{10} \left[\frac{\mu}{R_p + R} \sqrt{R\,R_i} \right] \tag{35}$$

$$= 32.3 \text{ db.}$$

Gain values recorded for Western Electric vacuum tubes are so measured that they represent the values computed by equation (35) when $R_i = 600{,}000$ ohms, and R is fixed at a value approximately equal to the average value of R_p for the given type of tube, under the voltage conditions at which the measurements are made.

APPROXIMATE METHOD FOR COMPUTING DISTORTION

We have seen that because the static characteristics of the three-electrode vacuum tube are curvilinear in form, the dynamic characteristic must also be non-linear. The curvature of the dynamic characteristic is decreased by increasing the load resistance, approaching linearity when the load resistance becomes very large compared to the plate resistance of the tube. This non-linearity results in distortion in the output of the tube. That is, for any given wave-form applied to the grid, the amplitudes of the output current or voltage components are not exactly proportional to the amplitudes of the same components in the input; furthermore, additional frequency components appear in the output, which are harmonics of the input frequencies or the products of cross-modulation between them.

If the form of the dynamic characteristic is known, it is possible to compute the magnitude of the various *distortion* components in the output with a precision depending only upon the degree of accuracy with which the dynamic characteristic is known. In the case

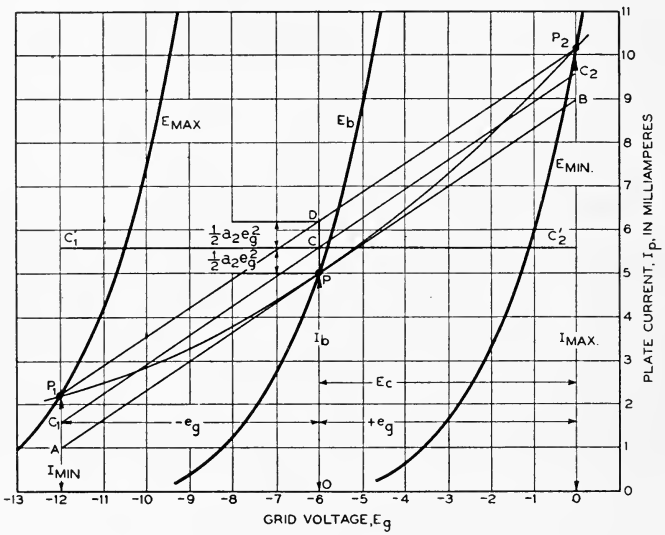

FIG. 15. Dynamic load characteristic of a triode.

of load impedances having reactive components, the computations are rather involved; but in the case of pure resistance loads the computation is relatively simple.

Simple equations for the computations of the approximate power output and distortion for three-electrode tubes with resistance loads have been given in the literature,[1] and have been in common use for several years. By making certain simplifying assumptions as to the form of the dynamic characteristic, these equations are easily derived.

Let us assume that curve P_1PP_2 of Fig. 15 is the dynamic characteristic of a three-electrode tube, obtained either experimentally or by computation from the static characteristics, in the manner previously given. Let us further assume that, taking the point O as origin, curve P_1PP_2 is represented by the equation

$$I_p = I_b + a_1 v + a_2 v^2 \tag{36}$$

in which a_1 and a_2 are constants; I_b is the steady value of the plate current with plate voltage, E_b, and grid voltage, $-E_c$, applied to the tube and with no variable input applied to the grid; v is the variable voltage applied to the grid, measured from the axis PO, and which in this case we shall assume to be sinusoidal in form and given by

$$v = e_g \sin \omega t \tag{37}$$

$a_1 v$ is, obviously, the equation of the straight line APB with the point P as origin, and whose slope is a_1; $a_2 v^2$ is the equation of the curve P_1PP_2 with P as origin, and its ordinates measured from the line APB.

I_p attains its maximum value, $I_{max.}$, and its minimum value, $I_{min.}$, when v assumes its maximum positive value, $+e_g$, and maximum negative value, $-e_g$, respectively. Substituting $v = +e_g$ and $v = -e_g$ in equation (36), the following equations are obtained:

$$I_{max.} = I_b + a_1 e_g + a_2 e_g^2 \tag{38}$$

$$I_{min.} = I_b - a_1 e_g + a_2 e_g^2 \tag{39}$$

Subtracting and adding equations (38) and (39)

$$a_1 e_g = 1/2 \ (I_{max.} - I_{min.}) \tag{40}$$

$$a_2 e_g^2 = 1/2 \ (I_{max.} + I_{min.} - 2I_b) \tag{41}$$

Now, if we substitute the assumed value of v from equation (37) in equation (36), we obtain

$$I_p = I_b + a_1 e_g \sin \omega t + a_2 e_g^2 \sin^2 \omega t \tag{42}$$

which reduces to

$$I_p = I_b + 1/2 \ a_2 e_g^2 + a_1 e_g \sin \omega t - 1/2 \ a_2 e_g^2 \cos 2\omega t \tag{43}$$

We see that, with the simple form of dynamic characteristic assumed, the operating plate current I_b is increased by the non-periodic component $1/2 \ a_2 e_g^2$; and the total steady component of plate current is represented by the ordinate OC in Fig. 15 The term $a_1 e_g \sin \omega t$ is the amplified output given by the ordinates of the straight line C_1CC_2 measured from the axis $C_1'CC_2'$. As previously shown

$$a_1 = \frac{\mu}{R_p + R} \tag{44}$$

In addition, there is in the output the second harmonic distortion term, $\frac{1}{2} a_2 e_g^2 \cos 2\omega t$, whose magnitude with varying values of ωt is given by the ordinates of the curve P_1PP_2 measured from the line C_1CC_2.

The output power of fundamental frequency is given by

$$W_0 = \frac{1}{2} a_1^2 e_g^2 R \tag{45}$$

which, on substitution of the value of a_1 from equation (44), is identical to equation (29).

Substituting the value of $a_1 e_g$ from equation (40) in equation (45) gives

$$W_0 = \frac{1}{8} (I_{max.} - I_{min.})^2 R \tag{46}$$

The maximum potential variation across the load resistance is equal to the maximum difference in plate voltage, and is given by

$$2a_1 e_g R = (I_{max.} - I_{min.})R = E_{max} - E_{min} \tag{47}$$

Substituting in equation (46),

$$W_0 = \frac{1}{8} (I_{max.} - I_{min.})(E_{max} - E_{min}) \tag{48}$$

We may take as a measure of the distortion the ratio of the amplitude of the second harmonic to the amplitude of the fundamental. Calling this ratio D, we have

$$D = \frac{1}{2} \frac{a_2 e_g^2}{a_1 e_g} \tag{49}$$

Substituting in equation (49) the values of $a_1 e_g$ and $a_2 e_g^2$ from equations (40) and (41),

$$D = \frac{1}{2} \frac{I_{max.} + I_{min.} - 2I_b}{I_{max} - I_{min.}} \tag{50}$$

Ordinarily it is not possible to express the dynamic characteristic of a three-electrode tube precisely by an equation as simple as equation (36). In general, the addition of third and higher power terms in v is necessary. This results in the appearance of third and higher order harmonic terms in the output. Consequently, equations (46), (48), and (50), must be regarded only as somewhat rough approximations.

In Table I, the power output and percentage of distortion computed by equations (46) and (50) are tabulated for the four dynamic characteristics shown in Fig. 13. With a plate potential of 150 volts and a grid potential of −9 volts, the plate resistance is 8000 ohms. When the tube works into a load resistance matching this resistance, the output power is seen to be 134 milliwatts with 12 per cent distortion. As the load resistance is increased, the output power decreases and also the percentage of distortion. With a load resistance of 15,000 ohms the output is 107 milliwatts with 3 per cent distortion. If the tube is required to work into a resistance matching its own plate resistance and with the distortion limited to 3 per cent, the maximum power of this quality is obtained with a grid bias of −6.7 volts, at which point the plate resistance and load resistance are each 6800 ohms. The output power is 80 milliwatts, or 75 per cent of the power of the same quality attainable at a grid bias of −9 volts and with a load resistance of 15,000 ohms. Furthermore, the plate current in the latter case is only 5.0 milliamperes compared to 8.1 milliamperes in the former.

TABLE I

Plate Potential = 150 Volts

Operating Point, Fig. 13	E_c (Volts)	I_b (Milliamperes)	R_p (Ohms)	R (Ohms)	e_g (Peak Volts)	W_0 (Milliwatts)	D Per Cent
P	−9	5.0	8,000	8,000	9	134	12
P	−9	5.0	8,000	15,000	9	107	3
P	−9	5.0	8,000	30,000	9	83	1.2
P''	−6.7	8.1	6,800	6,800	6.7	80	3

TEMPERATURE SATURATION AND FILAMENT ACTIVITY TESTS

We shall now return to the subject of temperature saturation or filament activity, and the effect of insufficient activity upon the operation of vacuum tubes. In the foregoing discussion of the three-electrode tube as an amplifier, we have assumed that the electron emission from the cathode is sufficiently large so that the static characteristics remain essentially unchanged over the range of filament current and temperature fluctuations permitted in service.

Now, it would be very difficult and uneconomical to maintain the filament current and temperature constant in practice. The amount of variation that must be tolerated varies with the service. For example, in the telephone plant a variation of plus or minus about 3 per cent from the mean filament current is allowed. In applications where small local batteries are employed, a wider range of variation must usually be tolerated. Where commercially supplied power is employed, a wider range of plus or minus 5 per cent and more must usually be tolerated, depending upon the locality and the type of service.

Let us assume that we have a tube sufficiently deficient in electron emission from the cathode so that the static characteristics vary appreciably from time to time with more or less erratic variations in filament current, over the permissible range. It was shown in the

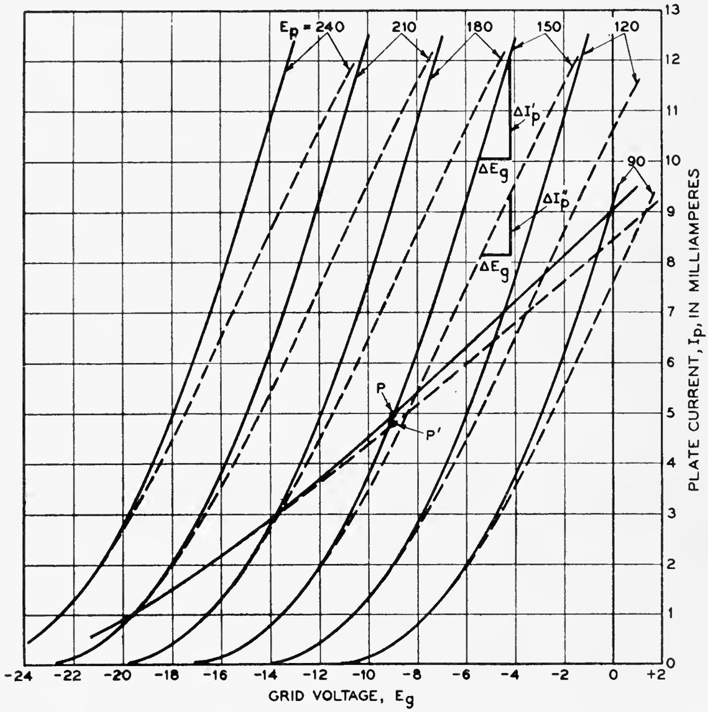

FIG. 16. Plate current-grid voltage characteristics of a triode, showing the effect of low electron emission.

foregoing discussion that the electrical parameters such as mutual conductance and plate resistance, and the amplification as well, depend upon the shape of the static characteristics. Consequently, these factors must change if the static characteristics change due to inadequate electron emission.

This point is illustrated by the curves of Fig. 16. The curves drawn in solid lines may be taken here to represent the static characteristics of a tube of somewhat low filament activity when its filament current is at the highest point in its permissible range. The curves in dashed lines represent the static characteristics of the same tube when the filament current and temperature drop to the lowest values permitted. The plate current is seen to be lower, the difference being proportionally greater at the higher values of plate current. Assuming that the plate battery voltage, E_B, remains unchanged in the circuit shown in Fig. 12, the operating point is now P' instead of P. The slope of the characteristic at point P' in Fig. 16 is smaller than at P. Consequently, the transconductance is decreased from the value at P. In a similar manner, it may be shown that the plate resistance is correspondingly higher. Furthermore, the slope of the dynamic characteristic or load curve is decreased. From equations (26), (29), and (35) it is clear that this must result in a reduction in the output current, output power, and also in the gain.

Not only does a tube of low filament emission show much greater variations in these factors with filament current variations than does a tube with high emission, but it also usually shows lower absolute values of plate current and gain and a higher value of plate resistance at the normal filament current than the same tube would show were the filament emission higher. This is evident from the curves of Fig. 16, but is further illustrated by the curves of Fig. 17. These curves show the gain of vacuum tubes plotted against filament current expressed in per cent of its normal value. The normal operating current is indicated by the vertical line aa'. Curves *1* and *2* are for good tubes of high filament emission, one with average gain and the other with the lowest gain permitted by the manufacturing test specification. The difference in gain between the two tubes is due to a difference in structural dimensions. In both cases the gain is seen to remain practically constant when the filament current is lowered to the value indicated by the line bb'. Curve *3* is for a tube of medium emission, which has a value of gain at aa' intermediate between curve *1* and curve *2* but which falls off more rapidly when the current is lowered to bb'. Curve *4* is for a tube of low emission. Not only is the gain appreciably lower at aa' than if the filament were in good saturation, but it also falls off much more rapidly as the filament current is reduced to bb'.

Not only does the thermionic emission vary markedly in different tubes of the same type, but it also varies with life in any individual tube. While the thermionic history of vacuum tubes differs widely, we may illustrate a typical life cycle approximately by curves *1*, *3*, and *4* of Fig. 17. The initial state is illustrated by curve *1*. It is seen to remain very flat until the filament current falls far below its normal operating value, when the gain falls off very rapidly. At a much later period in the life of the tube the condition is represented by curve *3*. The curve at the operating current *aa'* is not as flat as curve *1*, the knee of the curve has approached much nearer to the operating current, and, consequently, the filament is not nearly so far in temperature saturation as at first. The tube is assumed still to operate satisfactorily at this time. The time elapsing between the conditions represented by curve *1* and curve *3* represents by far the

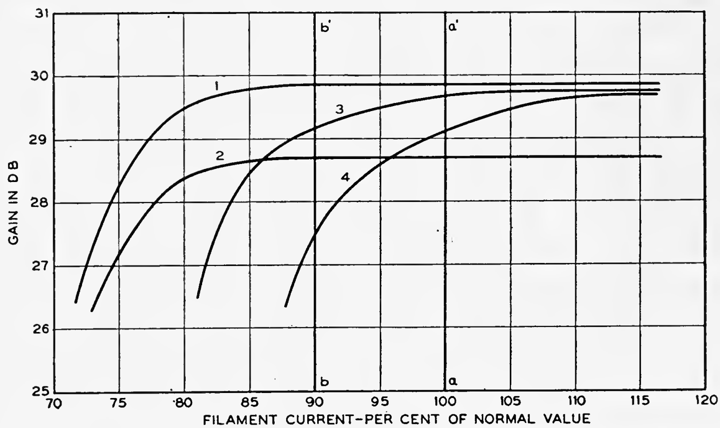

FIG. 17. Gain of vacuum tubes as a function of filament current, showing the effect of low electron emission.

greater portion of the life of the tube. From this point the deterioration increases at a more rapid rate until, in a period relatively short compared to the previous period, the condition is represented by curve *4*. Here the gain has dropped to a lower value, and changes so rapidly with decreasing filament current that the tube has become so unstable as to be unsatisfactory for further use, and must be rejected.

If, for the same tube, mutual conductance or plate current were plotted against filament current, curves similar in shape would be obtained. If the plate resistance were plotted, curves would be obtained rising rapidly instead of falling with decreasing filament current, because the plate resistance increases as the filament falls out of temperature saturation.

It is highly desirable to have some means of testing vacuum tubes to determine when their thermionic emission has decreased to a point where they can no longer satisfactorily perform their required function or have become so unstable as to constitute a hazard to the service. Such a test is called a filament or cathode activity test, the limits for which will depend upon the character of the service in which the tubes are employed. The most satisfactory test of this sort is to measure some electrical parameter or property of the tube such as the transconductance, plate current, plate resistance, or the gain, at the normal operating filament current or voltage represented by the line aa' in Fig. 17, then to repeat the measurement at a reduced filament current or voltage corresponding to the line bb'. Both the absolute value of the quantity measured and the percentage change may be taken into consideration in determining the quality.

CIRCUIT CONNECTIONS

In practice, a variety of methods are employed for connecting vacuum tubes in the circuits with which they are associated. A common method is that shown in Fig. 18, where the vacuum tube is connected to the input and output circuits by means of transformers T_1 and T_2, respectively. Transformer coupling is widely used in telephone amplifiers or repeaters, in the final or output stage of radio receivers, and in the output stages of amplifiers used in public address systems, sound-picture amplifiers, *etc.* The input terminals *1* and *2* of the input transformer, T_1, are connected to the source of the signal it is desired to amplify, such as a transmitter, or the output terminals of a preceding vacuum tube in case an amplifier of more than one stage is used. The output terminals *3* and *4* of the output transformer, T_2, are connected to the output load which, for example, may be a loud speaker or the input terminals of a following vacuum tube. The grid circuit and plate circuit are usually connected to the negative filament terminal as shown, and this point of connection, *c*, is referred to as the *common point.* Transformer coupling, especially for power amplifier tubes, has several advantages, among which are: (*1*) By proper design the transformers can be made to match the impedances between which they work. This results in high transmission efficiency; that is, it makes the best possible use of the input power available at terminals *1* and *2* to obtain the largest power possible under the conditions imposed, at the output terminals *3* and *4*. (*2*) By making the number of turns of wire in the secondary, S_1, of the input transformer larger than the number in the primary, P_1, a step-up is obtained in the voltage available to apply to the grid of the tube. This, obviously, increases the voltage amplification obtained. (*3*) The primary, P_2, of the output transformer, T_2, can usually be so designed as to have a reasonably low

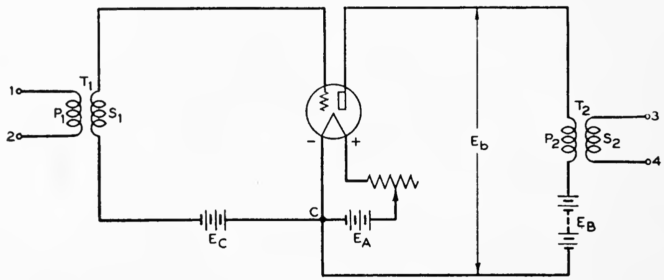

FIG. 18. Schematic diagram of a triode with transformer coupling.

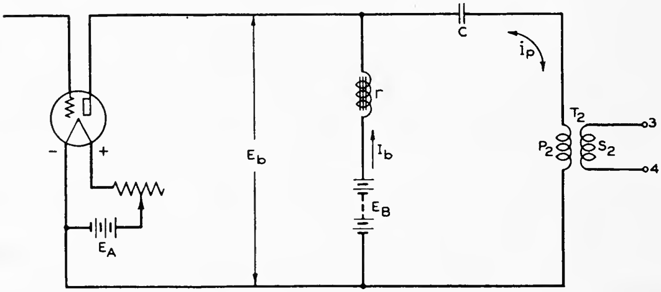

FIG. 19. Schematic diagram of a triode with the plate current supplied through a retard coil and with transformer coupling.

d-c resistance and, consequently, the potential drop due to the operating plate current, I_b, flowing through it is small. Hence the actual steady potential of the plate, E_b, is almost as large as the battery voltage, E_B, instead of being much smaller, as is the case in the circuit shown in Fig. 12. On the other hand, transformer coupling has the disadvantage that amplifiers so connected amplify uniformly over only a relatively limited range of frequencies. Equalization or another type of coupling is necessary where uniform amplification is necessary over very wide frequency ranges.

In some cases it is not desirable to have the plate current, I_b, flow through the primary winding, P_2, of the output transformer as shown in Fig. 18. A means of avoiding this, but still retaining transformer coupling, is shown in Fig. 19. The plate current, I_b, is supplied to the plate through the retard coil, r. A retard coil has very low resistance to direct current but very high impedance to alternating current. Consequently, the plate voltage, E_b, is very nearly equal to the plate

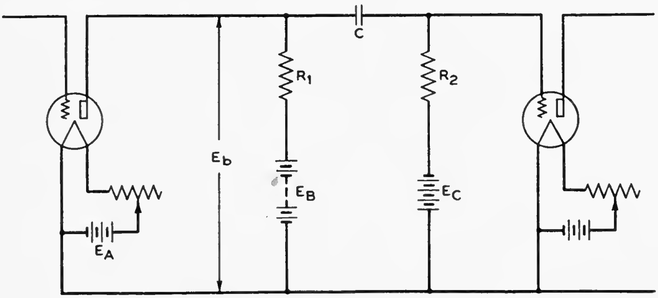

FIG. 20. Schematic diagram of a triode with resistance coupling.

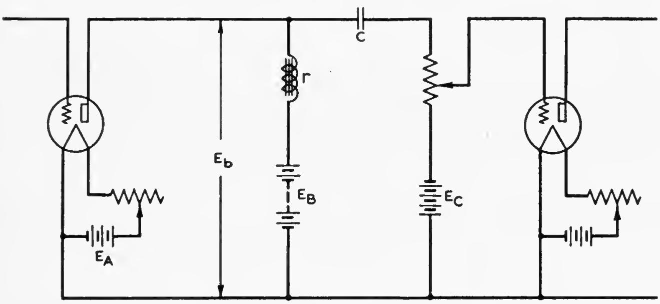

FIG. 21. Schematic diagram of modified resistance coupling, in which the plate battery is connected to the plate through a retard coil.

battery voltage, E_B. The alternating-current components produced by the signal are almost completely excluded from this branch of the circuit, due to the high impedance of the retard coil for such currents, and are constrained to flow through the condenser, C, and the transformer primary, P_2. The so-called blocking condenser, C, prevents direct current from the battery, E_B, from flowing through this path.

Where it is desired to amplify uniformly signals covering a large range of frequencies, resistance coupling is often employed. A typical circuit arrangement for this type of coupling is shown in Fig. 20. The plate current from the battery, E_B, flows through the resistance R_1, which is usually a large resistance of, say, 20,000 to 100,000 ohms, or even higher. The potential drop across R_1 is high and, consequently, the plate battery voltage, E_B, must be very much larger than the operating plate voltage, E_b. R_2 is usually large, in the range from one hundred thousand to several hundred thousand ohms. By proper choice of R_1, R_2, and C, resistance-coupled amplifiers can be designed to amplify over a large range of frequencies with a high degree of uniformity. Since the resistance, R_1, must be large, this type of coupling is best adapted to small tubes of low plate current drain, used in the early stages of high-gain amplifiers.

Where the requirements as to uniformity of amplification with frequency are somewhat less stringent, resistance coupling may be modified as shown in Fig. 21 where a retard coil, r, replaces the resistance, R_1, of Fig. 20. As previously discussed, the d-c. resistance of the retard coil is comparatively small, and E_B need be only slightly larger than the required plate potential. R_2 may be arranged as shown in Fig. 20 or in the form of a potentiometer, as shown in Fig. 21, which permits variation of gain by varying the input voltage applied to the grid of the tube in the next stage.

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THE 16-MM. SOUND-FILM OUTLOOK*

W. B. COOK**

Summary.—*After pointing out that the original difficulties in developing 16-mm. sound-film seemed only to spur the engineers to accomplish their solutions, it is shown how today a program of eight full reels of sound-film can be projected with quality exceeding that of 35-mm. quality at a corresponding stage of its development. The shortage of sound-film subjects that hampered the distribution of 16-mm. equipment is rapidly being relieved, and interest in the industrial and institutional uses of sound film are growing. Future progress depends upon the equipment manufacturers; the film problems have been solved. Projectors must be made simple to operate, the frequency response must be broadened, they must operate silently; and, most important of all, their ultimate success will depend upon the cost of equipment and film service.*

Older members of the Society will recall that in the early stages of sound recording it was decided that the former camera and projector standard speed of sixty feet a minute would be inadequate for recording sound, and the standard speed was arbitrarily changed to 90 feet a minute. Even with the greatly extended length of available recording track that resulted, several years of the most intensive research and experimental work were required to achieve uniform results of even passable quality.

To have predicted at that early date that a satisfactory sound track could be properly recorded upon and reproduced from a strip less than one-sixteenth of an inch wide and with a projection speed of only 36 feet per minute, would have seemed a wild hope or an idle dream. But the difficulties to be overcome served as a spur, and some of the cleverest engineers of the research laboratories turned at a comparatively early date to solving the difficult problems involved in producing and reproducing satisfactory 16-mm. sound-film.

During the earlier stages of research and experiment, the publicized results seemed to favor re-recording from 35-mm. to 16-mm. sound tracks as a means of making 16-mm. sound-films, but the Kodak Research Laboratories felt that photographic reproduction by optical

* Presented at the Fall, 1934, Meeting at New York, N. Y.

** Kodascope Libraries, New York, N. Y.

printing offered the more promising results. Such has proved to be so, and optical reduction is now the only system employed commercially.

Inasmuch as the decrease of length of the sound-track was 60 per cent, whereas the decrease of width was less than 15 per cent, optical reduction presents rather complicated problems, which have been met by different laboratories in several different ways, with more or less success. It is not the purpose of this paper to enter into the technical details of sound reproduction, but merely to state that a number of laboratories are now turning out 16-mm. sound prints from 35-mm. negatives of a quality distinctly superior to that of 35-mm. theatrical pictures at the corresponding stage of development. It should be remembered that dimensions of the photographic image of a 9000-cycle recording on 16-mm. film (which is easily attainable by optical reduction) would be about the same as those of a 22,500-cycle recording on 35-mm. film, if such a frequency could be audibly produced and recorded.

At this point, it may be in order to point out the efforts being made by European countries, particularly Germany, to adopt a standard of 16-mm. sound-film that shall have the same dimensions and relations of the picture image and the sound-track as those adopted by this Society, but exactly reversed as to the projection positions of the emulsion surface and the perforations. In the standard adopted by the Society of Motion Picture Engineers, when the film is threaded in a projector the perforations are at the right edge of the film (looking toward the screen), and the emulsion surface is toward the screen. In the standard advocated by European societies, the perforations are at the left edge of the film (facing the screen), and the emulsion surface is adjacent to the light and the condenser lens. The complication is clearly recognized by at least one European manufacturer, who advertises that he will supply either right-hand or left-hand sprockets as required.

Considering the development of sound-film projectors, it is gratifying to observe the progressive spirit that has inspired manufacturers in the field. All the leading manufacturers of 16-mm. silent projectors have already produced or are now working on sound projectors also. The RCA Victor Company has been the real pioneer in manufacturing 16-mm. sound-film projectors, and is already exploiting its third model. Thus a comparatively wide choice of projection equipment of varying capacity and price range is available. Most of the sound projectors are adapted to both 400- and 1600-foot reels, the latter permitting a program of eight full reels to be projected, with a single interruption for rewinding. As many theatrical features are only six or seven reels in actual footage, it becomes practicable to precede the feature by one or two shorts and yet have the entire program on two large reels.

A decidedly interesting recent development for the amateur has been a portable and compact 16-mm. sound-film camera, with which the amateur can make his motion pictures with a sound-record of the operator's voice. Accessories for recording the voice and sound-effects made by the subjects photographed are available at additional expense, but are for the present rather heavy and bulky. With further research and competitive manufacture and production, however, it is reasonable to expect that the amateur sound-and-picture camera will soon become practicable and popular.

Until recently, the sale and distribution of sound projectors have been hampered principally by the lack of an adequate supply of available sound-film entertainment subjects. Happily, this shortage is now being very rapidly remedied, and perhaps the most outstanding development in the new field has been the astonishing increase in the available supply of sound-film subjects during the past few months.

At the beginning of 1934, the available supply of 16-mm. sound-film entertainment subjects was perhaps less than 50 reels. At the present time at least ten times that number are actually circulating in the various libraries of the country. Sound-film service is available from coast to coast, and it is no exaggeration to say that several thousands of reels of additional subjects are now available for reproduction in 16-mm. size and will be in circulation just as quickly as the distribution of equipment arouses even a moderate demand for such a supply.

Most of the 16-mm. sound-film projection equipment thus far sold has been for industrial purposes; that is, for use by prominent manufacturers in showing their own commercial pictures, made to carry publicity or make sales for the products featured. Recently a decided interest in equipment has developed among institutions that desire to use sound-films but could not do so until the fire hazard and expense of 35-mm. prints and projectors had been replaced by the safety, simplicity, economy, and portability of their 16-mm. successors.

In the days of the silent picture, non-theatrical exhibitions lacked the charm and emotional appeal furnished by the orchestral accompaniment so cleverly cued to the picture in all the best theaters; but with the advent of 16-mm. sound-film, the family in the home, the children in the church, their parents at the club, or the shut-ins in the hospitals or institutions could for the first time enjoy every illusion of reality, previously enjoyed only by the spectator in the theater. The emotional appeal of combined sound and speech was beyond description and for the first time there was available a means of entertainment challenging the radio in its universal applications.

What of the future of 16-mm. sound-film? As a matter of fact, its future has already been firmly assured. Its present status is far ahead of that of the 35-mm. at a corresponding stage of development. Whereas the 35-mm. sound-film had to start from nothing, and an entirely new art, science, and manufactured product had to be developed, 16-mm. sound has but to follow closely in the footsteps already carved by its older and bigger brother. It should never seek to compete in the professional amusement field, but will doubtless completely encompass the entire non-theatrical field.

As any 35-mm. negative is capable of making 16-mm. reduction prints of quality comparable with their size, it is evident that any great film epic can be made available if the demand should justify it. Many of the greatest silent pictures were reproduced on 16-mm. film, and it is already evident that the 16-mm. sound-film will enjoy a popularity never imagined in the silent field.

But future progress will be dependent upon the equipment manufacturers. The film reproduction problems are solved. Projectors must be perfected to such a state that no skill is required and adjustments shall seldom be necessary; made so simple that any member of the family or any school-boy can operate them successfully; so silent and unobtrusive as to become a piece of household furniture, like the phonograph or radio. The present frequency response must be broadened so as to achieve sound reproduction on a par, at least, with that now attained in the average theater. And, perhaps most important of all, ultimate success will depend largely upon the cost of the equipment and its film service.

DISCUSSION

Mr. Crabtree: Assuming a given picture, on 35- and 16-mm. film, would people rather go to the theater, or stay at home to see it? It seems to me that people more than ever these days will not stay at home. What is your experience?

Mr. Cook: I can not answer that definitely. It obviously depends upon the disposition and temperament of the individual family. I am inclined to believe that the American people prefer to leave their homes and flock into places of amusement. That is not so in Great Britain, where the home libraries have attained a volume of business so greatly surpassing what we find in this country that we are forced to conclude that national characteristics must have much to do with it.

Mr. Lane: What is the demand for color in 16-mm. sound-films?

Mr. Cook: So far there has been no demand for sound combined with color. Our library experimented with color in silent pictures a year or more ago, and found that the demand for color in 16-mm. silent pictures was extremely limited. The demand was not encouraged by the fact that the color that was attainable at that time was distinctly inferior, but I believe that the interest shown in inquiring for the prints before they knew of their quality was rather limited.

Mr. Palmer: Do you believe that a sufficient demand might be created for 16-mm. amusement subjects for the home to warrant producing subjects for that field?

Mr. Cook: So far as regards the home exclusively, that is open to question. But if other non-theatrical activities were included, institutional and the like, I should say that it was a prospective field. In fact, it is already expanding at a rate that surprises some of our optimistic proponents of the field. The interest is certainly great, and those who see and hear the available productions, as a rule, are enthusiastic in their reactions to them.

Mr. Rosenberger: What proportion of the demand is for theatrical, purely entertainment pictures, and for educational pictures, including semi-scientific, geographical films, biological films, and the like?

Mr. Cook: So far as the experience of a library founded principally for *supplying entertainment* is concerned, I can say only that our demand for educational films is almost nil; and for scientific, even less. But it should be remembered that the libraries that have been established have appealed almost entirely to the urge for entertainment. It is rather difficult to know whether an exclusively scientific or educational library would receive a better response than we have. I believe it can be fairly accepted that the schools seem to have a preference for entertainment films.

Mr. Golden: I do not quite agree that the demand for educational films is practically nil, because my office has received thousands of letters from schools asking for sources of purely educational films. We maintain a bulletin service that is distributed on a subscription basis, listing the names of films of an industrial character. We also attempt to get as many of the educational films as are available. I do know from conversations with Dr. Koon, of the Bureau of Education, U. S. Department of the Interior, that they are very much interested in the strictly educational film for classroom and curriculum use. The main difficulty, according to the Department of the Interior, is that they claim they can not get sufficient educational films, so as to be able to recommend them to the school systems of the country, which in turn hampers the sale of the 16-millimeter sound-film projectors that have been developed in the past two years. I believe that the Bureau of Education is about at the stage at which, if they can be shown that sufficient educational films are available for use in the schools, they can benefit the manufacturers of 16-millimeter sound equipment considerably by endorsing the use of motion pictures in the classroom.

A PHYSICAL DENSITOMETER FOR SOUND PROCESSING LABORATORIES*

F. L. EICH**

Summary.—*A simple densitometer for use in sound processing laboratories is described, employing the Weston photronic cell and a 50-cp., 12-v. lamp. The cell current is measured by a microammeter, suitably damped. The instrument retains its calibration well, densities can be measured within 0.005, and readings are consistently duplicated.*

The applications of light-sensitive devices in industry have been manifold. The development of an efficient photoelectric cell which does not require any external energy supply besides the light incident upon it has increased the number of uses for photoelectric cells. Although prior to the introduction of this type of cell upon the market, it was possible to make a physical densitometer using the other types of cells, nevertheless it always has entailed an additional amount of equipment, which introduced too many variables and made it unsuitable for the commercial field.

The densitometer herein described has simplicity to recommend it without any sacrifice of accuracy. The device has been in constant service for a year at Paramount Laboratory and during that time has held to standard without adjustment (Figs. 1 and 2).

A Weston photronic cell is used as the photosensitive device. The light source consists of a 50-cp., 12-volt lamp mounted in a reflector and operated by a storage-battery. A condensing lens throws the light beam onto a plate with a rectangular opening 0.090 by $^1/_{16}$ inch, and an opal glass is placed beneath the opening to diffuse the light. A rectangular aperture is preferable because it integrates the density area of the sound-track better than a circular opening. Over this aperture the density to be measured is placed. The photoelectric cell is mounted upon a hinged arm which raises the cell to allow the placing of the film over the light aperture. A shield is placed around the cell so that when it is in the reading position no

* Received August 1, 1934.

** Paramount Productions Inc., Hollywood, Calif

light but that passing through the film reaches the cell. The photoelectric cell current is registered by a Weston model *440* microammeter with a 30-microampere range. A suitable shunt is placed across the meter to provide the desired damping. The characteristic of the cell is such that greatest efficiency is attained when using a low load resistance. For this reason a model *440* is preferable. The scale of the meter is calibrated in density from 0 to 1.0, which is sufficient for reading sound-track densities and sound negative gammas of the variable-density type of processing.

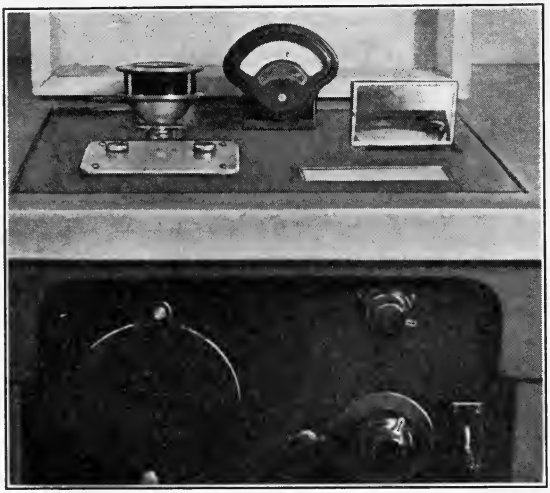

FIG. 1. The densitometer fitted to the examining bench.

In operation, the light falling upon the cell in the reading position is adjusted to register zero density on the meter without any film over the aperture. After this adjustment all that is required is to place the film over the aperture and read the density indicated by the meter.

The device is calibrated in two ways. With low load resistance, the cell current increases linearly per unit of light intensity over a large range of intensity Therefore, using a diffused light source, the relation between current and diffused film transmission will also be linear (Fig. 3). Hence by measuring known densities with the cell and calculating the densities from the current *vs.* transmission curve, a calibration of the device is obtained. A secondary check is made by measuring densities on the Bausch & Lomb polarizing densitometer and then by the photoelectric device (Fig. 4).

The accuracy of the device has been found to be within 0.005 in density, and readings are consistently duplicated. Ease of operation and the increased accuracy over the visual type of densitometer

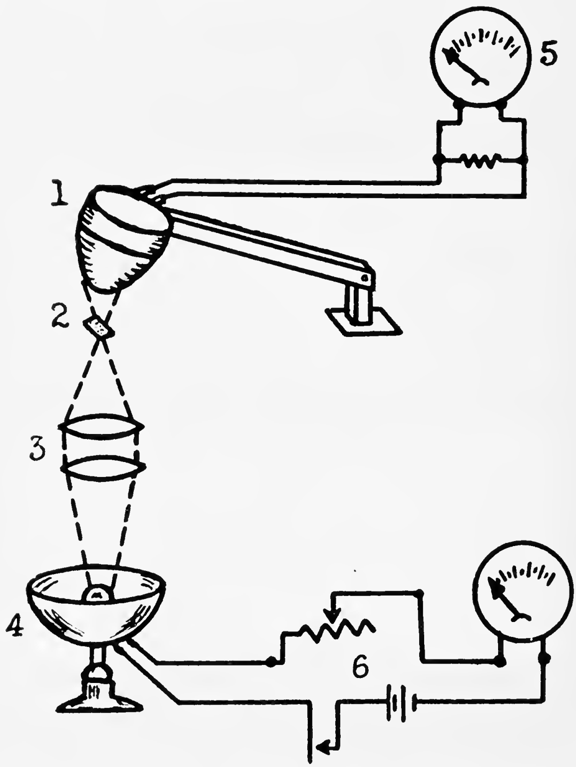

FIG. 2. Details of densitometer: (1) photronic cell; (2) aperture; (3) condensing lens; (4) reflector and lamp; (5) microammeter; (6) current supply for lamp.

are great advantages. Paramount, of course, is the fact that visual fatigue, which is an important factor in measuring densities with the visual type of densitometer, is eliminated. A disadvantage of the single-range instrument is that densities above 1.0 fall within a very narrow portion of the meter scale, and measurements of those densities are therefore not very accurate. However, by using a more sensitive meter and constant-resistance shunt networks of the attenuator type used in communication work, multiple ranges can be attained.

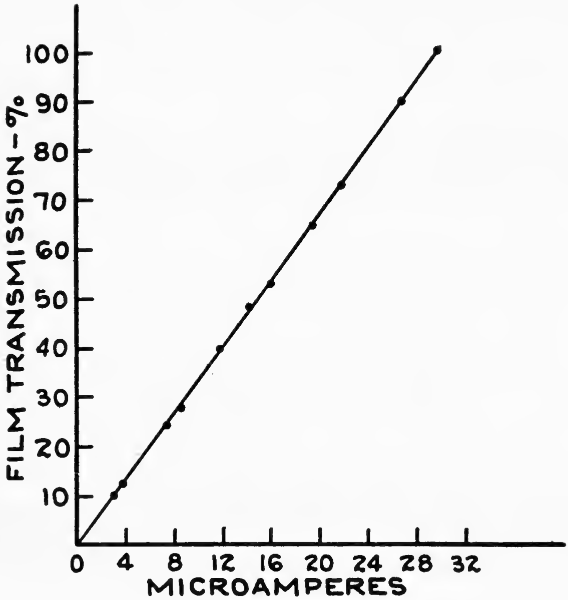

FIG. 3. Calibration curve of densitometer.

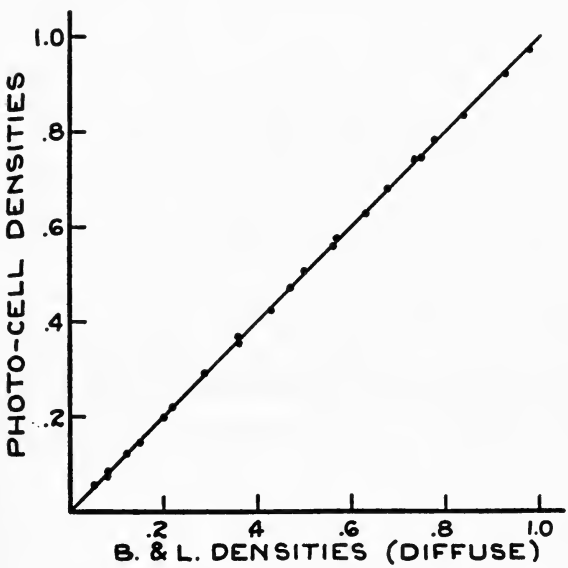

FIG. 4. Secondary check of densitometer.

SOCIETY ANNOUNCEMENTS

BOARD OF GOVERNORS

At a meeting held on January 11 at New York, N. Y., further plans for the Hollywood Convention in May, as described below, were evolved. The fiscal report of the Society for 1934 was presented to the Board by Mr. O. M. Glunt, Financial Vice-President, indicating a satisfactory trend in the Society's affairs and the ability to improve its service to the membership and the industry. The JOURNAL was enlarged by fifty per cent for 1935, and generous financial assistance was provided for the Local Sections to enlarge their activities and hold more attractive and interesting monthly meetings. In addition, appropriations were made for the JOURNAL Award and the Progress Medal, the design of which latter, submitted by Mr. J. I. Crabtree, Editorial Vice-President, was approved by the Board. Other actions taken by the Board, as regards the Sectional Committee on Motion Pictures, under the A. S. A., lapel buttons, *etc.*, were as described below.

HOLLYWOOD CONVENTION

As announced previously, the Spring Convention will be held this year at Hollywood, May 20–24, inclusive, headquarters at the Hotel Roosevelt. Members of the Society are urged to make every effort to attend, and contribute to making this convention the greatest and most interesting in the history of the Society. The Pacific Coast Section Board of Managers, under the chairmanship of Mr. G. F. Rackett, and with the Assistance of Messrs. E. Huse, Executive Vice-President of the Society, and W. C. Kunzmann, Convention Vice-President, are collaborating in arranging the details of the Convention and the Apparatus Exhibit.

The latter will be known as the "Studio Practice and Equipment Exhibit" and it is hoped that the contributions of the studios, in displaying the developments and advances in technic and equipment of the studios, will be quite extensive. Plans are being made for an interesting program of technical papers, and Messrs. J. I. Crabtree and J. O. Baker, Chairman of the Papers Committee, promise a number of outstanding demonstrations and presentations. Several technical sessions will be held in the evenings, in order to permit those to attend whose employment would not permit them to attend the day sessions. Visits to several of the studios are being arranged for the open afternoons.

ATLANTIC COAST SECTION

The first monthly meeting of the Section was held in the auditorium of the Electrical Association of New York on January 9, at which Mr. Rudolph Wolf, of Electrical Research Products, Inc., presented a paper entitled "Visual Accompaniment." The paper presented new ideas concerning the production of pictures to accompany music, rather than the usual method of arranging the music to supplement the picture.

As demonstrations of the principles involved, there were first projected two films produced by the Savage method, *viz., The Unfinished Symphony* and *Les Preludes;* followed by three examples of "Musical Moods," *viz., Fingal's Cave, Italian Caprice,* and *Barcarole.* All the films were done in Technicolor.

The meeting was well attended, and the presentation aroused considerable interest and discussion.

SECTION COMMITTEE ON MOTION PICTURES UNDER THE A. S. A.

As reported previously, a Sectional Committee on Motion Pictures, organized according to the procedure of the American Standards Association, is being established, with the Society of Motion Picture Engineers as sponsor. At the meeting of the Board of Governors on January 11, a list of those organizations, firms, and societies recommended for representation upon the Sectional Committee was approved, and invitations are now being mailed to those bodies to name their representatives to the Committee. As soon as the Committee will have been formed, an organization meeting will be called, a chairman appointed or elected, and an agenda of projects requiring study for possible and needful standardization will be drafted.

SOCIETY SUPPLIES

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

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

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

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SYLVAN HARRIS, EDITOR

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LIGHT SOURCE REQUIREMENTS FOR PICTURE PROJECTION*

F. E. CARLSON**

Summary.—*The light sources available for motion picture projection are discussed in relation to their performance characteristics and their application to existing equipment and conditions of service. The optical systems used with the sources, the usable size and shape of the source, the brightness and light output of the filament, and ventilation are discussed.*

During the past few years, important improvements in lamps and equipment have extended the scope of application of the several types of motion picture projectors. These improvements have been so far-reaching in their effect that a restatement of the factors determining the lighting performance of projectors may be of interest and value.

Desired size and brightness of projected picture, and the dimensions of the aperture or film through which light must be directed, form the starting point from which all development of optical systems and light sources must proceed. The designer is interested in the optimum result that can be achieved in each case. But he must also give consideration to matters of cost, of size and weight, and to operating features acceptable in the different classes of service. To form the best judgment of what would constitute a successful device for a given market, he must make as exact a determination as possible of the gains and losses involved in modifications undertaken because of economic and convenience considerations.

In Table I the more common markets or services are listed in conjunction with the three sizes of film that are applicable. The minimum light required in each case is indicated, together with the practical limitations as to the bulb size and operating features that experience has shown to be desirable. The most desirable values of light output are not so well established, but maximum acceptable values are in every case several times the minimum figures given.

* Presented at the Spring, 1934, Meeting at Atlantic City, N. J.

** Incandescent Lamp Dept., General Electric Co., Cleveland, Ohio.

OPTICAL SYSTEMS

Some consideration of the problems involved in applying lens combinations to picture projection is essential to an understanding of light source requirements. The focal length and limiting relative apertures (*f*/value) of the projection lens are fairly well established for each film (aperture) size employed. Increasing the relative aperture of an objective lens makes possible material improvement in screen illumination, because the light passed is inversely proportional to the square of the *f*/value of the lens. In the case of the 35-mm. film equipments, a value of *f*/2.0 is usually the limit.

TABLE I

Classification of Projection Service

Film Size and Type of Service	Picture Width, Range-Feet	Minimum Acceptable Screen Lumens (No Shutter)	Maximum Limit of Bulb Size	Desirable Lamp Voltage	Approx. Equip. Cost—Not Including Sound—$
8-mm.					
Toy	1–2	5	T-8 or S-11	100–120-Volt	10–40
Home	1–3	20	T-8 or T-10	Lamps Preferred but	25–100
16-mm.					
Home	3–6	50	T-8 or T-10	Low-Voltage Lamps Feasible	25–200
Educational and Business	4–8	150	T-10 or T-12	100–120	100–200
Small Auditorium	6–10	250	T-12	Any	100–300
35-mm.					
Portable—Educational and Business	8–12	300	Short T-20	100–120	100–375
Semi - Portable—Auditoriums	10–12	450	Long T-20	100–120	200–500
Theater	10–20	800	T-24	Any	500–

In the case of 8- and 16-mm. film objectives, the *f*/2.0 size has been most generally used. However, it has been found that for these services relative aperture values up to *f*/1.6 can be successfully employed.

If the projection lens is to pass the greatest amount of light, the source image must fill the entrance pupil of the lens. A uniformly lighted screen is also desired. It follows that for a given aperture and projection lens, the minimum size of condenser and the relation between the condenser diameter and the condenser-aperture spacing must be such that equal areas of condenser are visible through the optical system from all points of the screen. In the schematic diagram of Fig. 1, lines AI and $A'I'$ define this relation.

Assuming equal pick-up angle, the smaller the condenser, the smaller are the dimensions of the source from which the light can be redirected into a beam through the aperture to the projection lens. On the other hand, the losses at the aperture are minimized as the size of the condenser is reduced. Thus the particular combination of condenser diameter and condenser-aperture spacing employed must be a compromise between efficiency of utilization and the size of the source required for supplying the desired amount of light. The available light from a given source is utilized most efficiently with a condenser of maximum refracting power; that is, with the shortest

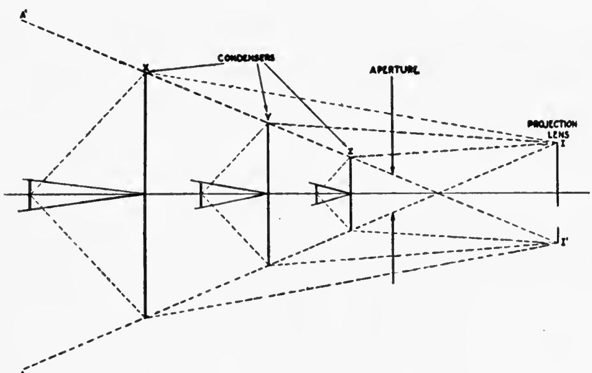

FIG. 1. Relation between condenser diameter and condenser-aperture spacing for uniformly lighted screen.

source-condenser spacing. Higher levels of screen illumination are, however, often attainable with sources of higher wattage and light output at greater distance.

These various considerations, having a definite bearing upon the wattage of the source, the type of the optical system, and the size and weight of the projector, have resulted in the typical systems upon which the following data are based.

USABLE SOURCE SIZE AND SHAPE

As pointed out above, the size of the source that the optical system can utilize depends upon the magnification of the system and the entrance pupil of the projection lens. The shape of the utilized source depends upon the position of the source image; it is round if it falls within the projection lens, and it approaches the rectangular shape of the aperture if it falls between the lens and the aperture.

Back-testing provides a simple method of determining the size and shape of the source that an actual optical system can utilize. This is done by placing a large diffusing source of light in front of the projection lens and a target for holding photographically sensitized paper at the source position. The diffusing source produces a spot of light upon the target that conforms in shape and dimensions to the area of the source that is effective. Table II presents a summary of such an analysis of typical optical systems as used in the several types of projectors. Data on stereopticon projection systems are not included because, within reasonable limits, source dimensions are not a governing factor in that service.

TABLE II

Summary of Back-Test on Typical Optical Systems

Type of Optical System	Av. Source Condenser Spacing (Mm.)	Projection Lens E. F.	Projection Lens f/Value	Back-Test Shape	Back-Test Av. Dimensions (Mm.)
8-mm.	15	1″	f/2.0	Oval	6.0
	18	1″	f/2.0	Oval	7.0
16-mm.					
Spherical Condenser	18	2″	f/2.0	Round	10.0
Aspheric Condenser	18	2″	f/2.0	Round to Oval	7.5
Aspheric Condenser	18	2″	f/1.65	Round to Oval	8.5
Aspheric Condenser	21	2″	f/1.65	Round to Oval	10.0
35-mm					
Prismatic	40	5″	Series 1	Oblong	12 × 7.5
Spheric	40	4″	Series 1	Round	15–20
Aspheric	40	5¾″	Series 2	Oblong	11–14

In addition to their importance from the standpoint of determining requisite source dimensions, these data are of interest as confirmation of some of the general statements made above. It is to be noted that, for the same relative aperture of projection lens, aspheric systems do not utilize as large a source area as do spherical condenser systems; their high efficiency is due to the large solid angle from which they are able to refract the light satisfactorily. On the other hand, the use of projection lenses of larger relative aperture increases the dimensions of the usable source with either type of condensing system.

BRIGHTNESS OF FILAMENT SOURCES

The source problem is thus one of providing the greatest total light output from the utilizable space consistent with feasible bulb size and acceptable lamp cost and performance

Brightness of source is dependent upon two things, the operating temperature of the filament and the amount of incandescent filament that can be disposed in a unit area. Temperature of the filament, and hence light output and brightness, fortunately increase rapidly as the source is designed for shorter life. For a given lamp life, filament temperature may be increased by the use of larger (thicker) filament wire. Thicker filament means either increased wattage, or reduced voltage and higher current. There is a limit beyond which low voltage and high current become disadvantageous due to the heavy heat conduction losses through the larger lead-in wires required.

The amount of incandescent filament that can be disposed within a unit area depends, aside from diameter, upon the filament construction employed. Filaments can be concentrated by coiling; in fact, a coil may be coiled upon a second mandril to form a coiled-coil. The coils can be disposed in more than one plane, to fill the open spaces that would otherwise be presented to the lens. Such constructions have become practicable due to the progress made in recent years in filament heat-treating processes. More favorable methods of mounting have also contributed to preventing distortion from the great stresses of heating and cooling. Thus these more efficiently disposed filaments are kept in place throughout the life of the lamp.

The concentration of filament is attained with some loss in efficiency of light generation because the temperature at various points of the filament is thereby made less uniform. It is the hottest point that determines lamp life, whereas the total light output depends upon the average temperature. The ratio of maximum to average temperature is greater for a coiled-coil filament than for a single coil, and still higher for a biplane source, which thus has the lowest efficiency in light generation although not in utilization.

The use of a spherical mirror behind the filament is important in achieving a more uniformly bright source and hence higher average source brightness. The increase is obviously not the same for all filament constructions, since they vary as to the open spaces to be filled by the reflected coil images. Thus the mirror increases the effective brightness of monoplane sources of the coiled-coil type by upward of 45 per cent, of monoplane sources of the coiled-coil type by about 35 per cent, and of biplane sources not more than 30 per cent.

Many of the heat and light rays reflected from the mirror are intercepted by the filament and increase its temperature. On the other hand, this means a slightly higher light output for a given wattage. Unfortunately, it also increases the disparity between maximum and average temperatures. Both these factors must be taken into account in the design of the lamp.

TABLE III

Light Output per Unit of Source Area

Source Construction	Watts	Volts	Average Source Dimensions (Mm.)	Life	Cp. per Sq. Mm.*
Monoplane (*CC13*)	200	100–120	7.8 × 8.1	50	10.2
Monoplane (*2-Seg-CC8*)	200	100–120	5.9 × 6.0	25	16.5
Monoplane (*C13*)	500	100–120	13.0 × 12.0	50	13.5
Monoplane (*C13*)	500	100–120	10.4 × 10.0	25	20.2
Monoplane (*C13*)	500	30	9.8 × 9.2	50	23.9
Monoplane (*C13*)	500	30	8.6 × 8.3	25	31.2
Monoplane (*C13*)	900	30	10.7 × 13.8	100	27.6
Biplane (*C13D*)	500	100–120	8.2 × 8.2	25	30.8
Biplane (*C13D*)	750	100–120	9.3 × 9.9	25	34.9
Biplane (*C13D*)	1000	100–120	11.0 × 12.1	25	35.2

The net effect of all factors upon the brightness is indicated by the data of Table III for the source forms that are in general most advantageous. It will be observed that the advantage of low voltage is hardly sufficient to outweigh the disadvantage of the weight and cost of auxiliary equipment in the classes of service in which portable projectors are usually employed. As to lamp life, the advantages of higher screen brightness outweigh the replacement cost for portable projectors used intermittently or for occasional service, whereas for continuous service in large projectors, as in the theater, replacement cost is a major factor and therefore longer lamp lives prevail.

Those portions of the source near the optical axis are more efficiently utilized than those farther from the axis. The lower portion of Fig. 2 shows the results of tests with sources of various sizes; the percentage of generated lumens reaching the screen (optical efficiency)

* These values apply when a spherical mirror is used and are an average through an angle of 100 degrees.

is plotted against the source dimensions. Although the data are those for a typical 16-mm. spherical condenser system with $f/2$ projection lens, the same general relations hold for other optical systems.

It will be noted that the data apply for a system that back-tested to a circular source of 9.8 mm. Yet the screen-lumen curve continues to rise for sources of greater diameter, illustrating the fact that the margins of the source are cooler than the center and that therefore a source of somewhat greater dimensions actually adds more light to the screen by bringing up the average brightness of the part used.

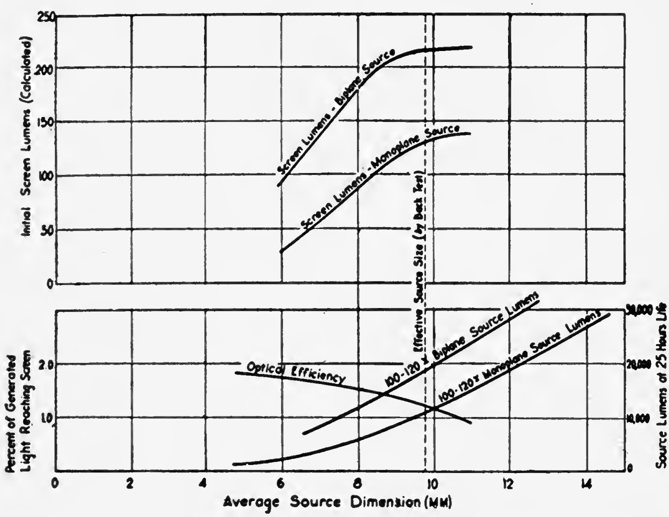

FIG. 2. Effect of optical efficiency on initial screen illumination with monoplane and biplane sources (typical 16-mm. spherical condensing system with $f/2.0$ projection lens).

PROJECTION LAMPS

Up to this point optical systems and source characteristics have been considered without regard to wattage. In practical application of these data in the selection of a lamp best suited to a given service other factors such as bulb limitations and cost must also be considered.

If the wattage is plotted against the source size, as in Fig. 3, it will be noted that the source producing substantially maximum screen illumination in that type of equipment consumes 750 watts. This particular optical system is designed for a source-condenser spacing that necessitates the use of either a centered-filament *T-10* bulb or a bulb of larger size with offset filament. This introduces problems of bulb temperatures and bulb blackening.

The limiting wattage for each bulb size depends upon the temperature at which the bulbs devitrify or soften and blister. This temperature varies with the glass employed. Both the volume of the bulb and the distance of the filament from the nearest wall govern the glass temperature, but the latter is the larger factor. Therefore, an offset filament in a larger bulb permits little gain in wattage, and

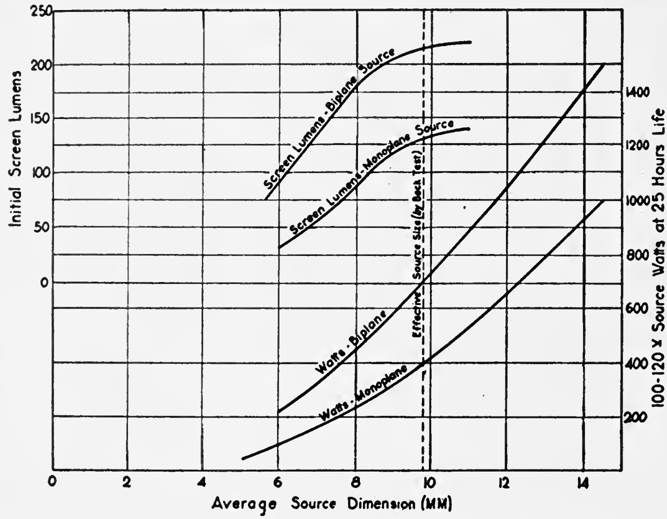

FIG. 3. Relation of initial screen illumination to wattage for monoplane and biplane sources (typical 16-mm. spherical condensing system with *f*/2.0 projection lens).

centered filament lamps in bulbs that will withstand high temperatures are to be preferred.

Bulb volume is important from the standpoint of concentration of blackening and increase of glass temperature due to absorbed radiation. An increase in bulb temperature through life of as much as 30 per cent occurs in extreme instances. Ventilation can do much to reduce bulb temperature, but there is a limit to what it can do because in extreme cases concentration of blackening opposite the filament occurs regardless of air volume.

The adequacy of the average light output throughout the life of the lamp is of greater interest and importance than initial screen lumens in evaluating projection lamps. Their rate of blackening must also be taken into account. This is illustrated in Fig. 4. In a given bulb, a wattage lower than that giving the highest initial screen illumination will often give a better average value.

Analyses for the various services similar to that represented by Fig. 4 have led to the following practice where sufficient ventilation is provided:

Bulb Size	Maximum Wattage
**T-8*	200
T-10	500
T-12	750
T-20 (Short)	1000
T-20 (Long)	1500
T-24	2500

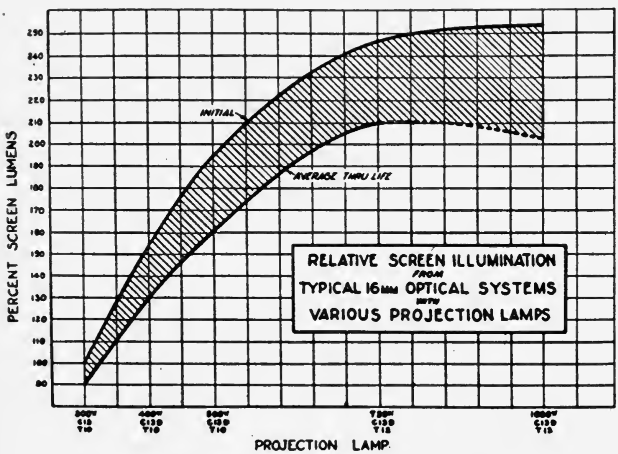

FIG. 4. Relative screen illumination.

The glasses employed in lamps and the ventilating systems provided in projectors of a few years ago would not have permitted a bulb of acceptable size for the total wattage that can now be concentrated in the space effective in contributing light to the screen. It has now also become possible to utilize Pyrex bulbs, which can withstand intermittent temperatures up to 550° to 600°F.

* *T* designates tubular bulbs; the numbers represent diameters in eighths of an inch.

VENTILATION

More effective flow of a given volume of air has been the third important feature in making possible the much-improved screen results from the newer projectors. Some types of equipment were already providing large volumes of air to cool the lamps and further increases would have produced severe problems of noise, excessive blower speeds, or even bulky blowers. Smoke pictures, disclosing the distribution and direction of air flow through ducts and lamp houses, and measurements of their relation to bulb temperature, furnish the key to efficient utilization of the air. The system illustrated in Fig. 5 provides adequate cooling for the new higher wattages, and accomplishes it without larger blowers or higher speeds. Only the air close to the bulb is really effective, and since the bulb is hottest in the region of the optical axis, restriction of the duct in this zone puts all the air to work and moves the air fastest where the bulb is hottest.

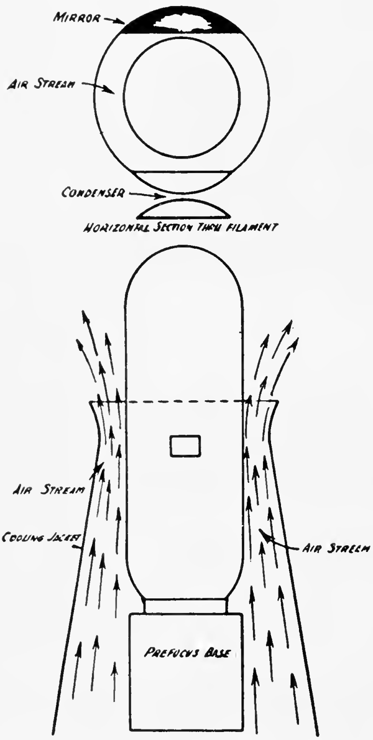

Fig. 5. Schematic diagram of suggested ventilation system for projection lamps.

TODAY'S PROJECTION LAMPS

The projection lamps presently available represent in many respects the most advanced product of the highly developed incandescent lamp art. These amazingly compact units were designed in accordance with the above analysis to meet existing as well as expanding requirements of the several classes of service in both optical characteristics and cost. There are, in the lower wattages, monoplane sources of single-coil filaments, highest in efficiency of light generation and lowest in cost; others in coiled-coil construction of greater concentration and slightly higher cost; and, finally, in the higher wattages, both monoplane and biplane sources giving every class of projector user the most economical service for his particular requirements. These modern lamps have made it possible, except in the very largest units, to dispense with the cost and inconvenience of low-voltage operation for new equipments and to substitute standard-voltage lamps in the older projectors as well.

DISCUSSION

MR. PALMER: Is the advantage of air cooling principally to prevent blackening of the bulb, or to give a longer filament life?

MR. CARLSON: Air cooling seems to be an unimportant factor in both bulb blackening and filament life, but forced ventilation is essential where high wattages are employed in a small bulb, if the glass is not to fail. Lamps that must operate in projectors having only natural ventilation are necessarily either of lower wattage for a particular bulb size or, for a given wattage, of larger diameter.

MR. MITCHELL: The problem of the amateur is different from that of the theater. First, there is no question of box-office benefit involved. Then, the amateur requires a maximum of light source and a minimum of bulk. The effect of air cooling is three-fold: first, it decreases lamp blackening; second, it increases lamp life; third, and perhaps most important, it keeps the projector cool, which is definitely desirable in equipment used by amateurs.

The amateur, and more particularly the industrial user, has pressed the manufacturer for more light—extra light is desired without appreciable increase in bulk. The researches referred to by Mr. Carlson make it possible to give the maximum effective light in the most compact form, and users of the small 16-mm. projectors have been able to show pictures of theatrical quality to fairly large audiences. For instance, with a 750-watt lamp we quite regularly show a 12- or 14-ft. picture to 1000 or 2000 people with quite satisfactory results.

MR. GAGE: Some time ago I had occasion to study condenser design for these small projectors to see what could be done, and I made a certain assumption, namely, that the filament of the lamp was going to be in the center of either a tubular or globular bulb. That then seemed reasonable for what seemed to be a necessary size of filament for adequate illumination such as is desired by the amateurs. It led to a bulb of a certain diameter, and therefore the glass of the condenser had to be placed outside the bulb. That led to a certain condenser design.

Those who make the projectors like to have very small condensers. Now the whole thing was completely revised from our standpoint by what the lamp designers did, pushing the filament of the lamp close to one side of the bulb. Then the projector manufacturers found that they could use those 750-watt lamps if they were ventilated. I do not see any reason why that can not be done with the professional-size projectors if it is found that the optics of the system will work with the filament brightness available. We are not now limited as to the position of the filament in the lamp if we are willing to use forced ventilation.

MR. BEGGS: The factors that Mr. Carlson presented are in good agreement with our findings, and therefore may be taken as representative. One of the most important items encountered in recent years is the limitation of bulb glass temperature. The purpose of the ventilation is primarily to prevent the temperature of the glass from rising to a point at which it bulges and the bulb fails.

Several years ago, smaller bulbs with higher wattages were introduced. Today they are the most common sources in amateur projectors of the higher power. The 500-watt lamp, for example, in the *T-10* bulb, looks exactly like lamps of smaller wattage that do not require air cooling. The lamp manufacturers wrap around each such lamp a cautionary label advising the operator to use forced draft ventilation.

This matter deserves special attention, because in some instances operators have used bulbs requiring air cooling in projectors that do no provide for it.

Mr. Palmer: Has the outside temperature of the bulb, anything to do with the life of the filament or with the blackening of the bulb?

Mr. Carlson: Surrounding temperature has not been a factor in filament performance. However, surrounding temperature (and, therefore, bulb temperature) might have some influence on the distribution of the blackening. The heated gas in the bulb naturally circulates, carrying the bulk of the evaporated tungsten to the upper portions of the bulb, where it forms a black deposit. If the tops of the lamps were cooled to a greater differential than at present, the gas currents would move more rapidly and more of the blackening would, theoretically, occur at the top and less in the optical zone. This idea has not been subjected to practical demonstration and therefore the actual improvement in average light output throughout the life of the lamp has not been determined.

Mr. Fritts: In recent years there has been continuous competition between the manufacturers of amateur projectors to provide more and more wattage in the lamp house without particular reference to the results on the screen. This has led to poor technical practice and more or less deception of the customer.

President Goldsmith: Do you suggest that the rating or the name-plate of the projector carry a statement of screen illumination or some proportionate equivalent, rather than a statement of lamp wattage?

Mr. Carlson: Illumination per unit of screen surface per watt applied to the light source.

Mr. Hardy: It is impossible to tell from the wattage of a lamp how much illumination will result from it on the screen. Projectors might be rated in terms of the size of the screen that they will illuminate to some specified level. I believe the public is not entirely to blame for the confusion that exists. The public has attempted to find some rating that would indicate the power of the projector. The only rating they have been able to find is the wattage of the lamp. If the practice had developed of recommending the screen size, the public might have been quite content with that.

Mr. Mitchell: There are quite a few practical difficulties in the way of rating the projectors. In industrial work, for instance, we consistently encounter cases wherein the user is in doubt as to whether to use, say, a 100-volt, 400-watt lamp on a 110-volt circuit, or a 110-volt, 500-watt lamp. In other words, he studies the total illumination as compared with lamp life and lamp cost. Some prefer more screen illumination even though it cuts down the life of the lamp. One man will be willing to pay for lamps, say, at the rate of 20 to 30 cents an hour whereas another will want the maximum illumination he can get at the lowest possible price and would object to a lamp cost of, say, 2 or 3 cents an hour. Even the cost factor is not a criterion. Some satisfactory empirical ratio of cost to screen illumination might be found, but to a large extent each individual has a different idea of what would be satisfactory.

MR. FRITTS: The wattages and screen illumination have been increased beyond what is needed in the average home, except for Kodacolor projection, even to the point where the black-and-white mixtures are ruined by the excessive illumination. But there exists the industrial field, the advertising field, where these larger wattages can be used to advantage with larger audiences.

The division between those two fields needs to be considered; the matter of filament temperature and lamp life is different in the two fields.

MR. TASKER: The problem of rating the optical efficiency of a projector seems to be a little like the horse-power rating of an automobile. We accept the horse-power ratings without knowing or caring about the conditions under which they were measured, hoping only that the conditions are the same for all manufacturers so that the rating will give a clue to performance. Similarly, the public is anxious to know how much light may be expected from the projector, the purchase of which is being considered. The only criterion that the manufacturer has as yet given the customer is that of lamp wattage, which utterly disregards the very important factor of optical efficiency.

It should not be difficult for the Society to work out a so-called S. M. P. E. rating for projectors which would indicate the relative screen brilliancy to be expected from a projector under a standard set of conditions as to lamp current, lamp voltage, screen size, *etc.* The public need not have any understanding as to what the technical conditions may be so long as they have reasonable assurance that the rating so determined is a criterion of the optical performance which they may expect from the projector. The result of such a measure should be to turn the competitive efforts of the manufacturers into a race for more efficient rather than more wasteful use of the customer's projection lamp dollars.

MR. FARNHAM: Unfortunately, the obtaining of greater screen intensity is not the simple matter of increasing the lamp wattage. As Mr. Carlson has shown, increasing the lamp wattage results in more rapid blackening of the bulb, and if the projector ventilating system is inadequate, the bulb blisters. Also, for a particular filament form the source area increases with increased wattage. If a special source construction were resorted to in order to minimize this, the cost of the lamp would go up. Five-dollar lamps can, for example, hardly be standard with fifteen- to twenty-dollar projectors. The factors of lamp wattage, bulb size, optical system design, ventilation, and lamp and projector cost are closely interrelated, and one can not be altered without affecting the others.

We have gone through a period of rather intensive study and development in lamps, optics, and projectors, and it is not surprising that it has led to a somewhat feverish commercial exploitation which has not always waited for the more complete answer. But by systematic and coöperative effort, we have arrived at a much better understanding of the limits of good practice, so that, although progress will continue, there is every indication that it will be more systematic, less rapid, and less upsetting than in the past few years.

MR. PORTER: Unquestionably it would be advantageous to both the purchasing public and the projector manufacturers to have some system of rating projectors that would show at a glance their limitations. The problem is complicated, but no more so than an almost identical one in connection with the manufacture and sale of sunlamps for health purposes. Such lamps used to be rated in accordance with the length of time required to produce a slight reddening of the skin (the beginning of sunburn, or erythema), with no account taken of the area covered by the irradiation. Consequently, the total energy received by the subject under treatment was directly proportional to the irradiated area. A lamp producing erythema on an area the size of a penny would have just as high a rating as one that would produce erythema over half one's entire body in the same period of time.

That situation was no more ridiculous than rating projectors in accordance with the wattage of the lamp. A new rating was developed for sunlamps which appraised them in accordance with the total amount of biologically effective energy delivered on a definite area at a given distance from the lamp. The sunlamp manufacturers then agreed to classify the various lamps into 6 divisions, each division having a maximum and a minimum energy limit. A neutral testing laboratory was chosen to rate sunlamps for the various manufacturers. Each new type of lamp produced is rated by that laboratory and all lamps sold have tags attached to them showing the entire 6 divisions and stating into which class the particular lamp falls.

The system has worked out very well with sunlamps, and I am sure a similar set-up could be developed for motion picture projectors. First it would be necessary to classify all makes and models of projectors as to their theoretical maximum possible output as limited by their optical systems. This could be done by measuring the total lumen output of the projector without film but with shutter running. For the purpose a uniform diffusive light source of fixed brilliancy (such as a piece of diffusing opal glass) entirely filling the aperture plate opening would be used. The degree of diffusion and brilliancy of this secondary test source would have to be standardized by the testing laboratory and agreed upon by the various manufacturers.

Such tests would then establish the theoretical maximum possibilities of the various projectors. The next step would be to test the projectors with all the available standard projection lamps that might be used in each projector. Here again the testing laboratory would have to select representative lamps, setting limits as to source size, lumen output, *etc.*, which limits should agree with the lamp manufacturers' ratings. Having made these tests the projectors could then be assigned percentage values representing the percentage of the theoretical maximum attained when the projectors were equipped with various styles of standard lamps.

With these data available the projector manufacturers could agree to certain classifications of projectors with maximum and minimum limits of lumen output for each classification. They could publish this classification together with the percentage tables. The lamp manufacturers could supplement the data with information as to the effect upon life and lumen output of operating the various lamps' over-voltage, indicating such cases as might be likely to result in blistered bulbs if this were done, indicating also the increase in rate of lumen output depreciation due to increased blackening. Data could also be given as to the foot-candle intensities on screens of various sizes that could be attained with any number of lumens.

We would then have tables looking somewhat like the following ones. As changes were made in projectors or new ones developed or brought out, they could be added to the data from year to year. The figures given are not accurate, but merely illustrate what the tables might look like.

Projector Type		Mfgrs.' Name	Theoretical Max. Lumen Output	Per Cent of Theoretical Max. with Lamps						
	Class			*A*	*B*	*C*	*D*	*E*	*F*	*G*
8-mm.	*E*	A Co.	200	40	65					
16-mm.	*B*	X Co.	450			60		82		
16-mm.	*B*	P Co.	500				80			
16-mm.	*A*	P Co.	475					73		
etc.		*etc.*	*etc.*	*etc.*			*etc.*		*etc.*	

Lamp	Watts	Volts	Approx. Amperes	Bulb	Base	Initial Lumens	Hours' Life
A	50	115	4.3	T-8	SC Bay	790	50
B	100	115	0.87	T-8	SC Bay	1,870	50
C	200	115	1.8	T-10	Med. P. F.	4,000	50
D	250	50	5.0	T-10	Med. P. F.	5,950	50
E	300	115	2.6	T-10	Med. P. F.	7,200	25
F	500	115		T-20	Med. P. F.	13,150	50
etc.	*etc.*	*etc.*	*etc.*	*etc.*	*etc.*	*etc.*	*etc.*

Notes

Operating the above projector lamps at over-voltage will result in the following:

Per Cent Volts	Per Cent Lumens	Per Cent Life	Per Cent Increase in Rate of Lumen Depreciation	Probable Destruction of Bulb Lamps
100	100	100	0	
105	120	50	5	
110	140	25	8	A, E, *etc.*
115	160	12	11	D, G, *etc.*
120	200	10	15	F, *etc.*

Projector Classification

When used with the standard lamps commercially recommended for the particular projector and tested at the rated lumen output of the lamps, projectors fall into the following classification:

Class *A*	800–1000 lumens
Class *B*	600– 800 lumens
Class *C*	400– 800 lumens
	etc.

Foot-Candle Intensity on Screens of Various Sizes

Lumens	Av. Foot-Candles						
	4 Ft.	*6 Ft.*	*8 Ft.*	*10 Ft.*	*12 Ft.*	*14 Ft.*	*16 Ft.*
80	7	5					
100	9	8					
200		15	5	1.5			
400			8	5	3.7		
600					5.5	4	3.1
1000						7	5.2

It seems to me that if the Committee on Non-Theatrical Equipment should develop something like these tables it would be a contribution of tremendous value.

MR. MITCHELL: Any attempt to measure illumination at the projection aperture is objectionable for three principal reasons: first, it does not take into account the efficiency of the projection lens; second, due to the small area of the aperture, the chance of error is too great; third, and perhaps most important, it does not enable the distribution of light across the field to be checked.

It is therefore recommended that the illumination be measured on a screen. Inasmuch as the only thing that really counts is the efficiency of the projector while showing pictures, all measurements should be taken with the projector running, preferably at not less than the normal speed of sixteen pictures a second. A standard screen size should be determined—a screen 3 feet wide would be large enough to obtain accurate measurements from the corners, edges, and center to check the illumination intensity distribution. The 3-ft. screen is a very popular size, and is a convenient standard.

A standard meter such as the new Weston photronic meter might be preferred on account of the better reproducibility of measurements. Nine readings might be made on such a screen: namely, at the four corners; at the top, bottom, and both sides; and at the center. The average of the nine readings could be taken and from that—figuring the size of screen used—the *effective* lumen output could be determined. In making such a test, it would be essential to use lamps of a uniform color temperature rating for lamps nominally the same. These would then be burned in the projector under *exact* voltage conditions so that fair comparative readings might be obtained.

Reverting to the matter of illumination distribution over the screen, it is recommended that variation in illumination from the corners or edges to the center should not exceed 15 per cent. The reason for this is that unless the projection optics—including the centering of the lamp, *etc.*—are correctly set, there might be a hot spot at the center of the screen that would upset any attempt to obtain a reasonable comparative reading. The suggestion of averaging nine readings has in mind the elimination as far as possible of any variation of this sort.

MR. CARLSON: The question was asked about the effect of operating incandescent lamps at other than their normal voltages or currents. Life changes according to about the 13th power of the voltage, light output to about the 3.5 power, and watts to about the 1.5 power. Since source size remains constant, wattage per unit area and source brightness change directly in proportion to changes in wattage and light output, respectively. Operating a lamp above its design voltage results in slightly less total blackening but, since lamp life is shortened by over-voltage, the rate of blackening is correspondingly more rapid. The reverse is true when the lamp is operated at less than its design voltage.

It has been suggested that further advances in screen illumination might be made with professional equipment if sufficient forced ventilation were provided to permit high wattages in relatively small bulb sizes. It is a fact that manufacturers of 16-mm. projectors have gone further in this direction than have the manufacturers of any of the various types of 35-mm. projectors. Probably much can still be done along these lines.

The subject of projector ratings or classifications is so far-reaching and presents so many complications that President Goldsmith has done well to refer the matter to the Non-Theatrical Equipment Committee in lieu of further discussion. Mr. Farnham has already pointed out that the developments of the past few years were particularly favorable to creating confusion in the minds of consumers and that we are now arriving at a point where this condition will doubtless be less marked. Mr. Porter mentioned the procedure employed with health lamps using ultra-violet sources. It may be well to point out that in that case there are three governing factors that have no parallel in the projector field: namely, there is a potential hazard to the user which makes specific instructions imperative; second, one is dealing with radiation that is not visible nor otherwise makes itself evident to the senses until after use; third, the technic of measurement is such that very, very few laboratories are equipped to function in this field. The reasons for a central rating organization are considerably less compelling in the case of projectors and, on the other hand, the many variables involved present so many more complications that any system adopted would have to be rather arbitrary and thus be more difficult of satisfactory administration. This further point must be kept in mind: despite any rating scheme, visual demonstration will doubtless continue to be the chief selling method. Abuses are not unknown, but the trend in the industry is definitely toward fair practice in that regard.

A MECHANICAL DEMONSTRATION OF THE PROPERTIES OF WAVE FILTERS*

C. E. LANE**

Summary.—*The nature of wave motion and amplitude and phase distortion of waves are discussed. Wave filters of different types and important uses of wave filters are defined and discussed, and finally, a mechanical model of a wave filter is described to demonstrate visibly their essential characteristics.*

Much of our experience is concerned with wave motion, *i. e.*, vibratory motion which originates at some source and which travels away from that source. These waves may occur in solid objects, in liquids, or in gases. An example of the last is sound waves traveling in air. Wave motion may occur also in wires carrying electric currents, the motion being the displacement of the electrons in the conducting wires. If wave motions are slow, corresponding to only a few oscillations per second, they are said to be of low frequency. If the waves are rapid they are said to be of high frequency.

The simplest kind of wave motion is simple harmonic motion, like that observed when a pendulum swings freely back and forth. The back-and-forth motion of the air particles when a pure tone is transmitted through the air is like the motion of the swinging pendulum. Such a simple wave motion is said to be of a single frequency, and when the displacement or the velocity of the motion is plotted as a function of time, the resultant curve is the familiar sine or cosine curve. Most wave motions with which we are concerned are complex, being made up of a large number of superimposed simple-harmonic components, or single-frequency waves which differ in frequency and magnitude. As a rule, the components of complex waves bear a simple harmonic relation one to the other, there being a fundamental frequency of vibration, and the frequencies of all of the other components are multiples of the frequency of the fundamental. Speech and music are complex waves made up of simple wave components, and

* Presented at the Fall, 1934, Meeting at New York, N. Y.

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

the important components are of frequencies ranging from about 60 or more vibrations per second upward as high in some cases as 8000 or 10,000 per second.

Curves A, A', B, and C of Fig. 1 are simple waves. The ordinates

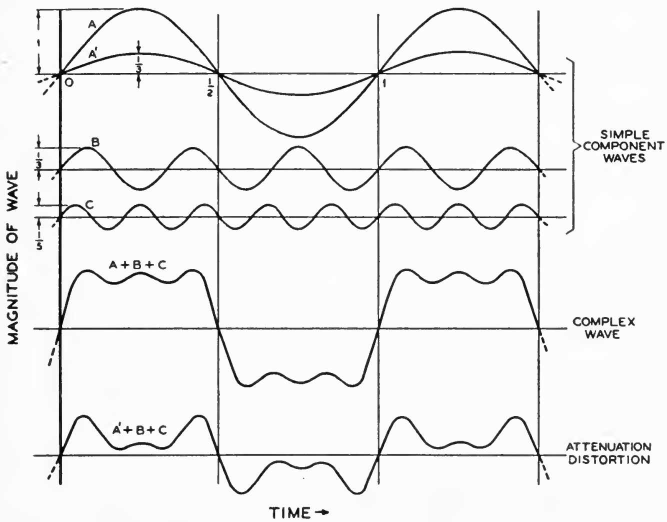

Fig. 1. Simple waves and attenuation distortion of complex waves.

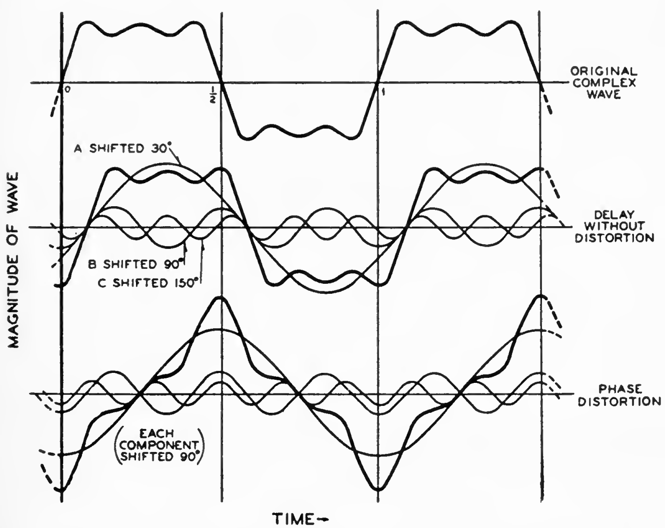

Fig. 2. Delay and phase-distortion of complex waves.

represent amplitude, velocity, or current, as the case may be, and the abscissas represent time. The two lower curves are the complex waves resulting from the simultaneous occurrence of the three simple components. Except for modulation, which is the introduction of new frequency components not originally present, there are but two things that can happen to change the shape of a complex wave as it appears at different places. The first of these is a change in the relative magnitude of the components, generally called *attenuation distortion.* The difference between the two lower curves of Fig. 1 illustrates attenuation distortion. The other change which may take place arises from *phase-shift,* or the difference in time at which the component waves pass through the maxima or minima values. When the phase-shift of all the component waves, measured in degrees or radians (one complete period is $360°$ or 2π radians), is proportional to the frequency, there is no phase distortion but a delay given in seconds by the slope of the phase curve $dB/d\omega$, where B is in radians and ω is 2π times the frequency in vibrations per second. Delay without distortion is illustrated by the middle curve of Fig. 2. When the phase-shift is not proportional to the frequency, the shape of the complex wave is changed. This is illustrated by the lowest curve shown in Fig. 2.

Wave filters are devices which may be put in the paths of these wave motions and which will virtually stop waves of some frequencies and allow waves of other frequencies to pass through them practically unchanged in magnitude. Wave filters may be made of solid parts and put in the paths of waves traveling through solid objects, or they may be made in the paths of sound waves in the air; or they may be made of electrical parts and put in the paths of electrical waves traveling through wires.

Filters which will permit waves of all frequencies up to some definite desired frequency to pass through them unaffected, but greatly attenuate waves of higher frequencies, are called *low-pass* filters. Filters which will stop the lower frequencies and permit the higher frequencies to go through them are called *high-pass* filters; and filters which will pass a band of frequencies over a certain definite frequency range and attenuate frequencies above and below this range are *band-pass* filters.

Electrical wave filters are used extensively in telephone systems to eliminate disturbance waves which otherwise would appear along with the transmitted message waves and interfere with the message reception. They are used to some extent for this same purpose in recording and reproducing circuits of sound-picture systems. In carrier-current telephony and telegraphy, for the purpose of economy, a number of messages are often transmitted simultaneously in different frequency ranges over the same wires. Here filters are used to separate the different messages, on the basis of frequency content, and confine them to their assigned frequency channels.

The illustrations that follow are photographs of a large mechanical filter* which can be used to demonstrate the action of wave filters. Although the filter is a particular type of band-filter, it possesses many features that are common to all types of filters. A mechanical filter is used for this purpose in preference to an electrical filter so that one can see the effect of the filter upon the transmitted wave. The filter is made large and its band of transmission is at low frequencies so that the motion can be followed both for frequencies in the transmission band and for frequencies adjacent to the transmitted band which are

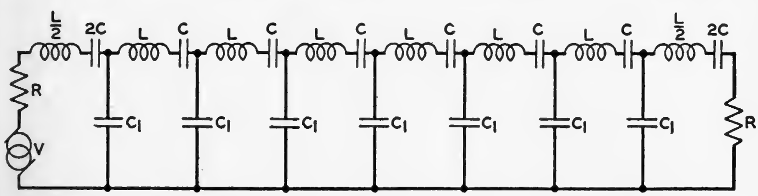

FIG. 3. Electrical analogue of mechanical filter shown in Fig. 4.

stopped by the filter. The filter consists of a number of pendulums connected together by flexible springs, and is so designed that it will permit wave motions of frequencies falling between 45** vibrations per minute and 59 vibrations per minute to pass through it but will greatly attentuate frequencies below or above this range. The filters used in voice- and carrier-frequency telephone circuits generally operate at frequencies which are from 1000 to 20,000 times as high as this.

If this filter were made of electrical parts instead of mechanical parts, its schematic diagram would be as shown in Fig. 3, which is its "electrical analogue." The mass of the pendulum bobs corresponds to the series inductances, the attraction of gravity upon the bobs corre-

* Except for small modifications this filter is the same as that described in the *J. A. I. E. E.*, Dec., 1933.

** Because of the very low frequency it is described in vibrations per minute instead of per second as is usual.

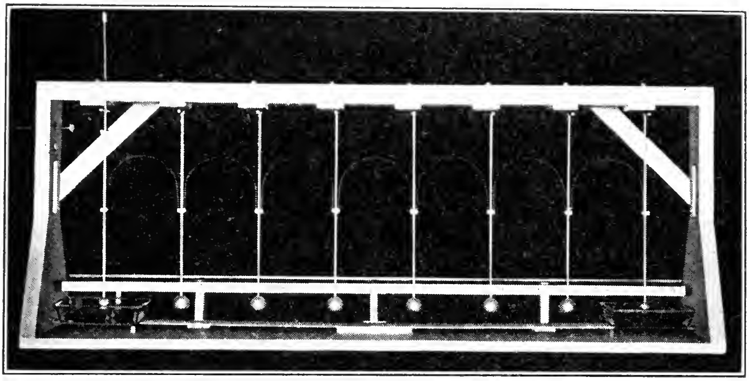

FIG. 4. Mechanical band-pass filter, with transmission band between 45 and 59 vibrations per minute: at rest.

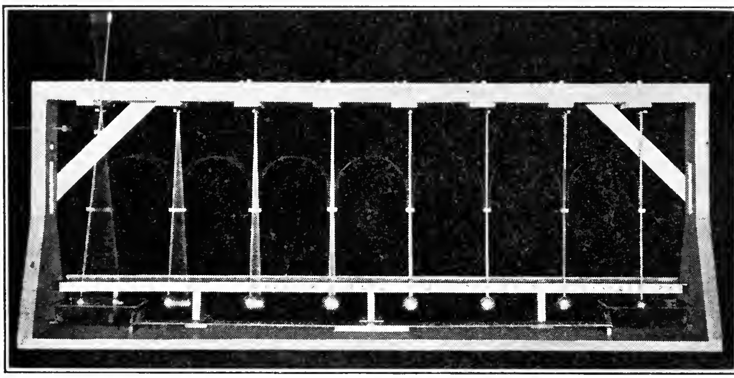

FIG. 5. Operation of mechanical filter below lower cut-off: 44 vibrations per minute.

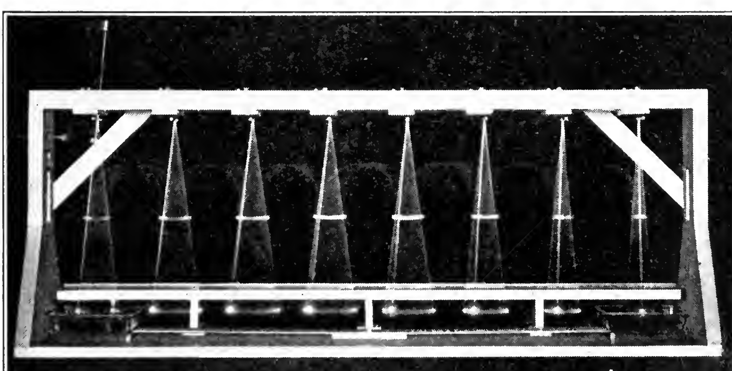

FIG. 6. Filter operating in transmission band just above lower cut-off: 46 vibrations per minute.

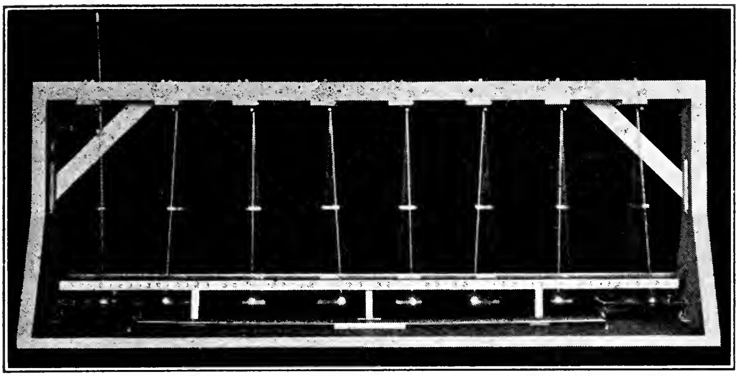

FIG. 7. Middle of transmission band of filter: $52^1/_2$ vibrations per minute.

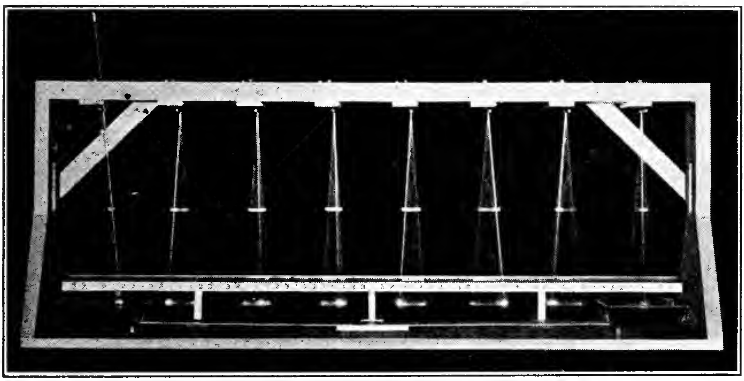

FIG. 8. Just below upper cut-off of filter: 58 vibrations per minute.

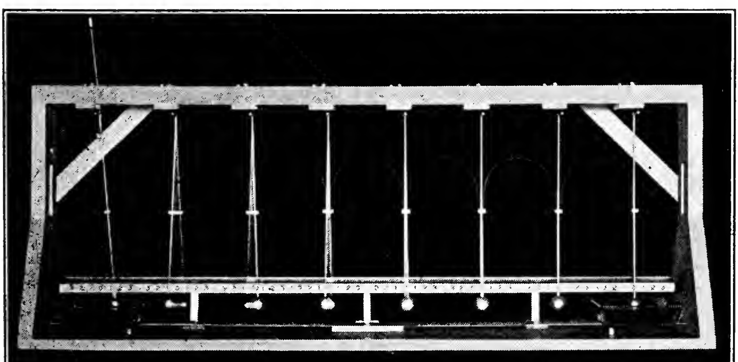

FIG. 9. Just above the upper cut-off of filter: 60 vibrations per minute.

sponds to the series capacitances, and the arched springs connecting the adjacent pendulums provide the shunt capacitances. In this comparison the velocity of motion in the mechanical filter corresponds to the current in the electrical filter. The first pendulum of the filter on the left may be driven sinusoidally by the flywheel of a small motor through the driving shaft and connecting spring shown in Fig. 4. A resistance termination is provided for each end of the filter by allowing the two bobs at the ends of the filter to swing through viscous oil.

The principal property of wave filters is that of permitting to pass through them wave motions of some frequencies and greatly attenuating waves of other frequencies.* The difference in frequency between waves freely transmitted and those not transmitted may sometimes be very small. In order to show this property of wave filters a number of photographs have been taken of the filter in operation. These photographs for different frequencies are shown in Figs. 5 to 9, inclusive.** In the case of Fig. 5 the frequency of the applied wave is 44 vibrations a minute. For this frequency the amplitude or velocity of motion of each successive pendulum bob is about half that of the previous bob. The motion transmitted through the filter to the far end is less than one hundredth of the motion at the end of the filter at which the force is applied. (The attenuation at this frequency is over 40 db., as expressed in terms of the standard logarithmic unit for measuring transmission.) Fig. 6 is for a frequency of 46 vibrations a minute, only a little over 4 per cent faster than shown in Fig. 5. However, there is now a decided change in the transmission. At this frequency there is very little change in the amount of motion from one successive pendulum bob to the next, and for the entire filter the amplitude of motion of the last pendulum is about three-fifths the amplitude at the input end where the motion starts (about 4 db. attentuation). Fig. 7 is for a frequency of $52^1/_2$ vibrations a minute,

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*The primary object of wave filters is effectively to eliminate certain frequency components. A device for changing the relative magnitude of desirable wave components to compensate for attentuation distortion is called an *attentuation equalizer*.

** All the photographs were taken after sufficient time had elapsed to allow the filter to reach a steady-state condition. For this filter, since it is working at such a low frequency, the time required may be a minute or more. The time required for the same type of filter for a mid-band at 10,000 cycles per second would be about 0.005 second.

which is just about the middle of the transmitting band of the filter. At this frequency there is no diminution whatever in the amplitude of motion due to its transmission through the filter. Fig. 8 is for a frequency of 58 vibrations a minute, which is just about the highest frequency that the filter will transmit. Fig. 9 is for a frequency of 60 vibrations per minute. At this frequency the amplitude is reduced by a factor of about two for each filter section, or from one pendulum

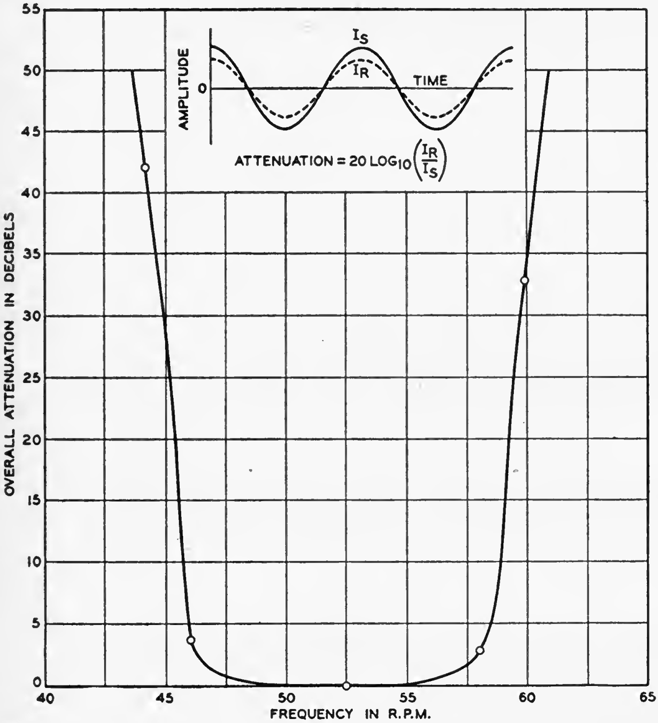

FIG. 10. Attenuation of filter in decibels, as a function of frequency.

bob to the next, again giving a total attenuation of over 40 db. At any frequency lower than 45 vibrations per minute or higher than 60 vibrations per minute the effectiveness of the filter in stopping the wave is greater than at frequencies between these values. Fig. 10 is a plot in decibels of the attenuation of the filter as a function of the frequency.

The photographs shown in Figs. 5 to 9 have been taken in such a way as to show more than the attentuation of the filter. The photographic exposure was maintained for several seconds so as to bring out the total arc of the swing of each pendulum. However, at some instant during the exposure an instantaneous flash was made, so as to record the positions of all the pendulums at that instant and thus to show the phase-shift. Phase-shift refers to the difference in the time of occurrence of maximum displacement (or any other point of reference) of the wave in different parts of the filter. In Fig. 5 all the pendulum bobs are moving together; that is, they all pass through

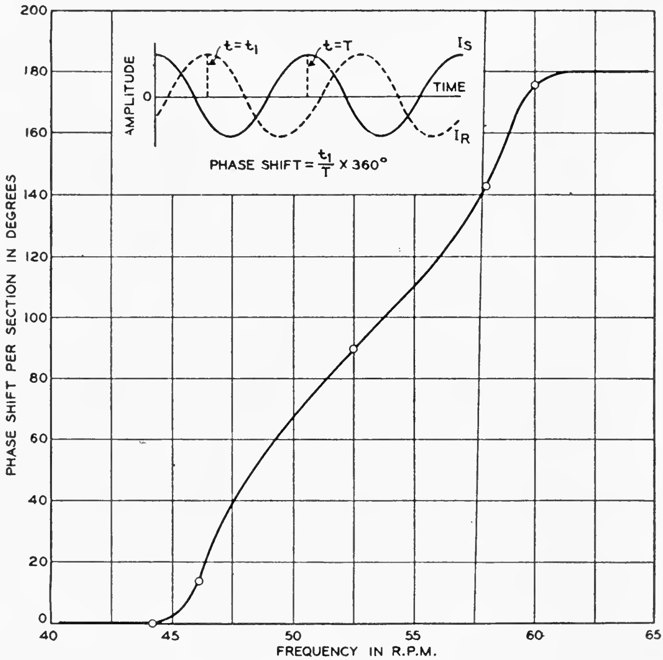

FIG. 11. Phase-shift per filter section, in degrees, as a function of frequency.

zero at the same time, and all have maximum displacements at the same time. Hence all the pendulum bobs are in phase, and there is no phase-shift. In Fig. 6 all the pendulum bobs are moving almost together, but not quite. The bob at the extreme right is about one-quarter of a complete period behind in its motion as compared with the one at the extreme left. The phase-shift from one successive pendulum bob to the next, or the phase shift per section of the filter, is about 12 degrees. In Fig. 7, every other bob is exactly opposite in phase, or 180 degrees apart. Hence there is at this frequency a 90-degree phase-shift per filter section. In Fig. 8, the phase-shift per section is about 150 degrees; that is, the motion of adjacent pendulum bobs is almost opposite in phase, but not quite. In Fig. 9 there is a 180-degree phase-shift in passing from one pendulum to the next.

We have noticed, then, that for the frequency of 44 vibrations per minute there is no phase-shift in the filter. This condition holds for

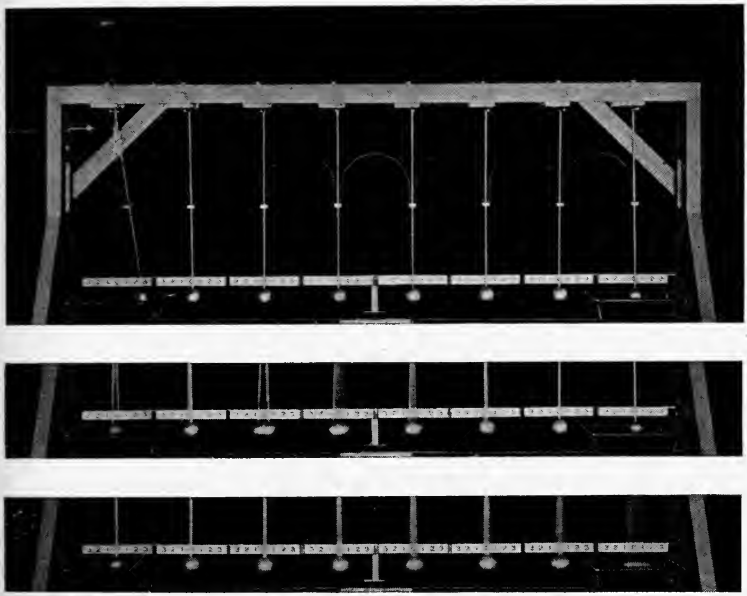

FIG. 12. The delay in the passage of transient impulses through the filter. (*Upper*) transient just starting; (*middle*) after 4 sec., transient approaching midpoint; (*lower*) after 10 sec.; transient reaching end of filter.

all frequencies below the transmitting range of the filter. We have also noticed that for 60 vibrations per minute there is a 180-degree phase-shift per section of the filter. This condition holds for all frequencies above the transmitting range of the filter. Within the transmitting band of the filter the phase-shift changes gradually from 0 to 180 degrees per section, passing through 90 degrees at about the middle of the band of the filter. A plot of this phase-shift per filter section as a function of frequency is shown in Fig. 11. The phase-shift characteristic shown is for this particular type of band filter. However, it may be stated as a general proposition that for any filter whatever the phase-shift in the non-transmitting ranges remains constant with frequency change either at 0 degrees or 180 degrees, whereas in the transmitting range there is a continuous increase in the phase-shift with increasing frequency.

We see, then, since the phase-shift of filters in general is not proportional to the frequency, that they introduce phase distortion. Fortunately, however, this distortion does not generally affect the quality of speech or music waves transmitted through them. The ear can not detect ordinary changes in the relative phases of the components of such complex waves. It would take fifty or more filters of the usual type in tandem to produce a detectable phase distortion of speech or music waves transmitted through them.

There is an initial delay in the attainment of the steady-state condition required for the steady transmission of disturbances through a filter, which is practically independent of the nature of the wave being set up. This initial delay can be related to the phase characteristic of the filter. It is determined by computing the minimum slope of the phase characteristic in its frequency range of transmission. For this filter the delay is about 9 or 10 seconds. What happens after this initial delay depends upon the nature of the wave being started.

The photograph shown in Fig. 12 was taken to illustrate this delay. The upper photograph shows the motion taking place in the filter during the first half second after starting a disturbance at the input of the filter by displacing the first pendulum bob and suddenly releasing it. During this interval the motion is confined solely to the first section of the filter. The middle photograph was taken between the fourth and fifth second after starting the disturbance. By this time this disturbance has reached the middle of the filter. The lower photograph shows the interval between the ninth and tenth second after starting the disturbance, by which time the disturbance has been propagated entirely through the filter. In other words, the delay of the filter due to the transient disturbance was between 9 and 10 seconds. Had the disturbance been caused by suddenly starting the driving motor at any frequency, the initial delay would have been the same.

In order to illustrate the effect of reflection which occurs when filters are improperly terminated, the photograph shown in Fig. 13 was taken. This is for a frequency of $52^1/_2$ cycles per minute, for which the phase shift is 90 degrees per section. Before taking this photograph, the terminating impedance of the filter was removed; that is, in language applicable to the electrical analogue of the filter, the filter was short-circuited at the output end. This caused complete reflection of the wave at the end of the filter. It will be noticed that the amplitude of every evenly numbered pendulum bob is doubled due to this reflection, the reflected wave being exactly in phase with the direct wave at these positions. On the other hand the reflected wave is approximately 180 degrees out of phase at the oddly numbered pendulum bobs, and hence the direct and reflected waves nearly cancel each other at these points and the motion is very small. If the frequency

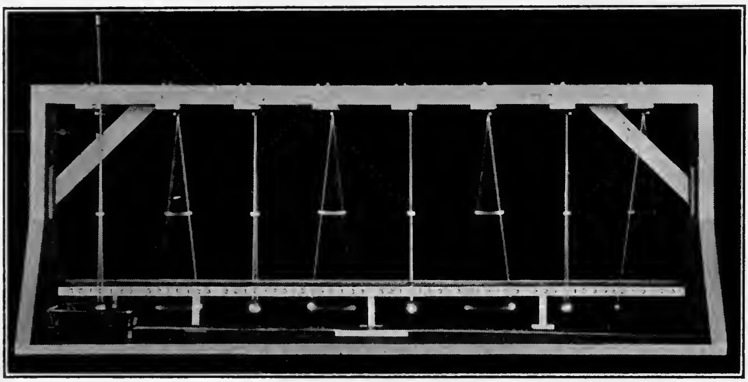

FIG. 13. Illustrating reflection occurring when filter is improperly terminated; in this case a short circuit: frequency, $52^1/_2$ vibrations per minute.

were to remain the same and the output of the filter open-circuited by holding the last bob still instead of short-circuited, as in Fig. 13, there would still be complete reflection at the end of the filter. In this case, however, the nodes would appear at the evenly numbered pendulum bobs instead of at the oddly numbered ones, as shown in the photograph. Photographs of this kind might be taken at other frequencies, and the resultant motion at any point along the filter would depend upon the relative phases of the direct and reflected waves.

The preceding discussion has been restricted largely to a certain type of band-pass filter. There are many other types of band-pass filters, the element configurations of which differ considerably. Also high-pass and low-pass filters of various element arrangements are used. These filters are described in many different publications.* The most complete description is perhaps by T. E. Shea, with tables showing the configurations for all the most commonly used filter sections and their attentuation and phase characteristics. Formulas are also given for the values of the elements of the various filter sections. Complete filters are formed by joining together a number of filter sections which may be alike, as in the case of the filter demonstrated, or which may differ from each other. In the case where filter sections of different types are connected together, it is necessary that the impedances of the sections at their junctions be alike. The total attenuation and phase characteristics of a composite filter is the sum of the characteristics of the individual sections which go to make up the filter.

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DISCUSSION

MEMBER: How serious is the phase distortion in electrical filters, in general? How are some of the other filters designed?

MR. LANE: A band of frequencies, roughly 3000 cycles wide, is required for reasonably good transmission of speech or music. This band may be located in the voice-frequency range or, by modulation, may be located at any position desired above this range. Filters are used in transmitting speech or music over telephone circuits which will pass the frequencies desired and provide 40 or 50 db. attenuation to other frequencies. The speech or music may pass through a number of filters in tandem and the effect of phase distortion is not detectable. Roughly speaking, it would take 40 or 50 ordinary band filters, providing this amount of discrimination, connected in tandem, to produce a phase distortion that would be at all noticeable. Only in very special cases is it necessary to use so many filters together, and when it is necessary, special filter designs are available that will produce less phase distortion than the ordinary and less expensive types.

As you observe, this filter may be regarded as built up of seven identical sections in tandem, each section having an inductance and condenser in the series arm and a single condenser in the shunt arm. This is one type of band-pass filter. The simplest filters are low-pass and high-pass filters. A low-pass filter has an inductance in the series arm and a condenser in the shunt arm of the filter section; and a high-pass filter, a condenser in the series arm and an inductance in the shunt arm. A low-pass filter such as this one will pass frequencies with little or no loss up to some certain frequency and from there on, the loss at higher frequencies will increase rather gradually, becoming infinite at infinite frequency. The simple high-pass filter has infinite loss at zero frequency, and the loss decreases gradually as the transmitting range of the filter is approached.

Both the low-pass filter and the high-pass filter sections may be modified so as to provide more abrupt increase in the attenuation in passing from the transmitting range to the attenuating range of the filter. This is accomplished in the low-pass filter by the use of a condenser in parallel with the inductance in the series arm or by use of an inductance in series with the condenser in the shunt arm; and in the high-pass filter by the use either of an inductance in parallel with the condenser of the series arm or a condenser in series with the inductance in the shunt arm. High-pass and low-pass filters having these additional elements have peaks of infinite attenuation which may be located as near or as far away from the cut-offs of the filter as desired. The closer these attenuation peaks are located to the edges of the transmitting ranges of the filters, the more abrupt will be the discrimination at the cut-offs of the filter. However, the movement of the attenuation peaks toward the cut-offs of the filter lowers the loss per filter section beyond the attenuation peaks.

The band-pass filter of the type of this model may be given an attenuation peak on the upper side of the band by introducing an inductance in series with the condenser in the shunt arm and modifying the value of the condenser; or by a condenser in parallel with the inductance and condenser of the series arm. The type of band filter used in this demonstration produces more loss above the transmitting band than below. There is a type of band filter available for use which is symmetrical in loss about the transmitting band. This filter has an inductance and condenser in series for the series arm, and an inductance and condenser in parallel for the shunt arm.

MEMBER: What would happen if there were no oil at the end of of the filter?

If there were no oil, it would be equivalent to terminating the filter in a short-circuit; as can be seen from the fact that if I should remove the oil, a little at a time, so that the pendulum should make less and less contact with it, the value of the terminating resistance would become smaller and smaller. The filter is open-circuited when the terminating impedance is very high; that is, it is open circuited when I held the last pendulum still with my hand. If the filter were short-circuited, or the oil removed, maximum motion would occur at the last pendulum bob and a node would occur at the one adjacent to it; the effect would be just the opposite of open circuiting the filter.

MR. SHEA: Notice that it is the velocity of the balls that corresponds to current through an inductance and not the displacement of the balls; so when thinking of what an open-circuit and a short-circuit is like in a mechanical system, you must consider the velocity and not the displacement.

MR. MCMANN: The behavior of an electrical filter has been shown here by means of a mechanical model. Isn't it so that complex mechanical problems are sometimes transformed into electrical analogues for solution, as in the case of loud speakers, microphones, *etc.*, with their masses and compliances?

MR. LANE: That is quite true. Electrical analogues are very frequently used which correspond to some mechanical system, like the loud speaker or the ear. To aid in understanding the performance, such electrical analogues are quite useful, though generally only approximate. They can be readily solved and understood, and afford good approximate solutions for the performance of mechanical systems.

MR. SHEA: Basically this is a demonstration of energy transformations. The relation between electrical and mechanical movement and the principles that underlie the mechanical wave filter are very much the same as underlie the loud speaker, where the air is pushed around instead of oil. This applies also to microphones, phonograph pick-ups, phonograph recorders, light valves, oscillographs, *etc.*

Some one several years ago pointed out that between the time the sound reached the microphone in the studio and the time it issued from a loud speaker in a theater, there might be as many as forty transformations from one kind of energy to another. If you were to pick out one course of education above all others that a motion picture engineer ought to go through in school, it would be on the relationships between wave motions in different forms—electrical, mechanical, magnetic, optical, and so forth—because in motion pictures you do go from one condition to another many times; even in a single projector installation. And that is the reason why this demonstration is so significant here, not as illustrating wave filters so much, but as illustrating the very things with which we deal every day.

ELECTRONIC TUBE CONTROL FOR THEATER LIGHTING*

J. R. MANHEIMER AND T. H. JOSEPH**

Summary—*Modern theatrical practice requires a switchboard capable of controlling elaborate electrical effects in connection with stage spectacles. Three-color house lighting, four- and five-color stage effects, frequently involving as much power as 1500 kw., require a flexible, compact, easily controlled system for accurately and rapidly effecting the various combinations and changes of lighting.*

The reactance dimming electronic tube controlled switchboard here described is capable of presetting the intensities and combinations of lights, and easily controlling the effects required for several scenes in advance without interfering with the combinations for the scene in use.

Rectifier-tube control for stage-lighting systems may be classed as a rather recent development. Naturally, the question has arisen as to why such a system is used. The answer is simple.

First, due to the increased size of the newer theaters, the number of circuits to be controlled and their wattages have increased to such an extent that the resistance type of dimmer has become impracticable in many cases. The resistance dimmer needs considerable contact pressure to carry its load and, as a result, the muscular effort required to operate a large bank of dimmers makes it impracticable. Second, stage space is always at a premium, making it desirable as well as economical to locate the dimmers at a remote point and to control them from a pilot-board at stage level. This, of course, might be done with motor-operated dimmers, but with such a system the flexibility afforded by a rectifier tube controlled system can not be achieved. Furthermore, the maintenance of such a system is an endless and expensive task. Third, for a succession of rapid light changes, presetting of resistance type dimmers for each change after the first is impracticable, but is conveniently accomplished with a tube-controlled board. Toward the end of attaining a stage-lighting system that is compact, easy to operate, and economical to maintain, the development of the tube type of stage switchboard has been aimed.

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* Presented at the Fall, 1934, Meeting at New York, N. Y.

** E-J Electric Installation Co., New York, N. Y.

The so-called preset switchboards providing only for the presetting of circuits have long been familiar. The real value of presetting lies in being also able to preset dimming. In order to do so, it is necessary to have a control unit so small that five or more can be mounted in a space much smaller than that originally occupied by a single control on the old type of preset board. Only tube control has made this possible; hence the development in this line. As the development advanced, it was found that other desirable features such as propor-

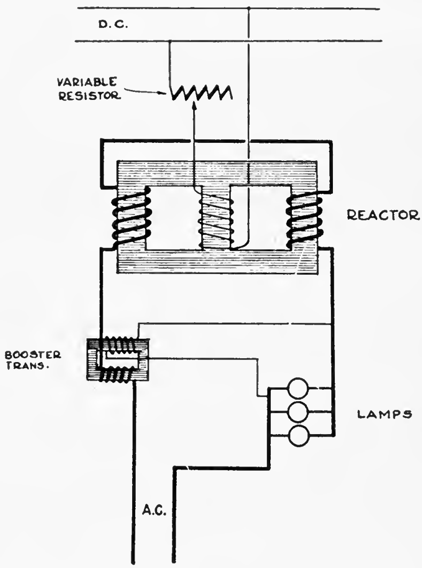

FIG. 1. An elementary reactance dimmer-control system.

tional fading, compact master control, and efficient remote control could easily be realized.

Although several types of tube controlled theater boards are in use at the present time, this paper will restrict itself to a description of one of the latest of these types which has just been put into operation in the Center Theater at Radio City, New York, N. Y.

In order to describe the system and explain wherein it differs from other tube control systems, let us first consider an elementary reactance dimmer-control system such as shown in Fig. 1. This consists of a reactance dimmer in series with the lamps which are connected across the a-c. power supply. The dimmer reactor consists of a three-legged saturable core reactor having an a-c. coil wound upon each outside leg and a d-c. coil upon the center leg. The two a-c. coils are connected in series with each other and with the lamps. The d-c. coil is connected to a variable source of direct current.

With no excitation in the d-c. coil, the impedance of the two a-c. coils is such as to cause a voltage drop in their windings sufficient to limit the lamp voltage to the desired minimum. The connections of the coils are such that in the center leg of the reactor the a-c. flux of each coil at any instant is equal and opposite to the flux of the other coil. Therefore, no alternating voltage is induced in the d-c. coil. When the latter is energized to the point of saturation of the iron in the reactor, the a-c. coils are unable to induce a voltage in their own windings, and the lamp voltage is equal to the line voltage less the drop due to the resistance in the a-c. coils. Intermediate values of lamp voltage are attained by intermediate values of direct current in the d-c. coil.

The intensity of light is varied by changing the small amount of direct current passing through the d-c. coil, "full bright" being attained when the direct current is at its maximum and "black out" when at its minimum. In order to burn the lamps at full brilliancy when the reactor is saturated, it is necessary to provide means of compensating for the voltage drop due to the resistance of the reactor windings. This is accomplished by a small booster transformer having a secondary voltage equal to the drop in the reactor and connected in series with the lamp circuit. The primary of this transformer may be connected to any source of alternating current of the proper voltage.

Reference to the diagram of the tube-controlled circuit in Fig. 2 will immediately suggest a great similarity to the circuit previously described. In the first place, the reactance dimmer is the same. The source of direct current consists of a full-wave rectifier tube; but the variable resistance for controlling this direct current has been replaced by the "hysterset," which is a device for enabling small amounts of power to control large amounts of power. The "hysterset" is controlled by a variable resistor connected across its low-voltage control circuit. Referring to Fig. 2, its mode of application is as follows:

Starting at the pilot switchboard, two transformers, of 120/12 volts, connected across two phases of a three-phase supply, provide the proper supply voltages. Across the outer ends of this supply is connected the control resistor, which has an adjustable slider. A small copper-oxide rectifier is used, having one anode connected to the adjustable slider and the other to one side of the transformer secondary. The cathode circuit of the rectifier is connected through the control coil of the hysterset to the middle point of the secondary. The pur-

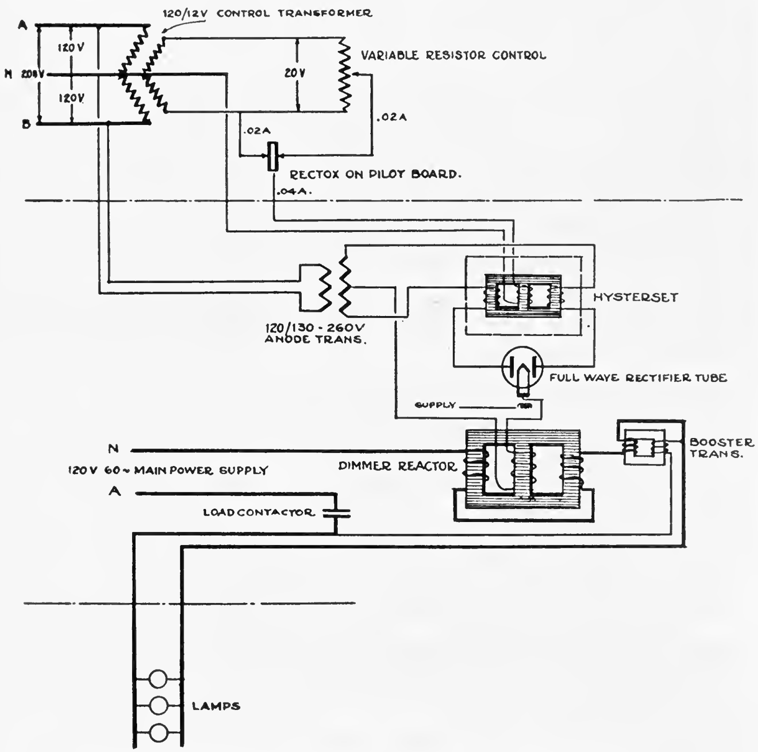

Fig. 2. The tube-controlled circuit employing the *hysterest.*

pose of this is to supply to the hysterset direct current which can be controlled as follows:

When the slider is in the lowest position, both anodes of the rectifier are connected to the same source, so that there is no difference of potential or phase angle between them and the rectifier acts as a half-wave rectifier with the anodes in parallel. The reactance of the control coil then permits only a minimum amount of current to flow, corresponding to the "black out" position of the dimmer. If the slider is moved to the other end of the resistor, the rectifier acts as a full-wave rectifier with the anodes 120 degrees out of phase. This allows maximum current to flow in the control coil, corresponding to the "full bright" position of the dimmer. Intermediate light intensities are attained at corresponding intermediate settings of the resistor.

The control coil operates through the hysterset so that during each

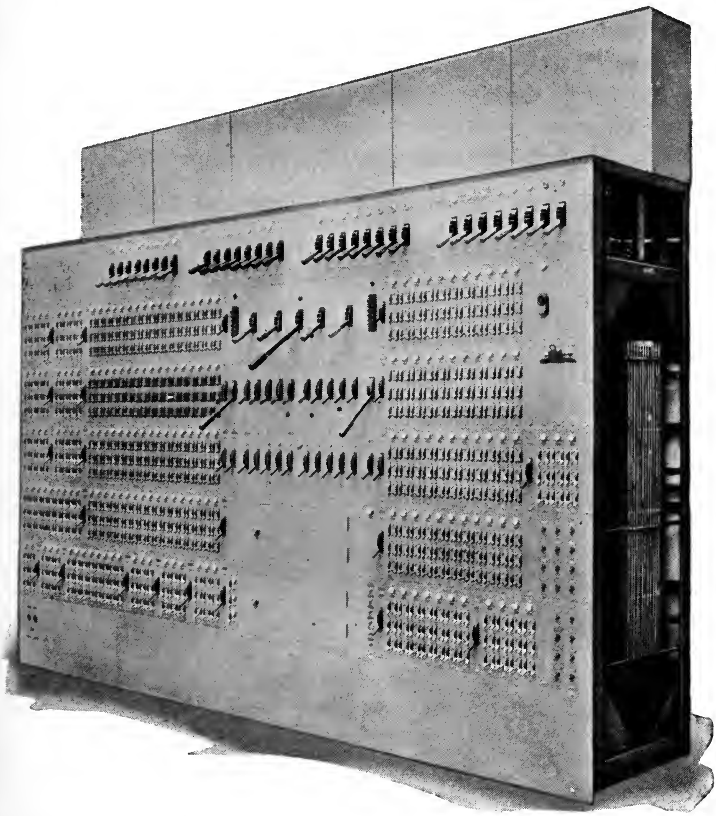

FIG. 3. Front view of the tube-controlled pilot board in the Center Theater, New York, N. Y.

half cycle the iron of the anode reactor is conditioned so as to predetermine the amount of current to flow during the next half-cycle of operation. The output of the hysterset is fed into a full-wave rectifier tube, the cathode of which is connected through the d-c. coil of the dimmer reactor back to the mid-point of the anode transformer. Thus by varying the pilot circuit, as previously described, the direct current in the d-c. coil is varied and the voltage at the lamps changed accordingly, as illustrated in Fig. 1.

Fig. 3 is a front view of the tube-controlled pilot board in the Center Theater. The individual sections at the left consist of one hundred and thirty stage controls, each with five presets and a rehearsal section, arranged according to color: top row, amber; next, red, green, and blue. On the right are fifty-one similar control units for the house lights.

The top row of thirty-two quadrants with handles control Selsyn generators operating four color frames in every incandescent spot and flood on the stage and in the house. The row below this, in the center

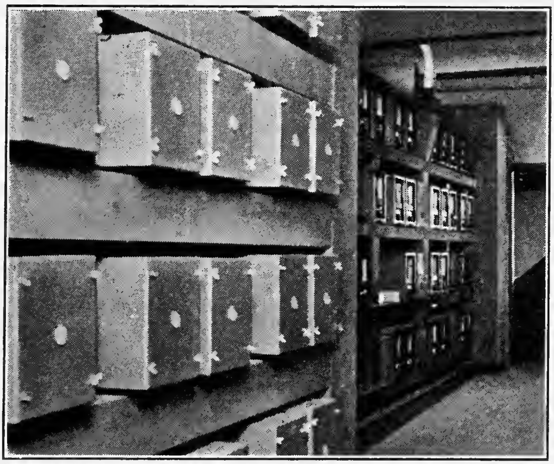

FIG. 4. Part of one of the attic reactor racks, with the reactors in place.

section, contains the Selsyn color masters and their grand master. Below these are smaller quadrants used as scene masters, five for stage and five for house. In the lowest row are the supplementary scene masters, five for stage and five for house lights. Between the row of scene master controls and supplementary controls are two buttons. The button at the left is used for "black out stage" and the button at the right for "black out house."

At each side of the center section are the color masters and stage and house grand masters. The two large handles at each side of the center panel are the stage and house faders. Immediately above each is a bank of five pairs of interlocking push-buttons for selective fading from one scene to any other preset scene. Scenes may be faded one into the other in any sequence or combination. Immediately at the center is a lock that shuts off the entire system except the work-light switches at the lower right. At the left and across the bottom left are individual controls and group masters to control pockets in the stage floor and elsewhere. At the upper right is a guarded "panic light" switch, which in conjunction with two others in the house, throws on the "full bright" amber house lights regardless of the position of the dimming controls.

Fig. 4 shows part of one of the attic reactor racks with the reactors in place. There are two reactor rooms, one in the basement and one on the gridiron level, so as to shorten the lengths of the circuits and so reduce the voltage drop. Circuits supplying the footlights, pockets, proscenium and portal floods, tower spots, *etc.*, are connected to the basement reactor group. Circuits running to borders, all top lights, and auditorium ceiling are connected to the attic reactor group.

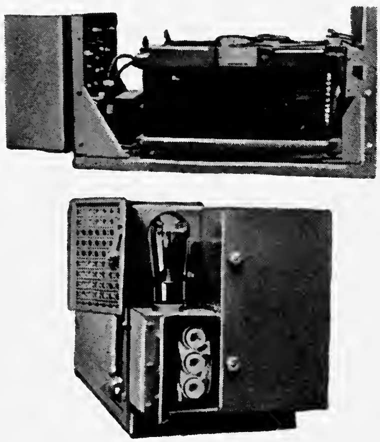

FIG. 5. (*Upper*) A reactor unit, from the side, without the tube panel; (*lower*) tube panel hysterset assembly.

Fig. 5 shows the side of a reactor unit without the tube panel, which plugs into the right-hand end. The tube panel hysterset assembly is shown just below the reactor. Mounted at the left end of the reactor is a contactor, one being supplied for every section controlled from the pilot board.

Fig. 6 is a simplified diagram of the color master control, which operates only in conjunction with the rehearsal presets, indicated in the diagram as individual resistors *1*, *2*, and *3*. The various color masters are connected to the same source of power as the other control units. The individual rehearsal units may be transferred from independent bus to master control bus by small double-throw switches.

Full-range control can be effected with the individual resistor controls provided the master variable autotransformer control is in the "full bright" position when the individual controls are thrown on the master bus; or, with the individual resistor controls when thrown on the independent bus. When on master control, the intensities of the various lamp groups can be varied collectively and proportionately by operating the master slider.

Fig. 7 shows scene master and supplementary scene master for two scenes connected for fader operation. This simplified diagram does not show the interlocking selective buttons and switches for optional transfer to fader control. By operating the proper selective buttons, the fader can be preset and so connected that with a single operation of the fader lever one scene can be "faded out" and another scene "faded in" proportionately. After the fader lever has reached the limit of its motion, a new combination of the selective buttons can be chosen so that the existing scene may be "faded-out" and the next scene "faded-in," *etc.*

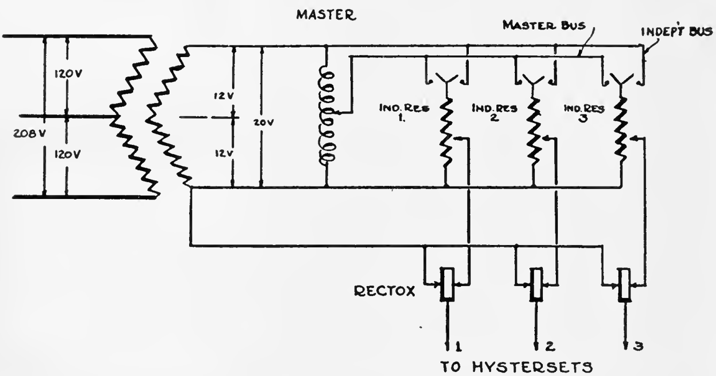

FIG. 6. Simplified diagram of color master control.

The lighting intensities of the various light sources correspond to the calibrated settings of the sliders on the individual presets, so that a combination of intensities from various light sources is possible ranging from nearly "black out" in certain groups to "full bright" in others. By setting some of the lights in a scene on a scene master and the remainder on the supplementary master, two master controls can be employed for each preset scene, permitting in effect ten preset scenes, although the board is known as a five preset board. Any set-up on the supplementary master can be transferred to the corresponding scene master without interrupting the continuity of the lighting by operating a small double-throw switch so as to put the entire lighting under the control of the one scene master. This feature is required when it is necessary to "take out" in a single operation all the lighting that may have been "brought in" by the operation of several controls.

Fig. 8 is a photograph of one of the preset variable resistor control panel units. This unit measures $2^1/_4$ inches in width and 12 inches in height; which gives some idea of the compactness of this type of control, considering that in this small space the equivalent of six dimming controls can be included. The space ordinarily occupied by one dim-

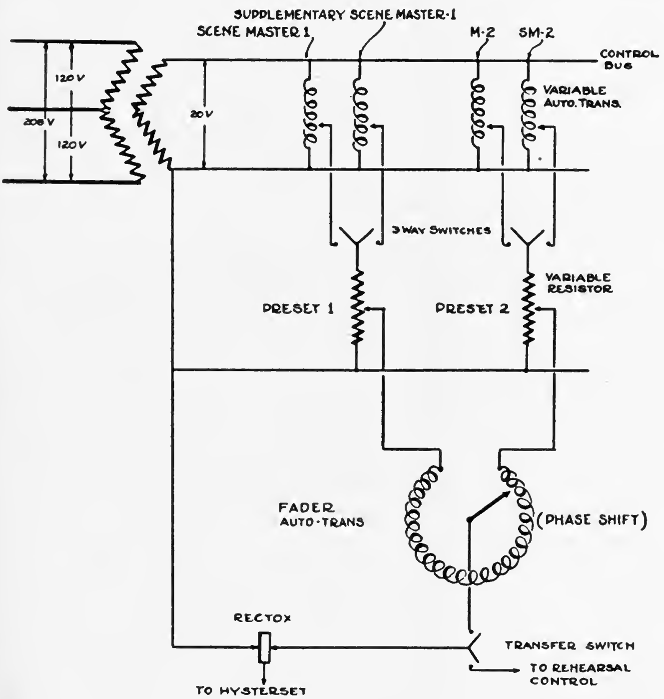

FIG. 7. Diagram of scene master and supplementary scene master, for two scenes connected for fader operation.

ming plate and its corresponding circuit switch requires considerably more than this.

At the top of this assembly is a pilot light, which indicates when the contactor in the reactor room closes. Below it are the preset controls for five preset scenes and one rehearsal. Each of the five preset scene controls is connected to a small double-throw switch used to transfer the corresponding preset from the scene master to the supplementary master, or *vice versa*. The rehearsal control is also equipped with a similar small double-throw switch for transferring its control from the color master to the independent bus, or *vice versa.* Each of the quadrants of the individual presets is equipped with a calibrated scale to indicate the intensity of the light for which it is to be set. These calibrations are based upon visual brightness, and not upon photometrically measured intensities.

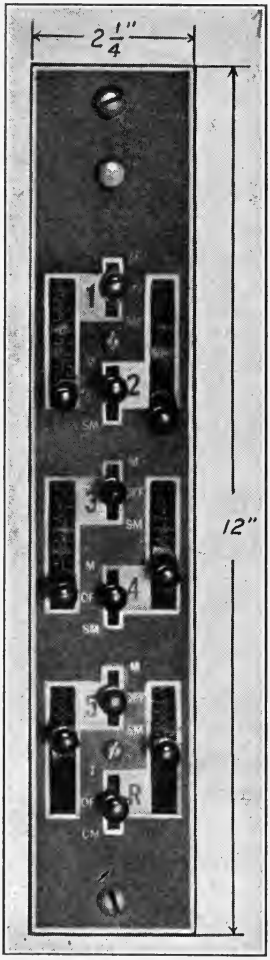

FIG. 8. One of the preset variable resistor control panel units.

This, in brief, describes the fundamental principles of the hysterset control. Of course, special features such as elaborate master control, preset control, extended control, *etc.*, are attainable with this system. Its advantages are many compared with the commonly used systems.

The tube is a simple two-element rectifier involving none of the delicate features of a grid-controlled tube. The operation of the tube is not affected by changes in ambient temperature. It is possible to replace one tube with another without having to recalibrate the tube or the circuit. The life of this type of tube is long, and the cost of replacement low. The equipment at the Center Theater has already seen approximately 1500 hours of service without a tube failure and no indication of any. The current required to operate the controls is very small, a total of over 750 kw. of lamp load being controlled by less than 2 kw. at the control board. For example, the main ceiling 70 kw. is controlled by a minute control consuming but a few watts. Great flexibility of the control is achieved, and the change in light level is so smooth that a comparable dimmer plate would need about 750 contact buttons to equal it. As to compactness, the pilot board occupies a space 11 feet 5 inches long, 26 inches deep, and 6 feet 6 inches high, and is operated by one man. Heat-producing apparatus is avoided on the stage, and the system is completely silent in operation.

The real test of a switchboard is its effectiveness upon the audience in its control of light. *The Great Waltz* performance, now being staged at the Center Theater, demands the use of the entire 650 stage presets on the board, and light control changes occur approximately every ten seconds and at times every second. The equipment and entire system were installed under the supervision of the C. R. Place Engineering Associates. The switchboard was manufactured and supplied by the Westinghouse Electric & Mfg. Co., in combination with the hysterset control, which is a recent development of the Ward-Leonard Company. Similar equipment, but differing slightly in certain features, is at the present time being installed in the Metropolitan Opera House in New York, manufactured and supplied by the General Electric Company, and installed by the E-J Electric Installation Co.

DISCUSSION

MR. HASKELL: What is the difference between the board now installed at Rockefeller Center and other tube switchboards?

MR. JOSEPH: The principle of most tube switchboards is the same, namely, to control a large current by means of compact and cool apparatus on the stage floor.

Tube boards depend primarily upon the use of reactors for the actual dimming. The first reactor board for theaters was installed by the wiring department of the United Electric Light & Power Company in Daly's Theater at 29th Street and Broadway, in 1888. The change of reactance was achieved by pushing an iron core in and out. After the board had been completed, Mr. Daly was requested to observe its operation. The first core pushed in dimmed the lights, but hummed like a hive of angry bees. The next core was somewhat smaller, and the hum assumed a higher tone. With the third and fourth cores, the result was similar except for the tone. Mr. Daly looked and listened. He asked whether the noise was necessary, and was told that it was unavoidable. "Very well," he said, "throw the whole thing out into the street." That was the end of the first reactor board.

Tube control can be broadly divided into two types: the Westinghouse-Ward Leonard type, in the Center Theater, and all the others. The control in the Center Theater, described in the paper, employs a regular full-wave rectifier tube, one for each reactor, for supplying the varying direct current required by the main reactor, and is controlled by a small reactor and associated apparatus called the *hysterset*.

The other types furnish the varying direct current directly to the reactor through grid controlled tubes. For the larger reactors a second tube is added, and connected in parallel to the first. Other types use grid controlled tubes, which are cascaded, as in a radio receiver, progressing from small currents and small tubes to large currents and larger tubes.

Either a potentiometer or a small inductor may be used for varying the grid current at the pilot board. Moving the inductor armature increases or decreases the magnetic linkage and varies the pilot current accordingly.

Each maker has different means of accomplishing the various master and fader controls. A complete comparison of these and other details would occupy more time and space than is available.

Mr. Haskell: How many tubes are used in this board as compared with the other one?

Mr. Joseph: One tube for every circuit. On the previous board, which this replaces, eight tubes were in the control unit and two tubes in the reactor set, making ten tubes per unit, instead of one.

ROENTGEN CINEMATOGRAPHY*

R. F. JAMES**

Summary.—*This paper primarily treats of the advantages of x-ray motion pictures from the physician's and anatomist's points of view. To this end the author cites two examples in which a test apparatus making x-ray motion pictures has been used for diagnosis and for anatomical research.*

The requirements necessary for satisfactory x-ray motion pictures are outlined, and the limiting factors of the apparatus that has already been used are discussed. Descriptions of two test arrangements of apparatus are given.

To the average individual, the thought of x-ray motion pictures brings a mental vision of skeletons, macaber-like, on the silvered screen. To the anatomist, and to the practicing physician, the thought of x-ray photographs capable of portraying the movements of the organs within the human body appears as a boon; a veritable light in the wilderness.

Far too few men realize the difficulties that beset the physician when he is called upon to diagnose the causes of human ailments. The diagnostician desires to locate the fundamental fault, and it is seldom that the patient is capable of describing accurately the symptoms or the conditions that preceded them. The physician is further handicapped by the fact that the human machine can not be easily and dispassionately disassembled for observation.

Text-books are not entirely satisfactory, because they speak in general terms, and fail to consider the specific patient who has a confusion of symptoms. Successful diagnosis is largely made up of experience, sound judgment, and luck; all three factors are present in varying relations, and a stabilizing agent is urgently needed.

Do not misunderstand the situation. There is ample proof that the effectiveness of the medical profession is steadily gaining, and a great measure of its gain is due to improved methods of diagnosis. The personal element is being assigned its proper relationship through the use of impersonal clinical and laboratory data. It is in

* Presented at the Fall, 1934, Meeting at New York, N. Y.

** Research Dept., Westinghouse Lamp Co., Bloomfield, N. J.

this particular field that the x-ray motion picture hopes to find its justification.

As early as 1866 it was known that an abundant muscle tissue existed in the urinary transportation tract, but as late as 1931, a well-coördinated function of this muscle structure was denied. It was assumed that the kidneys filled up and naturally spilled over into the bladder. It appeared that the laws of gravity were universally applicable.

Studies in pure anatomy had disclosed the muscular tissue but surgical observation of the moving organ was not conclusive. The motion could be attributed to a nervous spasm or to an involuntary response, and the time for a careful observation was necessarily limited by the conditions: the surgeon, in the press of an operation, has little time for contemplative meditation.

The use of x-ray motion pictures, furnishing a progressive record of motion, has proved conclusively that the muscle tissue in the urinary tract has a functional purpose and that this function is well coördinated. It has also shown that disease will affect this coordinated function, and hence x-ray motion pictures furnish another diagnostic procedure. We know now that the normal kidney and the ureter pump their contents with a rhythmic motion and do not depend upon gravity.

Unless a person has suffered from renal colic or other urinary disease this development does not hold much of interest. Another instance, more spectacular although of slightly less importance from a medical point of view, might be cited.

Not long ago, in the community in which the research on x-ray motion pictures was being carried on, several new-born infants died. It was unfortunate that they died and still more unfortunate that they were all first children. It is hard to reconcile a couple who have just had the harrowing experience of losing their first baby. All too often they seek the doubtful solace of recrimination.

The physicians attending the infants came to the conclusion that death was due to hypertrophy of the thymus, one of the ductless glands situated in the upper central section of the chest. There are cases where this gland grows to excess and causes death by strangulation.

The death of the infants was attributed to the enlargement of this gland. Why it enlarged no one knew, and hence no one knew how to prevent the excessive growth. There must be some sort of mental telepathy or "grape-vine telegraph" between expectant mothers, because the news of the "thymus deaths" spread rapidly despite the attempts at censorship, and soon a virtual panic was prevalent. The natural phenomenon of birth can not be conveniently postponed and the situation became critical. Deaths from hypertrophy of the thymus are rare, but impersonal statistics give small comfort to distraught parents-to-be.

At the height of the confusion it was decided to take x-ray photographs of each new-born child. It was hoped that this procedure might allay the common fear. It worked out very nicely so far as the parents were concerned, but it threw the hospital staff into a panic because an alarming number of the photographs showed a large shadow in the chest in the general location of the thymus. For some peculiar reason none of the infants showed the typical symptoms of the disease, and subsequent pictures did not show the shadow. The phenomenon was so consistent that it was concluded that x-radiation in minute doses would reduce the thymus. In all cases where there was an apparent enlargement of the gland, the shadow was reduced by the amount of x-rays necessary to take only several pictures. This seemed to be an ideal opportunity to try the x-ray motion picture, and to learn just how much energy was required for what appeared to be a specific treatment.

An infant having a thymus that was photographically shown to be enlarged was photographed with the x-ray motion picture camera. The first exposure showed a normal chest, the second showed an enlarged thymus, the third showed the shadow descending in the chest, and the fourth exposure showed that the thymus shadow was gone—it coincided with the shadow of the heart.

The infant anatomy shortly after birth might be described as plastic, in that the organs have not permanently found their location. The peculiarity that was shown on the serial pictures was a peculiarity of all the photographs, and the entire situation was a case of mistaken identity. The shadow attributed to the thymus was caused by the heart, and came and went with the pulse. In those cases that appeared to be hypertrophy of the thymus the x-ray "snap-shot" was taken when the heart was not in its customary position.

These two instances are cited to illustrate the practical value of a means for providing a photographic record of functional *motion*. There is no question as to the value of the present x-ray plate, which provides a static record; it is simply that the moving record provides a greater scope of diagnostic security. With no disparaging thought it may be said that the present x-ray photograph holds a position analogous to that of the old stereopticon of forty years ago.

It is quite true that present roentgenological technic has ways and means for observing motion. As a matter of fact, this technic was in general use prior to radiography. The fluorescent screen has been used since x-rays have been practicable, but it has certain definite limitations. Within the limits of present knowledge it appears that these limitations are inherent to the phenomenon of fluorescence.

A fluoroscopic screen is simply a sheet of transparent material, such as glass, covered with a thin but adherent layer of certain combinations of chemical elements that possess the property of fluorescing or giving off light when exposed to the proper radiations. This screen is placed between the observer and the objective, in the path of the radiant energy. The variations in the density or absorbing power of the objective cause corresponding variations in the degree of fluorescence, with resulting shadow-pictures.

The primary limitation of the fluoroscopic screen is that the screen does not provide appreciable light intensity. This fault contributes to the hazy image and poor definition. The fluorescent light may be increased by increasing the intensity of the primary radiation, but this is hazardous both for the patient and for the observer. Fluoroscopic observation is similar to looking at faint silhouettes through a frosted glass. It is not clear vision with satisfactory contrasts, and, above all, it is not a record that can be preserved for careful study.

The next logical step that was taken was the development of serial and periodic x-ray photographic plates. The period, or frequency, of exposure is timed so that the images form a record of successive positions, which may be translated into phases of motion. However, the number of images per unit of time required to analyze the recorded motion properly is a disputed point. The problem is different from that met in the ordinary forms of cinematography: it is not merely a question of obtaining an adequate number of images without subjecting the patient to a dangerous quantity of x-radiation.

There is no question but that a "continuous" film, such as the present cinema with sixteen frames per second, would be desirable; but it is questionable as to whether or not it is necessary. With the exception of the heart, the remaining organs move with a relatively slow rhythm. There are doubtlessly anatomical regions of high mobility, but the present x-ray technic does not provide sufficient contrast to render them visible.

Two schools of thought exist as to the best manner of obtaining x-ray motion pictures. One school holds that the periodic image is satisfactory and safest. The other group advocates the use of the "continuous." Both schools have their special apparatus which, in turn, has its respective advantages and disadvantages. The principles of operation of each type of apparatus are relatively simple to discuss and, it might well be added, at that point the simplicity ceases.

The apparatus for the "periodic" image consists essentially of a camera and an x-ray tube, with the object to be photographed placed between the two. The camera mechanically exposes and replaces the film, and thereby does away with the present manual technic. In the true sense of the word it can hardly be called a camera; nor, for that matter, can the resulting periodic images be called motion pictures.

The camera is without a lens, for the obvious reason that a lens has no proper effect upon the radiations that act upon the film. The film itself is a strip six to eight inches wide and about twenty feet long. It is fed from one spool to another as the exposures are made, the movement being actuated by a motor-drive controlled through an adjustable electric timer. The usual fluorescent intensifying screens are used to provide contrast to the picture. The camera is usually arranged to fit just below the top of the treatment table in place of the regular film holder, and it is brought into focus by moving the x-ray tube and observing the fluorescent image on the film intensifying screen.

The rate of making exposures is optional with the operator and is based upon his experience, the selected rate being set on the timing device. The first section of film is moved into place from lead-shielded compartments in the camera, the intensifying screens are pressed against the film, and the timer closes the circuit applying the electrical energy to the x-ray tube for the desired time.

After the exposure is made, a motor-driven mechanism releases the screens from contact with the film and moves the spools that bring a fresh supply of film into place, thus completing the cycle. As the film is moved it is in contact with an electrically grounded surface to discharge the accumulated static and prevent brush discharges.

The resulting film is nothing more or less than a series of the usual x-ray plates taken at intervals. Studies of these photographs may be made in several ways. The strip of film may be moved in front of an illuminated glass screen, which is usually adequate for preliminary study. For a more detailed consideration a different technic is used. The method is rather unique and entails considerable work, but the advantages justify the effort.

Tracings are made from the strip of film showing the boundaries of the particular organ under study. These tracings are made on white paper and pasted onto a black background in proper order. The silhouettes are then photographed with a 16-mm. camera and the studies made from the 16-mm. film. The results are reminiscent of the early animated cartoons, but they give a splendid impression of the movements and travel of the viscera.

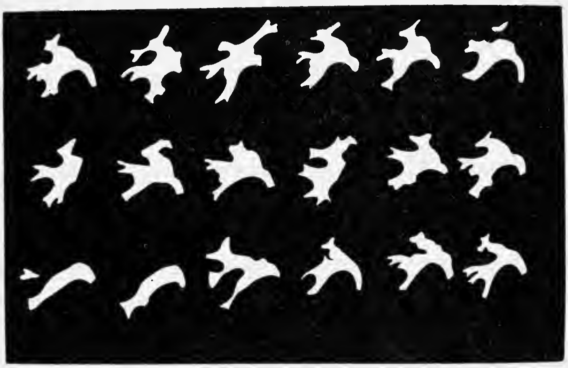

FIG. 1. Cut-out silhouettes of normal kidney.

Fig. 1 shows the cut-out silhouettes of a normal kidney. There are no two images alike. If only one photograph had been taken, as is the usual custom, the diagnostic value of such a single photograph would have been doubtful. It is entirely conceivable that a diagnosis of disease might have been made, because there are indications of pronounced kidney activity. These photographs were from a test case, and the activity was due to beer.

Fig. 2 shows the conditions due to an obstruction in the low ureteral region. The over-distention is marked, and has caused a reversed peristalsis. The obstruction was removed by surgical means.

There are objections to this method of studying the interior of the human anatomy. It takes time and infinite patience and is expensive. The original film is cumbersome and the cost prevents many "retakes"; the tracing must be done by a skilled technician, and the final film has a pronounced "flicker." In spite of these faults it provides sufficient contrast so that physical measurements may be made. With care and a knowledge of the optics involved, it has been possible to make computations to determine the actual size of the organ and its periodic changes in volume. These computations have been confirmed and found accurate within the experimental error.

There is a second method of achieving the desired results which better merits the title of roentgen cinematography. This method is the photography of the moving image on the fluorescent screen,

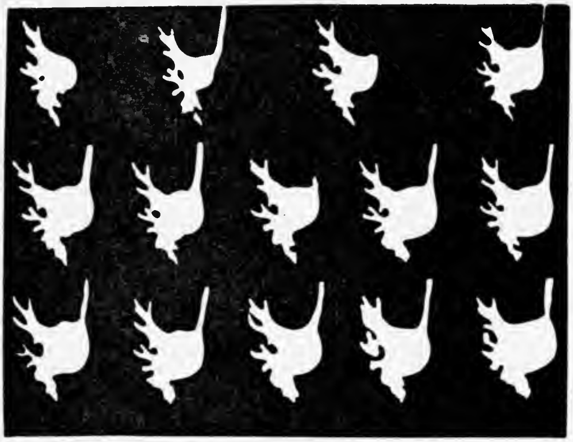

FIG. 2. Over-distention and reversed peristalsis, due to obstruction in low ureteral region.

which is accomplished by synchronizing the shutter on the camera with the electrical impulses to the x-ray tube so that the object is not subjected to an overdose of radiation. The result more closely approaches the typical motion picture, although the number of frames per second is usually reduced because of the low intensity of visible light from the fluorescent screen.

As a matter of fact, the limitations imposed by the fluorescent screen are the essential handicaps to this technic. The visible light given off from a fluorescent screen is *not* intense, and the images are not sharply defined. These conditions require that a wide-aperture lens be used with a high-sensitivity film and a relatively slow film-travel.

These limitations are essentially of a mechanical nature and hence are being met and overcome. New developments are increasing the light from the fluorescent screens, faster films are becoming available, and new types of x-ray tubes that will withstand the rigors of rapid "on and off" service are on the market. The problem is one of removing the irksome "bugs"; the theory has been proved to be correct, and the usefulness is self-evident.

MY PART IN THE DEVELOPMENT OF THE MOTION PICTURE PROJECTOR*

THOMAS ARMAT**

It is difficult to trace to its beginning and fix a date for the conception of an idea that leads to an invention. Of the interesting impressions of my childhood, the one made by the toy known as the Zoëtrope was among the most outstanding. The idea that its principles might be applied to producing a series of consecutive instantaneous photographs of objects in motion, so as to reproduce the motion, was suggested by something I had read, and the fascinating thought persisted in my mind until the Anschutz tachyscope I saw at the Chicago World's Fair in 1893 brought a realization of its actual accomplishment.

A toy magic-lantern was also one of my much prized playthings, and from it I had learned, among other things, that microscopically small objects could be projected upon a screen and greatly enlarged. My first thought upon seeing the tachyscope was of the possibilities that would be presented if its pictures could be projected upon a screen. The tachyscope was a peep-hole apparatus, and the picture I saw was that of an elephant trotting along in a most realistic manner. It was an outdoor scene, a foreign setting. The idea of bringing scenes from far and interesting countries and projecting them upon a screen before comfortably seated spectators, was an exciting thought.

In the summer of 1894 I saw at Washington the first exhibition there of the Edison kinetoscope. It interested me greatly. About that time Mr. H. A. Tabb, who had known me since my boyhood days, and who also was a friend of both members of the firm of Raff and Gammon, exclusive agents for the kinetoscope, dropped into my office in Washington and endeavored to interest me in a business way in the kinetoscope. He gave me glowing accounts of the public in-

* Prepared at the request of the Historical and Museum Committee; received Jan. 7, 1935.

**Washington, D. C.

terest in kinetoscope exhibitions and as to the profits to be made out of them.

One of the places Mr. Tabb had in mind for the profitable exhibition of the kinetoscope was Atlanta, Georgia, anticipating the large crowds that would attend the Cotton States Exposition scheduled for the following year.

After investigating the matter I told Mr. Tabb that I could not see anything very promising in the kinetoscope as a commercial project, but that I could see a lot in a machine of the kinetoscope type if the pictures could be projected upon a screen, and that I believed that I could devise such a machine.

Mr Tabb's answer to that was that he did not believe it was possible to project such pictures successfully, because he knew that Raff and Gammon had urged the Edison Company to produce such a machine and that they had failed to do so, and he, therefore, did not believe it could be done. From what I knew of stereopticons it did not seem to me that the problem presented insuperable difficulties, and I began a research to find out all I could as to the state of the art and what, if anything, had been accomplished in the way of projecting such pictures upon a screen, at the same time starting preparations for experimental work.

I had been inventing for a number of years and had received several patents, among them No. 361,664, filed January, 1887, covering an automatic car-coupler, which had been developed to the point of making a model and which received some very favorable consideration. A subsequent patent, No. 521,562, filed March, 1893, covering a conduit electric railway system, also received favorable criticism from various sources, among others from Professor Louis D. Bliss, founder and head of the Bliss School of Electricity of Washington, D. C., who wrote me a letter in which he said, "It is most decidedly a model of perfection when compared with the crude system of the General Electric Co., and the cumbersome, complicated, and unreliable mechanism of the Wheeless system."

In the fall of 1894 I enrolled as a student in the Bliss School, largely for the purpose of acquiring practical information as to handling an arc light that I proposed to use in my motion picture projection experiments. When I explained my purpose to Professor Bliss, he told me that there was another student in his school who was also interested in motion picture experiments. A few days later, at one of the classes, Professor Bliss introduced to me C. F. Jenkins, the student in question. Jenkins was a stenographer in the Life Saving Service, a branch of the U. S. Treasury Department.

It developed that Jenkins, with the coöperation and assistance of Professor Bliss and E. F. Murphy, the latter having charge of the Edison kinetoscope in the Columbia Phonograph parlors in Washington, had assembled a modification of the Edison kinetoscope, in which all Edison parts, films, sprockets, *etc.*, were used. Jenkins called this peep-hole machine a "phantoscope," and applied for a patent on it November 24, 1894. The patent was issued as No. 536,539 on March 26, 1895. As the patent shows, the Jenkins modification differed from the kinetoscope only in respect to the shutter. Instead of using a rotating shutter with a slit in it for exposing the continuously running film over a stationary electric light bulb, Jenkins rotated the bulb itself. This modification accomplished no improvement in results. It amounted to a somewhat different way of doing the same thing in a somewhat less efficient manner. Its only virtue consisted in the possible avoidance of certain claims in the Edison kinetoscope patent, in which a specifically described shutter was included as an element. These claims were cited by the Patent Office against the Jenkins application.

Practically every night that we met at the Bliss School Jenkins urged me to join with him in experimental work to develop a motion picture projection machine. He was fully convinced that a successful projection machine could be built upon the principle of the continuously running film of the Edison kinetoscope type of exhibiting machine. I was not so certain about that, but I felt that an experimental start had to be made and the sooner the better, and finally agreed on March 25, 1895, to join with Jenkins under an agreement which he prepared. In April or May of 1895 we completed a projection machine built on the kinetoscope principle. The machine turned out to be a complete failure, for reasons now obvious to anyone familiar with motion picture projection problems.

After that I took complete charge of further experimentation, at my own expense, and finally we produced the first projection machine ever made that embodied an intermittent movement with a long period of rest and illumination of the pictures on the film. Application for patent on this machine was filed on August 28, 1895, and later issued to Jenkins and Armat as patent No. 586,953 (Fig. 1). The patent drawings were made from the machine itself, completed a short time before the application was filed. As may be seen, we mounted

(No Model.) 2 Sheets—Sheet 2.

C. F. JENKINS & T. ARMAT.

PHANTOSCOPE.

No. 586,953. Patented July 20, 1897.

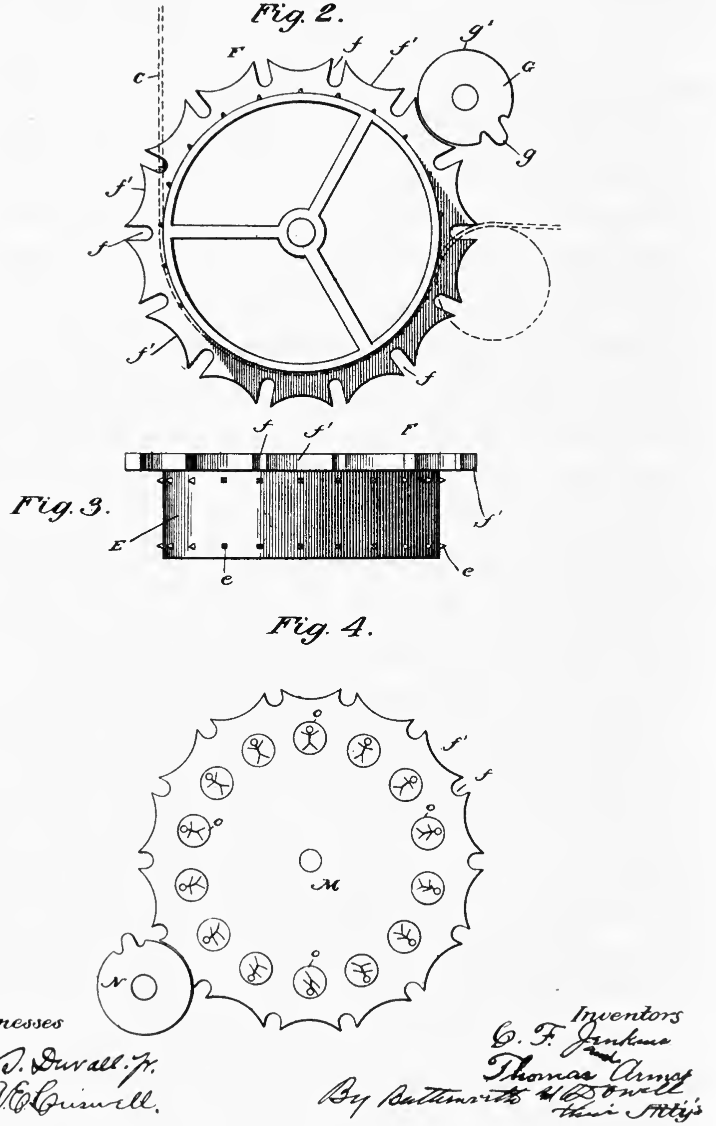

Fig. 1. Arrangement for providing a long period of rest and illumination, and quick shift of pictures.

an Edison kinetoscope sprocket upon the mutilated gear illustrated in the patent. This arrangement gave the desired long period of rest and illumination and quick shift of the pictures, and demonstrated the value of the method. The machine, however, was a mechanical failure.

The Edison films we used (the only kind obtainable at that date) were all taken at the rate of approximately forty per second. The machine could not run the films at more than half that speed, and it thus gave a slow-motion effect to all the scenes. It made a terrific noise. The sprocket and mutilated gear weighed more than a pound, and after a few experimental exhibitions the recesses in the driven gear were battered out of shape and made useless. The machine was never exhibited outside my office at No. 1313 F St., Washington, D. C. I still have the original sprocket and mutilated gear in my possession.

Under date of August 30, 1895, Jenkins wrote his friend Murphy that the machine was a "grand success," but I regarded it as a complete failure so far as its having any commercial value was concerned, and addressed myself to the task of devising a practicable machine. This I accomplished a short time after the failure of the Jenkins and Armat machine, with a modification of the Demeny camera intermittent negative film movement, adapted to projection machine requirements. I hurriedly assembled a crude machine, tried it out and found it satisfactory. Immediately afterward I had a more substantial machine made, and with it gave a number of successful exhibitions in my office to friends and acquaintances. An account of this machine was published in the Baltimore *Sun* of October 3, 1895.

In the month of September, 1895, we took this machine to the Cotton States Exposition at Atlanta, Georgia. Subsequently I had two duplicate machines made and sent to us there for exploitation purposes. I obtained a concession from the Exposition authorities and built a theater in the grounds for giving exhibitions, with the thought that receipts from the theater would help to pay the exploitation expenses. The anticipated Exposition crowds did not materialize, the receipts were small, and a very considerable loss was incurred.

While at Atlanta, Jenkins borrowed one of the three machines, saying that he would like to take it to Richmond, Indiana, to give some exhibitions to his friends on the occasion of his brother's wedding, and that he would be back in a few days. Jenkins gave an exhibition with this machine in his brother's store in Richmond, as announced in the Richmond *Daily Telegram* of October 30, 1895.*

After Jenkins' departure from Atlanta I made some important improvements in the machine, including a loop, or slack-forming means, that improved the exhibitions and greatly reduced the wearing of the films. Subsequently I remodeled the machine, to give it a more commercial form.

In the month of December, 1895, I got in touch with Messrs. Raff and Gammon of New York, who were the exclusive agents for the Edison kinetoscope and films. My idea was to arrange for a supply of films. In reply to a letter to them asking that they come to Washington to see my machine, I received an answer to the effect that they had no faith in motion picture projection machines, since they had endeavored to induce the Edison Company to produce one and they had failed to do so, and they did not believe motion pictures could be successfully projected. After a further exchange of letters Mr. Gammon agreed to come to Washington if I should pay his expenses, which I agreed to do. Mr. Gammon arrived with a sort of apologetic air of having been fooled into a wild-goose chase. When I took him into the basement of my office and threw a picture upon the screen, his attitude underwent a complete transformation. His excitement and interest were most apparent.

The result of the interview was a contract under the terms of which Raff and Gammon undertook to furnish films and to manufacture a certain limited number of machines, and licenses were to be granted upon a royalty basis to users of the machines and films, with territorial restrictions. No machines under any circumstances were to be sold. The Edison Company was to make the machines from a model I was to send them.

Mr. Edison wanted to see an exhibition of the machine before details as to the number of machines to be made by him, the supply of films, *etc.*, were to be decided. It was arranged that I should give Mr. Edison an exhibition. I sent a machine over to the Edison Works at Orange, N. J., and later Messrs Raff and Gammon and I went over from New York to give the exhibition. The exhibition took place in a large room in the Edison plant and the sheet was a

**Editor's Note:* It has been stated several times in the literature that C. F. Jenkins gave an exhibition with his projector at Richmond, Indiana, on June 6, 1894, but no proof of this earlier date has been obtained by the Historical Committee. A photographic copy of the Richmond *Daily Telegram* for Oct. 30, 1895, describing the showing on October 29, 1895, is in the files of the Committee.

large one. Mr. Edison was obviously surprised at the excellence of the exhibition and so expressed himself. On the way back to New York Mr. Gammon told me that Mr. Edison had agreed to all our plans but expressed the opinion that we were planning to have more machines made than necessary. We planned to make eighty machines at first, but Mr. Gammon said that Mr. Edison believed that fifty machines would be sufficient to cover the country. This (oft quoted) statement might seem strange coming from a man of Mr. Edison's vision, but it should be borne in mind that up to that date (February, 1896) no pictures of outside scenes had been taken by the Edison Company. The scenes were all such as had been taken in the Edison "Black Maria," as they called it, a sort of open-air, black-lined stage adapted to be rotated so as to face the sun. The necessity for bright sunlight was largely due to the high speed of taking. The pictures were restricted to such as could be taken in the limited space of the small stage, and they were all of vaudeville subjects.

Arrangements were made by Raff and Gammon to introduce the machine, or rather its exhibitions, to the New York public, and I was asked to come to New York to supervise the installation and operation of the machine. This I did, and on the evening of April 23, 1896, I gave at Koster and Bial's Music Hall in New York, the first exhibition ever given in a theater of motion pictures as we know them today, embodying, as such exhibitions do, the feature of relatively long periods of rest and illumination of each picture on the film. I personally operated the machine the first night. All the scenes shown, with one exception, were what might be called vaudeville turns, or stage subjects. A crowded audience applauded each of the scenes with great enthusiasm. The one exception to the stage scenes was an outdoor scene that Raff and Gammon had succeeded in getting from Robert Paul, who by that date was experimenting with motion pictures in England. This scene was of storm-tossed waves breaking over a pier on the beach at Dover, England—a scene that was totally unlike anything an audience had ever before seen in a theater. When it was thrown upon the screen the house went wild; there were calls from all over the house for "Edison," "Edison," "speech," "speech."

A graphic account of the exhibition was published in the New York *Herald* of May 3, 1896, and previously to that date, on April 4 the New York *Journal* and the New York *World* published long accounts of the exhibition that I had given at the Edison Works.

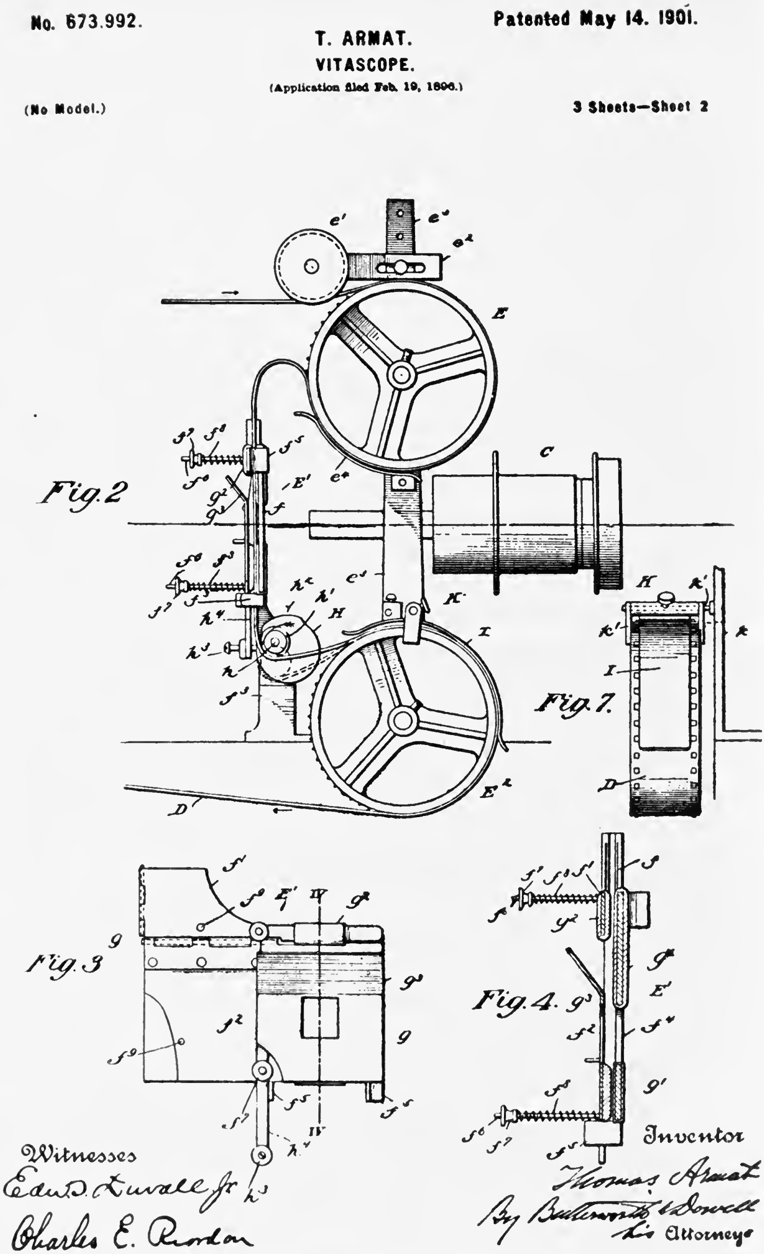

FIG. 2. Mechanism of the *Vitascope*.

It should be here stated that, by mutual agreement, it was decided that Edison's name should be used in connection with the machine. This was done partly for the commercial advantage of the prestige of his name and partly because he was the producer of and had patents pending covering the films, an essential part of the machine, that he was to supply. Prior to this, when I had gotten the machine in all its details into what I considered practicable commercial shape, I applied for a patent on it on February 19, 1896 (Fig. 2), and selected *Vitascope* as a name for the machine. This name was applied to a projection machine for the first time in this patent application, and it would seem that I added a word to the English language as the word *Vitascope* now appears in most modern dictionaries. The Vitascope, Edison Vitascope, so-called, made an immediate hit and was in great demand all over the country.

Subsequently I invented and patented another projection machine with a greatly superior intermittent movement. This machine is shown in my patent No. 578,185 filed September 25, 1896, issued March 2, 1897 (Fig. 3). This intermittent movement is known as the "Star Wheel" or Geneva Cross movement, and it superseded all others by 1897 and is in use today in practically every motion picture theater the world over. It was not, however, a part of the Raff and Gammon arrangement, being a somewhat later development. The intermittent movement has been called, appropriately I think, the "heart" of the motion picture projection machine. In the early days this intermittent movement of my patent No. 578,185 was used in the Edison Projectorscope, the Powers Cameragraph, the Vitagraph, the Lubin machine, the Baird machine, the Simplex machine, and many other early machines.

The Raff and Gammon licensing arrangement started off auspiciously and the financial returns were satisfactory, but troubles developed shortly. None of my patents had been issued at that date, and the applications were still pending in the patent office, two of them involved in "interferences" which greatly delayed their issue. No patent protection could be given until patents were actually issued. Piratical machines began to appear, and, in the absence of patents, could not be stopped. Later on the Edison Company began to be slow in supplying films. Friction, for that reason among others, developed between the Edison Company and Raff and Gammon. Still later the Edison Company began to market a machine that infringed my pending patents. As soon as my patents were issued I

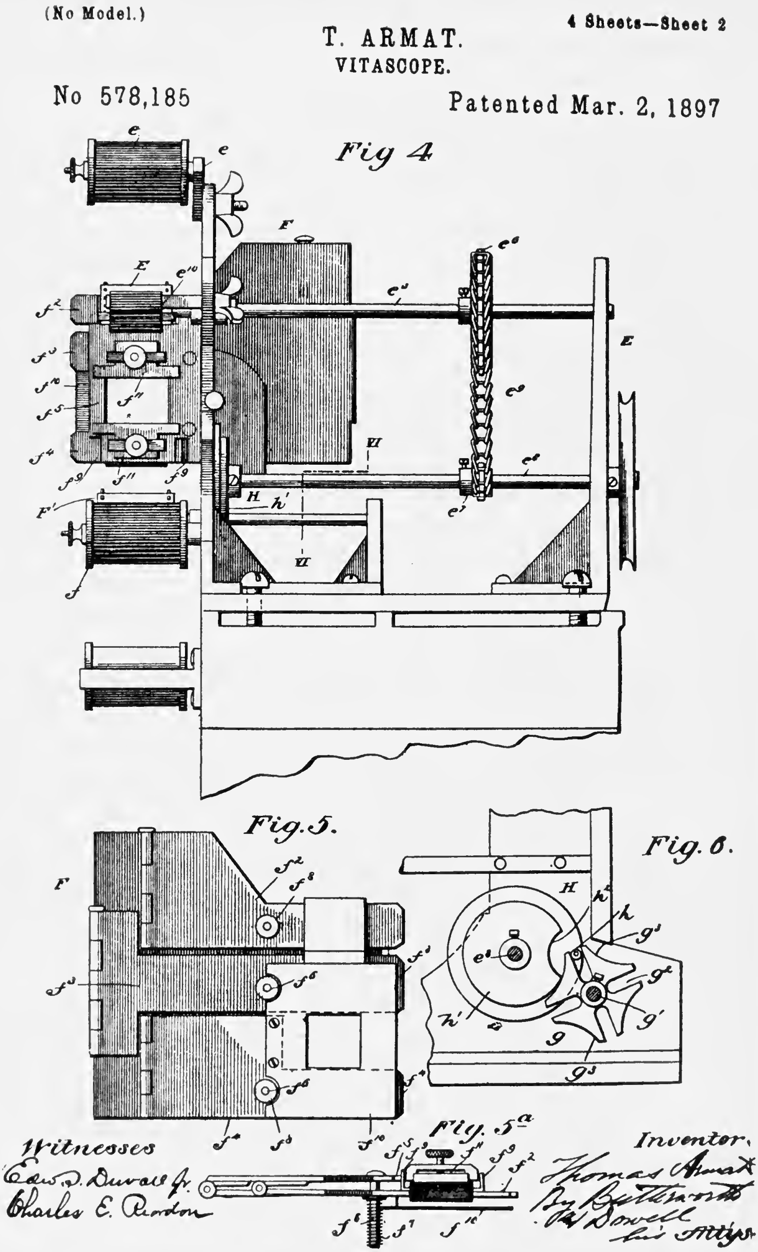

Fig. 3. Intermittent movement employing the star-wheel, or Geneva cross.

organized a company, to which I transferred my patents. Warnings were sent out to infringers, and suits were filed. In many cases the suits were rendered fruitless by the simple expedient of fading away on the part of the sued infringer. The Edison Company was making and selling large numbers of machines that they called *projectorscopes* which infringed no less than three of my patents. We notified users of the machines that they must promptly arrange to pay us royalties for their use or they would be sued for infringement and damages. The Edison Company notified users of projectorscopes they had sold that they would be protected against any suits that we might bring. That made it necessary for us to sue the Edison Company. In the meantime a suit we had brought against the Biograph Company reached its final stage and was decided in our favor, and the company was enjoined. On the strength of that decision an injunction was obtained against the Edison Company. The Edison Company had pending in the Patent Office an application covering the only successful method of taking motion pictures and an application covering the perforated film.

So long as the Edison Company and my company were fighting each other, no exhibitor could give an exhibition without risk of being sued by one side or the other. I had pointed out a number of times to the Edison Company the obvious advantages of our getting together on some basis that would not involve the sale of projection machines, but without avail. After we obtained the injunction against the Edison Company they tried in various ways to obtain a license from my company under which they would be permitted to sell machines. To that I declined to agree. From the beginning I had refused to sell machines, or to license others to do so, for the reason that I felt that whatever monopoly we might be entitled to under our patents would be destroyed by any sale of machines; and I also felt that any profit we might make out of the sale of machines would not be remotely commensurate with the earning power of the machines themselves. I wanted a royalty from exhibitors, small enough not to be felt by them, but which in the aggregate would net a handsome income to my company.

The suit against the Biograph Company was for an injunction and damages of $150,000. Damages were also asked in the suit against the Edison Company. Both companies posted bonds and prepared appeals. While damages in patent suits are rarely collectible, a favorable decision in an injunction suit where damages are claimed creates a very uncomfortable feeling on the part of the defeated party and the holders of any of their securities.

The American Mutoscope and Biograph Company had outstanding a bond issue of $200,000. Some of the bonds were held by the Empire Trust Company of New York, who took notice of the success of our suit for injunction and damages against the Biograph Company.

Among the stockholders of the Empire Trust was J. J. Kennedy, a very distinguished consulting engineer as well as a man of rare business ability, who was requested by the Empire Trust Company to study the motion picture patent and commercial situation and work out a plan that would help the Biograph Company and their bondholders out of their difficulties. Mr. Kennedy got in touch with Mr. H. N. Marvin, also an engineer of distinction and an inventor, who was the president and general manager of the Mutoscope and Biograph Company. Together Mr. Kennedy and Mr. Marvin, after holding consultations with all interested parties, formed a stock company to take over all the valuable patents in the art, the stock to be distributed to the patent owners. It was a closed corporation, the stock was placed in escrow, and none of it was sold.

This holding company was called the Motion Picture Patents Co., and the principal beneficiaries were the Edison Company, the Biograph company, and the Armat Moving Pictures Company. I owned most of the stock in the latter. The Motion Pictures Patents Company was an immediate success. The royalties that it collected put no burden upon the industry but resulted in a large net revenue to the Patents Company. A royalty of half a cent a foot was paid by the producers, and a royalty of two dollars a week was paid by the exhibitors to the Patents Company.

At the date of the organization of the Patents Company there were in this country between ten and twelve thousand small theaters, or *Nickleodeons*, as they were called. The royalty of two dollars a week was an entirely negligible sum to them, but, as it was collected without cost to the Patents Company by the simple expedient of having the distributors add two dollars a week to their weekly film rentals, it amounted to a practically net revenue of between $20,000 and $24,000 a week. The revenue of half a cent a foot as film royalties also amounted to a handsome total. Unfortunately for the stockholders of the Patents Company, as the Motion Picture Patents Company came to be known, its life was rather a short one.

Some of the producers, for reasons that I have never quite understood, were refused licenses by the Patents Company. These producers, calling themselves "Independents," formed an organization and put up an all-around fight. At that date anything that smacked of being a monopoly or trust was very unpopular with the public and the courts.

The Independents charged the Patents Company with being an unlawful monopoly under the Sherman Anti-Trust law, and instigated a suit by the Government against them on that ground. In a decision by Judge Dickinson it was held in substance, as I recall it, that while a patentee had a legitimate monopoly within his patent claims, he could not, under the Sherman act, lawfully combine his patent with other patents, and the Patents Company was ordered dissolved.

I have always felt that Judge Dickinson was influenced in his judgment by the fact that the Edison Company (under the domination of Gilmore) had sold thousands of projection machines without restrictions as to their use, in some instances guaranteeing the right to their use, and, later, through the Patents Company, participated in royalties collected for their use.

Judge Dickinson said, "Every theater was required to pay royalties for the use of projection machines, even where the machine had been owned before the combination was formed." He appeared to overlook, or to ignore, the fact that the machines had been sold without license or other authority from the owners of the projection machine patents.

I have always felt that the Patents Company, instead of being an organization in restraint of trade, the thing that the Sherman law was designed to prohibit, was in effect an organization to facilitate trade; for the reason that prior to the date of the Patents Company's acquiring the right to grant licenses, under all the controlling patents, no producer or exhibitor could do a legitimate business—that is, a business that did not infringe one or more patents—and the fear of running counter to the patent laws could certainly have had a deterrent effect upon the business of all except those piratically inclined.

Many erroneous statements have been made and published as to when and by whom the first motion picture projection machine was made. To clarify the facts I have been asked several times to list the more or less basic inventions upon which the motion picture industry was initially established, as shown by U. S. Patent Office records. I have been regarded as qualified to do so because of my own pioneer inventions in the art and my connection with the beginning of the industry founded upon them. Subsequently to this early experience I was called upon to testify, as an expert in the art, in litigation under my patents, and later under the Edison and other patents owned by the Patents Company.

There have been a great variety of motion picture projectors, produced under different names, that vary as to their mechanical details but embody all the inventions that may be called basic—basic in the sense that they are necessary for successful projection and have been used since the beginning or near the beginning and are still being used. The following is my list of the eight most important inventions in the motion picture art:

(1) The Edison camera: Patent No. 589,168, dated Aug. 31, 1897. Filed Aug. 24, 1891. This was the first camera employing a perforated film which was given an intermittent motion so that a given number of perforations and a given number of pictures would be intermittently moved, rather than a given length of film. The result was a film having equally spaced, juxtaposed pictures throughout its length. The first practicable motion picture camera ever produced.

(2) The Edison motion picture film: Patent Reissue No. 12,038, Sept. 30, 1902. Filed Aug. 24, 1891. The first perforated motion picture film ever produced having equally spaced, juxtaposed pictures, necessary to successful motion picture projection and an essential part of every motion picture projector in use the world over today. This Edison film when first made some time prior to 1891 was $1^3/_8$ inch wide over all, contained four perforations to each picture, the picture itself being 1 inch wide by $^3/_4$ inch high. The number of perforations per picture and the film dimensions have not been changed in standard size machines since they were first made by Edison some time prior to 1891.

(3) The Edison peep-hole kinetoscope: Patent 493,426, dated March 14, 1893. Filed Aug. 24, 1891. This was the first motion picture exhibiting machine employing a perforated film with equally spaced, juxtaposed pictures. The first practicable motion picture exhibiting machine of *any* kind, but incapable of projecting pictures successfully because it gave the film a continuous motion instead of an intermittent motion.

(4) The Jenkins and Armat intermittent motion projection machine: Patent No. 586,953, dated July 20, 1897. Filed Aug. 28, 1895. The first motion picture projection machine giving the pictures an intermittent motion with a long period of rest and exposure. A mechanical failure, it nevertheless demonstrated the necessity and value of long exposure, essential to successful projection.

(5) The Vitascope: Invented and patented by Thomas Armat, Patent No. 673,992, dated May 14, 1901. Filed February 19, 1896. The first projection machine employing a loop-forming means and the first projection machine embodying a practicable intermittent movement giving the pictures the required long period of rest and exposure. A loop-forming means is essential in projection machines employing a long length of film.

(6) The star-wheel intermittent movement: Invented and patented by

Thomas Armat. Patent No. 578,185, dated March 2, 1897. Filed September 25, 1896. By means of this intermittent movement a small sprocket carrying the film could be given a gradually accelerated intermittent movement without film wear and tear and without jar to the mechanism. This movement superseded all others by 1897, and has been continuously used up to date. The intermittent movement is called the "heart" of the projecting machine.

(7) The Albert E. Smith framing device: Patent 673,329, dated April 30, 1901. Filed March 15, 1900. This device frames the pictures while the machine is running, and is a practically essential device.

(8) The John A. Pross shutter: Patent 722,382, dated March 10, 1903. Filed January 19, 1903. An important improvement for reducing scintillation or flicker. Not so essential in the earlier days of 1895 and 1896 when Edison films were the only ones obtainable, since these films were taken at approximately forty per second, but quite essential with pictures taken at the later commercial lower rates.

The foregoing is a complete list of the pioneer inventions covering all the essentials of the motion picture camera, the motion picture film, and the motion picture projector, and they are all in universal use today in the most modern and up-to-date equipment. The addition of color and of sound accompaniment belong to a later period.

For the possible benefit of those who have not investigated the matter, I believe it might be well to point out some of the differences between a camera and a projection machine, from the patent and invention standpoint. These differences were pointed out by me in the Patent Office interference in which my Vitascope patent, No. 5 on the list, was involved. I am not an attorney, but my familiarity with the art and its requirements enabled me to conduct this case successfully myself, preparing the brief and arguing the case personally before the several tribunals of the Patent Office and the Court of Appeals of the District of Columbia, all of which tribunals accepted my views and decided in my favor. In taking a picture of an object in motion it is essential to make the exposure of the image on the sensitive film as short as possible, consistent with the sensitiveness of the film, for the reason that if this is not done there will be time for the image of the moving object to be displaced on the sensitive film, causing a blurred or indistinct picture. In an exhibiting apparatus the reverse is true. There is, in the exhibiting apparatus, a picture fixed beyond the possibility of any such image movement's causing blur, and the longer the picture is exposed to the eye, the better the results. In a camera we are dealing with a moving object and a sensitive film. In an exhibiting apparatus we are dealing with a fixed picture and the human eye. No question of flicker or scintillation enters into the problem of taking pictures. That question enters very extensively into the problem of exhibiting pictures.

In a camera, the sensitive film does not coöperate with the mechanism to produce a complete or final result. The film has to be taken out and developed and printed before the operation is complete. The film is run through the camera but once. The Patent Office and the Courts held that the film is no more a part of a camera than the paper is of a printing press. In an exhibition machine the film with pictures on it is an essential part of the apparatus. It is a part of the mechanism which coöperates with the other parts to produce the complete and final results. In an exhibition machine the film is used over and over again in the apparatus and has to be so used whenever the apparatus is used. In passing upon this question the Patent Office had this to say:

"If Latham with his Exhibit Machine No. 12, and Casler with his Exhibit First Machine, both of which were taking cameras, could, without invention, have produced a machine of the construction called for by the issue, it is remarkable that they did not do so at any proven date before the filing of their application.

The evidence shows that neither Latham nor Casler was an ordinary mechanic but that they were inventors of considerable capacity, and yet neither of them produced a machine having the new and beneficial results which are claimed for the machine described in Armat's application."

The Patent Office said further:

"In our opinion, proof of the existence of a camera for taking pictures of an object in motion, said camera having in combination with a sensitive film, mechanism for giving the film an intermittent motion in which the periods of pause exceed the period of motion, said mechanism comprising in addition the other elements called for by the issue and a shutter, is not a reduction to practice of this issue; unless there is proof to show that when this camera was used for projecting the shutter was either omitted altogether, or was so adjusted as to provide for such relative periods of pause and illumination and periods of motion as are called for by the issue."

OVERCOMING LIMITATIONS TO LEARNING WITH THE SOUND MOTION PICTURE*

V. C. ARNSPIGER**

Summary.—*Although many limitations to learning have been overcome by the inventions of such tools as the telescope and the microscope, education has had, to a large extent, to depend upon the printed word. The introduction of the sound motion picture, in numerous forms and combinations, makes available for education the benefits of all such tools, including the advantages of slow-motion, time-lapse, and animated cinematography, and sound recording and amplifying devices. The educator is thus enabled to transcend many obstacles in the way of presenting and clarifying abstract concepts.*

There are certain limitations to human learning which have seriously restricted the development of school curricula from the kindergarten to the post-graduate level of instruction. Outstanding of these limitations are: the difficulty with which the individual acquires concepts which depend almost wholly upon verbalism for their presentation; his inability to perceive certain movements in nature because of the rapidity or slowness with which they occur; his inability to see objects which, because of their extremely small size or because of their great distance in space, are beyond the range of the unaided human eye; his inability to hear sounds which, because of their extremely small volume or because of their great distance from the hearer, are beyond the limits of unaided perception; and his inability to reach backward into the past and reproduce objects and actions which contribute to the conditioning of his present environment.

These rather obvious limitations have to some extent been overcome by mechanical means which have been developed in the course of scientific research during the nineteenth and twentieth centuries. The modern telescope has enabled the individual to make excursions into space which until recently were impossible. The microscope has brought into the range of human vision objects which, without

* Presented at the Spring, 1934, Meeting at Atlantic City, N. J.

** Erpi Picture Consultants, New York, N. Y.

its assistance, would have been forever beyond perception. The motion picture camera has extended the arm of the interpretive artist so that for a good many years he has been able to record, for the eyes of the future, objects in action which hitherto would have passed into unreality to be reproduced only by means of indefinite forms of verbalism. The slow-motion and time-lapse devices which have been added to this instrument have contributed to the clarification of many concepts which in the past were beyond the perception of the individual learner. Modern sound recording, amplifying, and transmitting devices have made many significant and fundamental contributions upon which the reality of concepts depends.

Although these products of modern invention have been available, some of them, for many years, education has to a great degree continued to depend largely upon the printed word for the transfer of ideas. This dependence upon the product of the printing press has resulted in many restrictions in the scope and range of the curriculum. The aims and objectives of education have been established sometimes with, and often without, a conscious realization of these restrictions imposed by this mechanical invention. A glance into the activities of the traditional primary school will reveal the nature of these restrictions. At the time of his entrance into the school, the normal pupil has during the first five or six years of his life already attained a rather profound mastery of several tools of learning in the form of the five senses. Through the use of these tools, learning from his immediate environment has proceeded at a very rapid rate. By the time he starts to school, however, the returns from his immediate environment have begun to diminish. In order for full development to continue, a significant elaboration of this environment must be furnished. This elaboration of environment is one of the responsibilities which the school must assume. It is generally true that this institution is so organized that it is literally forced to await the mastery of additional tools of learning before it can proceed at a very rapid rate toward the fulfillment of this responsibility. It is needless to recall the emphasis which at present is placed upon these "tool subjects"—reading, writing, and arithmetic—of the traditional elementary school curriculum. By far the most important of these is reading. Many concepts which are fundamental to the future elaboration of the pupil's environment he can not acquire with the optimal degree of mastery through the use of this "tool" because of the complexity of certain mental processes which learning through reading presupposes.

The sound picture has at its disposal, in numerous desirable combinations, the inherent advantages of the telescope, the microscope, the motion picture camera (with its many devices such as slow-motion, time-lapse photography, and animation), and sound recording and amplifying devices. Clarification of concepts through this medium is not necessarily dependent upon the "tool subjects" of the curriculum. Thus, the sound picture holds out to those responsible for the construction of the curriculum a unique challenge.

This challenge can be met by the application of instruments of research, many of which are now available, some of which have yet to be developed. What effect, if any, will the use of these mechanical devices have upon the mastery of the time-honored "tool subjects" of the present curriculum? Are there objectives of education which are withheld until the later years of school life solely because of this dependence upon the mastery of concepts which are too "difficult" to present through reading? Can certain objectives be attained with the aid of these products of modern invention? Can much time of the school be saved and energy of teachers conserved for more important duties?

It is possible that the answers to these questions would release the curriculum specialist from many of the restrictive influences which are inherent in the present methods of subject matter presentation, to the end that the extension of the curriculum would be determined not by the present limitations to learning, but by the needs of the race.

During the past few years films have been produced which were designed to transcend the obstacles to learning in a manner not possible by means of traditional methods of instruction. The educational sound-film *Fundamentals of Acoustics* demonstrates these facts more impressively than would be possible by talking about the problem in an abstract way. In this film abstract phenomena are visualized—intangible phenomena that can not be perceived by means of the visual senses; such as, for example, the movement of sound-waves through the air. By means of animation it is possible to represent the sound-waves visually and in motion, with their characteristics under various conditions. In the traditional methods of instruction, such phenomena were generally taught by reading and lectures. The student's comprehension of the concepts involved depended to a very large degree upon his comprehension of the printed page. In reducing these abstract and difficult concepts to a sound-film, the student is enabled to comprehend them irrespective of his reading ability. His progress is then determined solely by his innate mental ability.

During the past few decades, the older subjects have become fairly well established at certain grade levels in the school curriculum. For example, physics is usually first taught in the junior or senior year of the high-school. This is largely due to the fact that it was supposed and probably rightly, with prevailing methods of instruction, that this subject could not be properly comprehended at a lower level. But through a medium such as the sound-film, in which abstract and intangible concepts can be made, in effect, concrete, it is now possible to present them at a much lower level, possibly even in the advanced grades of the elementary school.

The film *Fundamentals of Acoustics* reproduces certain sound effects and demonstrates the alteration of speech and music by limiting the frequency range or by attenuation and change in the quality of sound. Demonstrations such as these are difficult, and in most high-schools impossible, due to limitations of equipment and the tremendous cost that would be involved—referring particularly to such scenes as those dealing with reverberation in different kinds of rooms; the limitation of the frequency range; echoes; and outdoor attenuation. Attention is also called to the possibility of visualizing invisible phenomena, which is well illustrated in this film by an authentic sequence on the functioning of the human ear. Finally one of the most important contributions resulting from the use of such films in school instruction should be emphasized—the number of concepts that can be presented in the mere span of ten minutes. As a result, the concepts become closely integrated, and the relationships of one to the other become self-evident.

A ROLLER DEVELOPING RACK FOR CONTINUOUSLY MOVING THE FILM DURING PROCESSING BY THE RACK-AND-TANK SYSTEM*

C. E. IVES**

Summary.—*In order to obtain machine type development in the rack process, a rack has been devised by means of which the film is moved continuously over rollers during processing. The film traces a helical path passing over rollers carried by an upper and a lower shaft, and is then led back along the bottom of the rack where a closed loop is completed by splicing the ends together.*

The film is propelled by rotation of the upper shaft and rollers which, in turn, are driven by a motor and a reduction gear. The lower shaft is allowed a slight parallel displacement in the vertical direction to compensate for changes in the length of the film which occur when it is wetted.

A rewind and roll holder are mounted upon a removal plate for use in loading and unloading film or leader, and the film is removed to a reel for drying. A wide variety of processing conditions have been met successfully in processing sound and picture negatives and prints.

Continuous machines now in almost universal use for processing motion picture film in the larger laboratories are, for many reasons, poorly adapted to experimental work. The time of treatment allotted for any stage of the process can usually be varied only slightly, while the processing solutions which are ordinarily supplied from a recirculating system containing a large volume of liquid can not be changed readily. Consequently, the execution of an experimental procedure requiring the use of new processing solutions and any considerable variation in the time of treatment is slow and extremely costly.

When developing by the rack-and-tank method,[1] the degree of uniformity of development is not satisfactory for precision sound recording owing to the formation of rack marks,[2] but it was considered that if the film could be moved continuously, a degree of uniformity could be attained comparable to that attainable with com-

* Presented at the Fall, 1934, Meeting at New York, N. Y. Communication No. 539 from the Kodak Research Laboratories.

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

mercial processing machines. Accordingly, a roller rack was constructed which was capable of moving a 200-foot length of film continuously, as in the usual developing machine, but which was portable and could be used in conjunction with the tanks of the type used in the rack developing process.

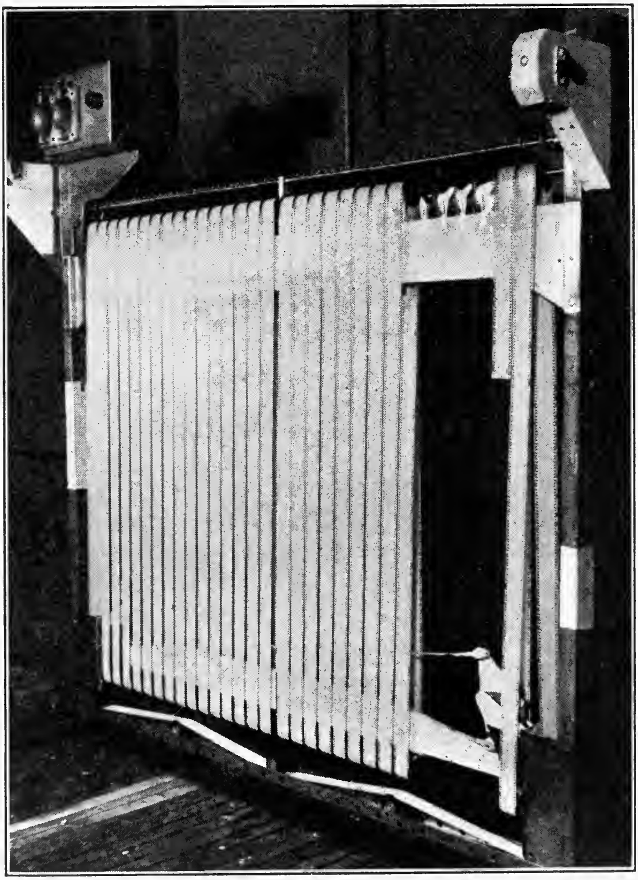

Fig. 1. The roller developing rack threaded with film.

Although a rack capable of handling film in the manner described must have parts which function similarly to the corresponding parts of a continuous developing machine, the literature reveals no attempts to use such a device for this purpose. A rack described by Crabtree[1,2] was equipped with rollers to permit a slow movement of the film backward and forward through a distance of a few feet for the purpose of eliminating the sharply defined rack markings which otherwise occurred where the film rested against the upper and lower cross bars, but the type of treatment afforded by continuous rapid motion of the film as in a developing machine was not attained.

The Film Path.—In studying possible paths for the film on the rack, the arrangement commonly used in the rack-and-tank process, as well as in developing machines, was chosen. The film is carried in a spiral or helical path over a succession of rollers at the top and bottom of the rack, the upper and lower rollers each having a common shaft. In order that a 200-foot length of film may be allowed to move continuously in one direction, it must form a closed loop when threaded on the rack. This requires a path for returning the film to the starting point after it has traversed the rack. The arrangement shown in Figs. 1 and 2 by which the return path is located along the bottom of the rack, was finally chosen. Thus, starting at one end, the film reaches the other end of the rack by following a helical path, turning around rollers along the top and bottom, leaves the last upper roller to go to the lower corner of the rack while making a quarter turn, traverses the length of the rack on the supporting rollers along the bottom, and then after making another quarter turn arrives at the starting point.

Since the film increases in length slightly when it is wetted, provision was made for automatically increasing the length of the loops to the extent of $1^1/_4$ inches. Various materials, as for example, coated film and uncoated leader, expand in various degrees, and for this reason it is not sufficient that the lower shaft be free to rise and fall, but it must do so in such a manner as to redistribute the slack created locally by this differential expansion. This is accomplished by compelling the lower shaft to remain parallel to the upper shaft while it moves up and down. If parallelism is maintained, then any slack which appears while the film is running is immediately redistributed, because the shorter strands receive the full weight of the lower shaft. If, on the contrary, the lower shaft were allowed to tip, any slack or excess tension appearing at one end would be accommodated by tilting of the shaft, whereupon some of the remaining loops would hang clear of the roller flanges and become overlapped.

One of the simplest ways of maintaining the lower shaft parallel to the upper in its vertical motion is probably that sometimes employed in developing machines. It consists in including the lower shaft in an approximately square rigid frame which slides along the side members of the rack structure, as on rails. This type of guide is not so well suited to a rack which is long in the horizontal direction because it requires large heavy parts to maintain the necessary rigidity in the guiding members. Therefore, this scheme was discarded in favor of a device which relies on two evener plates connected to the ends of the lower shaft assembly by short rigid links and to each other by $^1/_{16}$-inch stainless steel* wires. Other methods of effecting this parallel motion are dealt with later.

In order to support the paralleling mechanism and guide the lower shaft in its vertical motion, a supporting structure was provided at both lower corners of the rack, and space was left for the vertical return path of the film between the side members of this structure.

The Motor Drive.—Although a large stationary drive would be more advantageous for use with a number of racks, it was decided to mount an individual drive on this experimental unit. The motor ($^1/_{20}$th-hp.) and reduction gear (1:10) are contained in a stainless steel box at one end of the rack, above the upper shaft. The repulsion-induction motor running at 1725 rpm. drives the reduction gear through a *V*-belt running over pulleys chosen to give a linear speed of film travel of 85 feet per minute. The upper shaft is driven from the reduction gear by a $^1/_8$-inch, $^1/_2$-inch pitch stainless steel roller chain and 7-tooth stainless steel sprockets (1 to 1). Some advantage might be gained by the use of a suitable motor with built-in reduction gear, but materials available on the market at the time were used.

The housing was used to shield the drive from corrosive liquids and the film from oil and corrosion products. Since the housing hinders the dissipation of heat from the motor, connections are provided so that compressed air can be used for cooling after long runs. Inasmuch as the upper rollers are completely immersed during processing, the chain carries along appreciable quantities of the processing solutions, and in order to protect the interior of the drive housing, the reduction-gear shaft was supplied with a splashproof fitting where it passed through the end wall. As shown in Fig. 2, this consists

* The expression "stainless steel" is used to signify alloy steels containing chromium and nickel in the proportion of, roughly, 18 per cent chromium and 8 per cent nickel, and sometimes described as "super-stainless steels." This is the only metal used for parts of the rack proper.

of a flanged extension cap of stainless steel which, with the sprocket at the outside, makes a splashproof closure.

The Rack Frame.—Although the drive elements are far from oversize for the work, their weight, in addition to that of the other necessary parts, is sufficient to cause the rack frame to bend somewhat during handling. A frame stiff enough to resist the force of this weight would be too heavy to be handled readily.

With this realization, the uprights and upper beam (Fig. 2) were made of wood, and the bracket, corner gussets, and the channel at the bottom were of stainless steel to save weight, where practicable, and still maintain a reasonable degree of rigidity. Attachments at the top for suspending the rack in the processing tanks allowed it to hang free of strain during processing.

Shaft Bearing and Roller Assembly.—In order to avoid misalignment of the upper roller shaft and the wiper shaft in their respective bearings, self-aligning bearings were adopted by the use of free-fitting pins and a spring spider, as shown in the detail of Fig. 2. The bearing at the middle of the shaft is given a large clearance.

This problem does not arise in connection with the lower shaft, which is held rigidly in line by its own beam with which it floats practically free of the rack frame, as regards distortion.

Although the film is driven by virtue of the rotation of the upper shaft and rollers, a certain amount of differential motion among both upper and lower rollers is necessary to assist in the redistribution of slack when a difference in length exists in the strands at different parts of the rack. This freedom to turn is allowed to two out of every three rollers. The type of roller shown in Fig. 2 has only one flange for economy of space. On the upper shaft the spacing is regulated by fastening every third roller by means of a stainless steel set-screw; the spacing requires checking occasionally. It will be noticed that the rollers are separated into two groups by the middle rack bearing, at which point a single flange is added to each group to complete the last roller. The shaft is secured in position with respect to the axial direction by a collar at one end and the drive sprocket at the other, both of which rest against the end shaft bearings.

Some difficulty was expected at points where a stainless steel shaft ran in stainless steel bearings without lubricant, although at the slow speed of operation and with ample bearing clearances it was not believed that the bearings would seize. When operated dry, even at moderate speeds, the bearings were found to be scored and it was necessary to refinish them. At this point the practice of lubricating with a small drop of liquid soap whenever bearings were run dry was commenced. This dry condition was found only when the rack had not been in use for processing for several hours. No further trouble has since appeared. Recently it has been found that

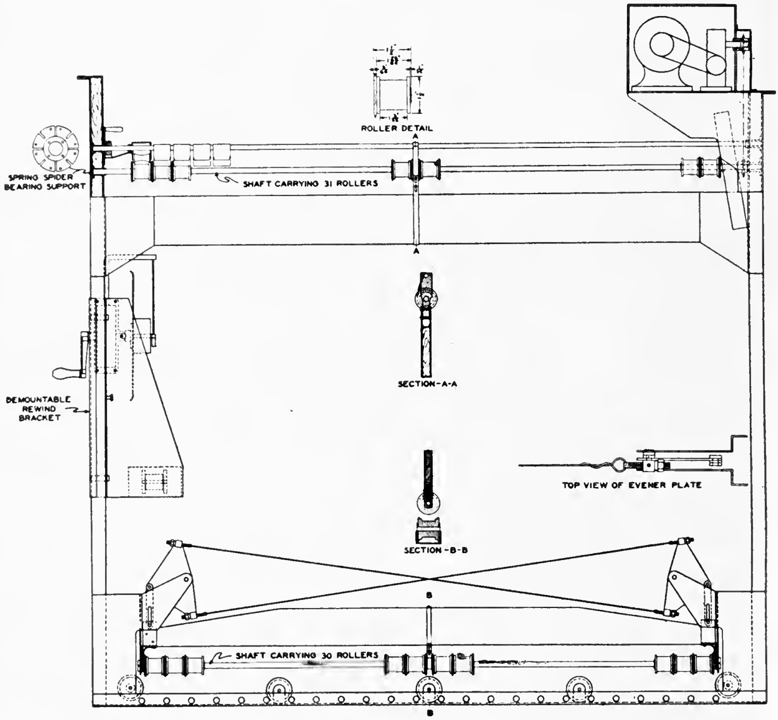

Fig. 2. Assembly drawing of roller rack.

synthetic resin compositions gave satisfaction when inserted as bushings in similar service.

The lower roller shaft is maintained rigidly in line by the use of a stainless steel beam which at the same time supplies, by its weight (15 pounds), the necessary tension on the loops. While this weight is undesirably large, it is necessary in order to overcome friction in the evener and to maintain sufficient tension while the rack is being lowered into the liquid. All rollers on this shaft are free to turn, the shaft remaining stationary at all times. In order to prevent excessive spacing between the rollers, a spring was placed at either end of the shaft. This spring is rather short and is shaped in such a way that only a very light force is applied when the roller stack-up clearance is taken out, but a much greater force as soon as the rollers move apart. Thus, under normal conditions, frictional resistance where the rollers come together is very slight. These special provisions for maintenance of exact spacing are necessary only in the case of rollers which have a flange at one side only. With such rollers, excessive spacing permits the film to run out of position to such an extent that the roller treads are in contact with the portion of the film opposite the picture or sound-track. This danger is obviated by the use of rollers having double flanges which, however, require appreciably more space. If the lower shaft were not kept parallel to the upper by the evener, this simple means would be inadequate for maintaining proper spacing.

The Evener.—The action of the evener is as follows: Referring to the drawing (Fig. 2) and the close-up view (Fig. 3), it will be seen that the extremities of the lower shaft assembly are connected to the triangular evener plates by links, the evener plates being mounted so that they rotate about a pin carried by side members from the frame. On each plate and equidistant from the center of gyration are attached swivels to which are fastened crossed tension wires from the other plate.

If force is applied to raise the right-hand end of the shaft assembly, the link is put under pressure, causing the right-hand plate to rotate in a counter-clockwise direction. This results in tension in the wire attached at the bottom of this plate which, in turn, causes tension to be applied at the top of the plate on the opposite end of the rack, thereby producing clockwise rotation, tension in the link at that end, and elevation of the shaft assembly. The other possibilities are obvious.

Lower Shaft Assembly Guide.—In order to make the film loops as long as possible, the lower shaft is located below its beam, with the result that the assembly is somewhat top-heavy. In order to maintain correct vertical alignment, the end of the beam is held in a clip lying between the evener supporting members (see detail in Fig. 2) which are shaped in such a way as to form guides at this point. In addition, a prolongation of the roller shaft at either end is fitted with a collar which travels between guides (Fig. 3).

Vertical motion is limited by means of the connecting link wristpin which is extended at both sides to pass through slots in the side plates. Swinging of the assembly in the direction parallel to the shaft axis is also prevented by this pin. Clearances at all these points are such as to prevent any interference with the necessary movement of this assembly by a distortion of the frame which might occur in normal use.

Method of Use.—The rack is prepared for use by completely threading the film path with leader, which also remains upon the rack when it is not in use. When film is to be loaded, a plate bearing the feed stock and rewind is mounted on the rack, as shown in Fig. 4. The end of the film to be processed is attached to one end of the leader

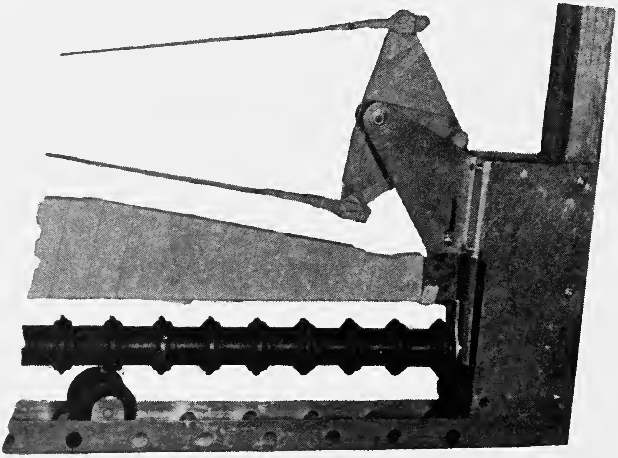

Fig. 3. Close-up of evener mechanism.

by means of the mechanical splicer, while the other end of the leader is led to the rewind. The motor is started and leader is run off as the film is led onto the rack. During the loading operation a tension is maintained at the rewind and feed roll so that the lower shaft assembly is kept near the upper limit of its range. When all the film is transferred (215 feet max. length), the leader is cut off at the rewind and spliced to the end of the film. The motor is run again for a moment to redistribute any slack.

The rack is then placed in the developer by two men who grasp it by the upright ends (Fig. 5). The motor is started as soon as the film is fully immersed, and is not stopped until the instant the rack is to be removed from the developer. Immediately after the rack is first placed in the developer, the sheet-rubber wiping pads are brought down to the position shown in Fig. 6, where they sweep off any airbells which may have become attached to the film during immersion of the rack. At the end of one-half minute the wiper shaft is rotated by means of the small crank, bringing the wipers to the position shown in Fig. 2, where it is locked by the spring catch visible below the crank. When the end of the development time is reached, the motor is stopped and the rack is transferred to the fixing bath, following a definitely timed sequence of movements. The film is kept in motion during fixation and during part of the washing operation.

FIG. 4. View of the demountable feed stock and rewind as used in threading the rack.

Processing operations are timed by means of an electrically driven darkroom clock. The duration of any treatment may be as long as desired, but a development time of less than 1 minute requires a degree of precision in timing the transfer operation which is difficult to attain.

Running speeds of 40 and 85 feet per minute have been attained by changing two pulleys in the drive.

Drying.—The film is transferred to a reel for drying in the manner illustrated in Fig. 7, loose water being removed by means of the pneumatic squeegee.[3] This operation is somewhat different from the loading process. Inasmuch as the leaving strand is not under tension, it is found desirable to diminish resistance on the incoming strand by unthreading the return path at the bottom of the rack so that leader is drawn directly to the last lower roller as shown. At this time the small soft-rubber guide roller is brought down to the position shown in Fig. 6 to increase the traction on the film drive roller. The frame supporting the guide roller rotates freely about the wiper shaft between two collars. It is held either in the operating position or vertically upward by the flat spring shown in Fig. 6.

Before using the rack again, loose water is removed by the application of a blast of compressed air to the rollers.

Uniformity of Development.—The rack was found capable of producing very uniform development when operated at 85 feet per minute. In order to attain the highest degree of uniformity, a compressed-air agitator was placed in the developing tank during processing. This produced a worthwhile improvement in uniformity but caused ex-

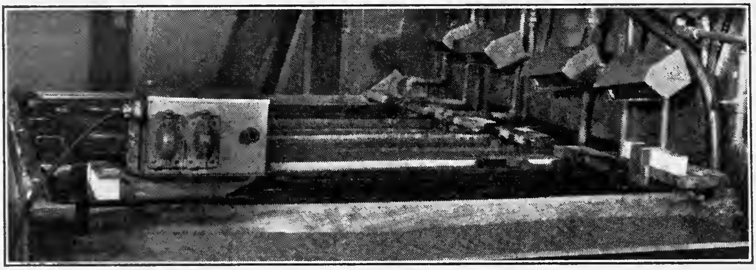

Fig. 5. The rack in operating position in the developing tank.

cessive scratching of the film base by making it run against the stationary parts of the rack within the film loops. Various remedies were tried. One consisted in stretching sheets of dental-dam rubber over these parts but was unsuccessful because the wet film and rubber adhered so strongly when the rack was out in the air that the rack could not be unloaded. A solution was found in the use of Kodatape as a cover for all these surfaces, except for a small area where application of the rubber was more convenient and caused no interference.

A desirable form of compressed-air distributing device consists of astainless steel pipe resting upon the bottom of the tank, drilled to provide outlets at regular intervals. In order to attain good distribution of air or other gas it is necessary to make holes just large enough to deliver the correct volume of air at the working pressure. If the holes are too large the distribution is uneven, and if too small, they are easily obstructed. A better method of securing good distribution of air at varying pressures is to cover the pipe with a loosely fitting rubber tubing fastened at either end by a wire clamp and perforated with nail holes at frequent intervals. Since the holes in the rubber adjust themselves to the flow of air and do not become clogged with sediment, it is thus possible to use large holes in the pipe.

The uniformity of density of a flashed film processed on the roller rack was found to be equal to that obtained by the best available continuous machine processing.

A technic has been devised for processing the necessary H&D strips for a time-gamma determination in a single run, and then in a subsequent run obtaining a check of any desired point on the time-gamma curve.

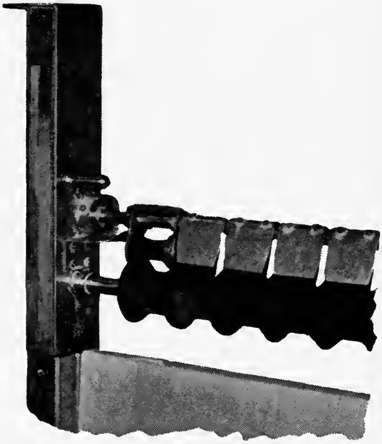

FIG. 6. Close-up of upper shaft wiping device, and guide roller.

Table I shows typical data chosen at random from the results of individual runs made with a number of different emulsions and developers. It is seen that the gammas obtained were, for the most part, within ±3 per cent of the required values. In one case where the developing time was only 1 minute and 25 seconds, the error was greater than this, which is an indication of the difficulty of accurately timing the manipulation of the rack in transferring from the developer to the fixing bath. The wide variety of conditions met may be judged by the fact that the gammas ranged from 0.52 to 3.08 with times of development of 1 minute 25 seconds to 15 minutes. The degree of accuracy indicated is likewise attained in duplicate runs.

The rack has been used successfully for both picture and sound records with various emulsions and developers.

Replenishing.—A replenishing solution described previously[4] was used successfully for maintaining the activity of the developer. It was added at the rate of one-half gallon of double-strength replenisher to a 75-gallon tank for every 8 minutes of development with air agitation. The rate of replenishing was apparently governed largely by the action of the air used in agitating the developer, since it was based successfully upon the time of treatment instead of upon the footage developed.

Alternative Methods of Obtaining Parallel Motion.—A number of alternative mechanisms for producing a parallel motion of the lower shaft assembly have been considered as follows:

(*a*) It is evident by reference to Fig. 8(*B*) that if the evener plates were cut in the form of circles so as to function as pulleys for the

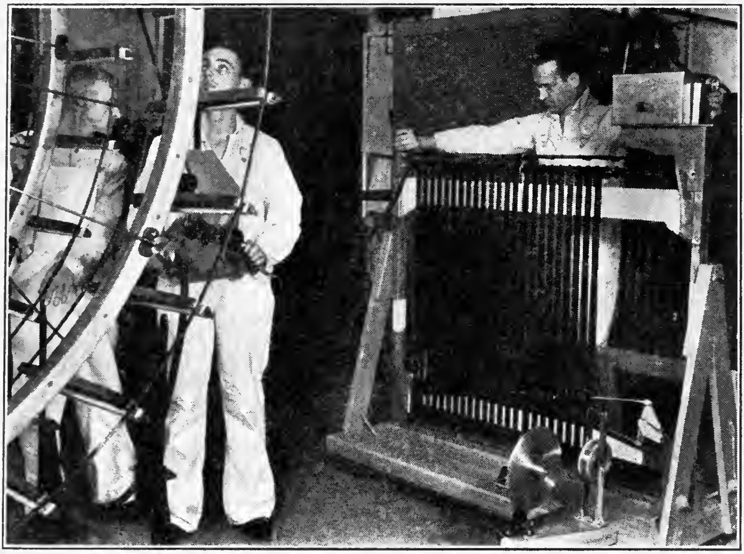

FIG. 7. Method of transferring the film to the drying reel.

wire, more latitude would exist in the choice of proportions for the plates.

(*b*) Fig. 8(*C*) illustrates a hydraulic evener consisting of metallic bellows at either end of the lower shaft with cross-connected piping. Such an arrangement would eliminate frictional resistance almost entirely. Tension in the loops could be maintained by the use of an additional bellows at the center of the beam connected with the water or compressed air line, thus eliminating the need for much of the weight in the beam. A valve in the pipe leading to this bellows could be used conveniently to lock the lower shaft assembly in position while the rack was being moved from one tank to another.

TABLE I

Data from Individual Runs Following the Indications of Gamma-Time Curves

Gamma Required	Time of Development from Curve	Gamma Obtained
0.52	9 Min. 15 Sec.	0.52
0.60	2 Min. 50 Sec.	0.60
0.60	2 Min. 12 Sec.	0.61
0.60	2 Min. 35 Sec.	0.60
0.60	2 Min. 33 Sec.	0.58
0.60	2 Min. 36 Sec.	0.60
0.60	2 Min. 6 Sec.	0.60
0.65	4 Min. 30 Sec.	0.64
0.65	8 Min. 15 Sec.	0.64
1.3	2 Min. 10 Sec.	1.27
1.5	2 Min. 40 Sec.	1.51
1.5	2 Min. 30 Sec.	1.42
1.5	2 Min. 30 Sec.	1.47
1.5	6 Min. 30 Sec.	1.56
1.7	4 Min.	1.74
1.8	1 Min. 25 Sec.	1.94
1.8	4 Min.	1.90
2.0	4 Min.	2.05
2.0	4 Min.	1.98
2.0	4 Min.	2.01
2.0	4 Min.	2.00
2.0	4 Min.	1.97
2.0	3 Min. 48 Sec.	2.00
2.2	1 Min. 50 Sec.	2.26
2.3	15 Min.	2.27
2.4	5 Min.	2.45
2.4	15 Min.	2.49
2.5	8 Min. 30 Sec.	2.49
2.6	5 Min. 30 Sec.	2.65
3.0	5 Min.	3.00
3.0	8 Min.	3.08

(*c*) A device similar to that used on drafting boards, consisting of loops of wire or cable passing around pulleys and cross-connected to the two ends of the shaft assembly to be maintained in alignment.

(*d*) Other devices working on the rack-and-pinion principle were considered. In one arrangement the racks are secured to the developing rack frame and are shackled to small pinion gears on a shaft carried by the lower roller assembly. In another application of this principle, the long pinion gear shaft under torsion was eliminated by mounting small segments of large gears rotating on pins set in the beam associated with the lower roller shaft. These gear seg-

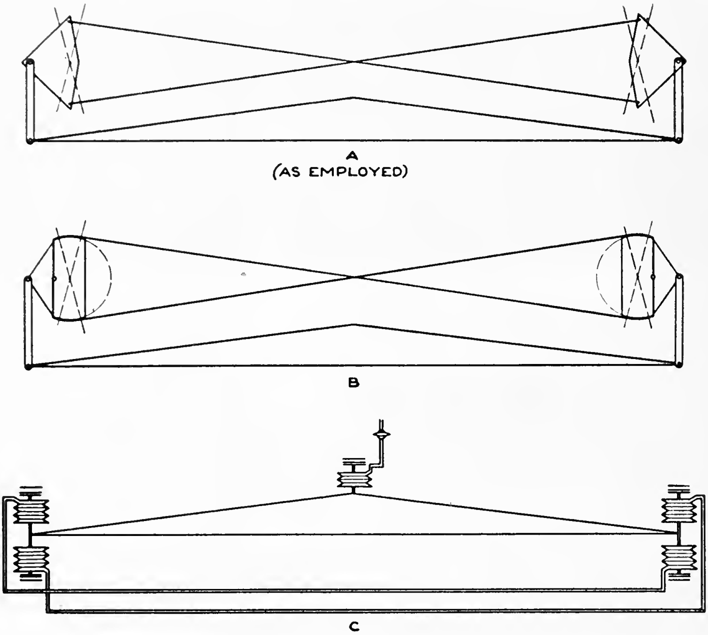

FIG. 8. Schematic drawing of evener mechanisms.

ments engage each other at the midpoint of the beam and mesh with the racks located at the ends of the main developing rack frame.

Acknowledgment.—Grateful acknowledgment is made of the assistance and suggestions given by Messrs. S. Forsyth and W. Bahler during the construction and testing of this apparatus.

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[2] CRABTREE, J. I., AND IVES, C. E.: "Rack Marks and Airbell Markings on Motion Picture Film," *Trans. Soc. Mot. Pict. Eng.* (Oct., 1925), No. 24, p. 95.

[3] CRABTREE, J. I., AND IVES, C. E.: "A Pneumatic Film Squeegee," *Trans. Soc. Mot. Pict. Eng.*, **XI** (Aug., 1927), No. 30, p. 270.

[4] CRABTREE, J. I., AND IVES, C. E.: "A Replenishing Solution for a Motion Picture Positive Film Developer," *J. Soc. Mot. Pict. Eng.*, **XV** (Nov., 1930), No. 5, p. 627.

WILLIAM VAN DOREN KELLEY

(*1876–1934*)

William Van Doren Kelley was born at Trenton, N. J., March 8, 1876. While a youngster in the Trenton schools, he exhibited a talent for invention and in addition, became interested in theatricals. Thus was laid the foundation for his later activities in the field of the motion picture. His ability as an inventor and his interest in the theater led him to stage acts of magic and illusion with the acumen and showmanship of a much older person.

While still young, "Bill" began to earn his living as a show-card and window-display artist. This activity led to a partnership in an advertising sign business with a brother, George Kelley, in Brooklyn, N. Y.

The history of their business was marked by the invention of many successful devices, among them being the "flashing light" type of sign introduced about 1910, which became very popular and made a good income for the company.

In the meantime, as funds became available from the profits of the business, Kelley devoted his spare time to working on a process for coloring motion pictures. He had first become interested in the problem after a trip with Joseph Mason to England for Biograph in 1910. Kelley's job at that time was to decorate and make attention-attracting devices for the Biograph showhouses in England, and he also worked with the Biograph camera. He realized the value that color would give to the films, and from then on his cherished dream was to invent a process for coloring motion pictures. Every spare cent and every moment not used for earning a livelihood was directed toward achieving this goal.

In 1913 he formed a company called "Panchromotion" for the development of an additive color process somewhat similar to the Kinemacolor of that time. In order to minimize color fringing, one of the deficiencies of such systems, he increased the number of pictures taken in a given unit of time. He also tried to improve the color rendition by using three and four colors in the color-wheel on the projector; the Kinemacolor used only two

The color experiments were conducted in the basement of a house at 1586 E. Seventeenth St., Brooklyn, N. Y. During this time a double-coated stock and a bleach formula which had much to do with the success of the later Prizma process were perfected. From Brooklyn the Panchromotion Company moved to quarters in a vacant garage in Jersey City, N. J. By this time, a certain measure of success had attended Kelley's endeavors, and Prizma Incorporated was formed with sufficient capital to undertake regular production.

Subsequently to 1916, Prizma sent cameramen with the Prizma filter-wheel cameras throughout the world to make travel and nature pictures. The negative films were returned and finished at the Prizma laboratory.

The first Prizma film was *Our Navy*, released in 1917 at the Forty-Fourth Street Theater in New York City, and also shown about the same time at the Strand Theater in that city. The color was produced by an additive process, using a color-wheel on the projector.

Kelley was not satisfied, however; he believed that the color could be applied directly to the film by a subtractive system. In order to carry out this idea, he entered a partnership with Carroll H. Dunning and Wilson Saulsbury, and a laboratory was opened at 205 W. Fortieth Street in New York City under the name "Kesdacolor."

Their first film made by the subtractive process was a picture of the American flag. In a length of fifty feet it was shown at the Roxy and Rialto at New York, on September 12, 1918.

Shortly after the success of this showing, Kelley returned to the Prizma Company, which was reorganized. Longer films were undertaken, and in 1919 a single-reel travel subject was subtractively colored.

J. Stuart Blackton of Vitagraph saw this picture and was so impressed that he decided to make a feature-length picture in Prizma color. *The Glorious Adventure* was released in April, 1922.

Kelley continued his researches far afield in a search for yet untried methods in color. In 1919 he produced a series of colored animated cartoons which were drawn by Pinto Colvig; in 1923 he developed a stereoscopic motion picture novelty in color; in 1924 he introduced Kelley-Color which was an imbibition process. In this last-named system, two colors were imbibed upon a black-and-white key image. In 1926 he became associated with Max Handscheigl in the formation of the Kelley-Color Company which was bought by Harris-Color in 1928. In 1929 Kelley started his experiments with the bi-pack negative method, which has since been widely used in making "process shots" and color-separation negatives.

During the last days of his life, Kelley was working upon a system in which the bi-pack negative films were cemented together before perforating, thus assuring better registration and a closer union of the two strips of film during the photographing. The cemented films were to remain cemented until after development.

W. V. D. KELLEY

The only medal ever issued by the Society of Motion Picture Engineers was presented to him on October 13, 1919, "for achievement in color motion pictures."

Kelley contributed many papers dealing with color photography to the *Transactions* of the Society, and served as chairman of the Color Committee for many years.

The Society and the industry sustained a great loss in Bill's passing.

W. E. THEISEN

SPRING, 1935, CONVENTION

SOCIETY OF MOTION PICTURE ENGINEERS

HOTEL ROOSEVELT, HOLLYWOOD, CALIF.
MAY 20–24, INCL.

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Headquarters

The headquarters of the Convention will be the Hotel Roosevelt, where excellent accommodations and Convention facilities are assured. Registration will begin at 9 A.M. Monday, May 20. A special suite will be provided for the ladies attending the convention. Rates for S. M. P. E. delegates, European plan, will be as follows:

Single: \$2.50 per day; one person, single bed.
Double: \$3.50 per day; two persons, double bed.
Double: \$4.50 per day; two persons, twin beds.
Suites: \$6.00 and \$8.00 per day.

Technical Sessions

An attractive program of technical papers and presentations is being arranged by the Papers Committee, laying special emphasis upon the developments in the technic, equipment, and practices of the studios. Several sessions will be held in the evening, to permit those to attend who would be otherwise engaged in the daytime. All sessions will be held at the Hotel.

Studio and Equipment Exhibit

The exhibit at this Convention will feature apparatus and equipment developed in the studios, in addition to the usual commercial equipment. All studios are urged to participate by exhibiting any particular equipment or devices they may have constructed or devised to suit their individual problems, conform to their particular operating conditions, or to achieve economies in production, facilitate their work, or improve their products.

Those desiring to participate should communicate with the General Office of the Society, Hotel Pennsylvania, New York, N. Y. No charge will be made for space. Each exhibitor should display a card carrying the name of the particular studio or manufacturer, and each piece of equipment should be plainly labeled. In addition, an expert should be in attendance who is capable of explaining the technical features of the exhibit to the Convention delegates.

Semi-Annual Banquet

The semi-annual banquet of the Society will be held at the Hotel on Wednesday, May 22. Addresses will be delivered by prominent members of the industry, followed by dancing and entertainment. Tables reserved for 8, 10, or 12 persons; tickets obtainable at the registration desk.

Studio Visits

S. M. P. E. delegates to the Convention have been courteously granted the privilege of visiting and inspecting the Warner Bros. First National Studio, the Fox Hill Studio of Fox Film Corp., and the Walt Disney Studio: admission by registration card only. A visit has also been arranged to the California Institute of Technology.

Motion Pictures

Passes will be available during the Convention to those registering, to Grauman's Chinese and Egyptian Theaters, Pantages', Hollywood Theater, Warner Bros.' Hollywood Theater, and Gore Bros.' Iris Theater.

Ladies' Program

An especially attractive program for the ladies attending the Convention is being arranged by Mrs. E. Huse, *hostess*, and her Ladies' Committee. A suite will be provided in the Hotel where the ladies will register and meet for the various events upon their program.

Further details of the Convention will be published in the next issue of the JOURNAL.

SOCIETY ANNOUNCEMENTS

PACIFIC COAST SECTION

The regular monthly meeting of the Section, held on January 31 at the Los Angeles Museum, was attended by almost a hundred members and guests. Through the courtesy of the Museum, not only the Motion Picture Exhibit, but also adjacent sections were opened to the members. Much favorable comment was expressed concerning the Motion Picture Exhibit and the efforts made by Mr. W. E. Theisen, *Honorary Curator* of the Exhibit and chairman of the Historical and Museum Committee of the S. M. P. E., in building it up.

Opening the meeting, Mr. G. F. Rackett, *Chairman* of the Section, first outlined the history and aims of the Society for the benefit of the guests, and then introduced Mr. Theisen, who presented an excellent talk on the history of motion pictures, beginning with references to the persistence of vision by the ancient writers. Carrying the subject through the many and varied devices developed throughout the years, the history terminated with the description of Edison's application of the motion picture film produced by George Eastman.

Following Mr. Theisen's talk, several pictures were shown illustrating the vast improvements in the art of depicting motion, and covering the span from 1898 to the present time. Included were three reels of Fairbank's *Robin Hood*, of 1921, and one of the most recent Technicolor "Silly Symphonies"—*The Tortoise and the Hare*, by courtesy of Walt Disney.

PROJECTION PRACTICE COMMITTEE

At a meeting held at the Paramount Building, New York, N. Y., January 23, the topics to be included in the Spring report of the Committee were discussed. In addition to other subjects, it is planned to include a revision of the report of August, 1931, containing the recommended arrangements for projection rooms, bringing it up to date and amending it wherever necessary in the light of recent developments and the experience of the past few years.

STANDARDS REPRINTS

Reprints of the Standards Adopted by the S. M. P. E. and Recommended Practice are now available in booklet form. They may be obtained from the General Office of the Society, at the price of twenty-five cents each.

The Society regrets to announce the death of one of its members:

JAMNADAS SUBEDAR

October 9, 1934

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SYLVAN HARRIS, EDITOR

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SOME PHOTOGRAPHIC ASPECTS OF SOUND RECORDING*

C. E. K. MEES**

Summary—*Since 1928, a very considerable amount of study has been devoted to the photographic problems which arise in connection with recording and reproducing sound. A general understanding has been reached as to the principles involved and as to the conditions which will permit satisfactory quality in the sound reproduced. This lecture represents a summary, therefore, of the general conclusions which have been reached by those interested in the subject.*

Sound has three attributes, namely: (1) loudness, (2) frequency or pitch, and (3) wave-form, quality, or timbre. For perfect reproduction of sound, the reproduction should be perfect in respect of all these three attributes. The intensity range is limited primarily by the ground noise, and secondarily by the modulation which is permissible before the wave-form becomes sufficiently distorted to be noticeable to the ear. The ground noise is due primarily to physical defects in the films, such as scratches and dirt, although even in a perfectly clean film there is a very small amount of ground noise due to the granular structure of the silver deposit. This ground noise can be diminished by systems of noise reduction.

The reproduction of high frequencies is dependent upon the resolving power of the photographic film, and the effect of loss of these high frequencies will be illustrated. Special apparatus has been designed for an investigation of the quality of the reproduction, including special sensitometers and densitometers. The analysis of the quality of reproduction and the application of graphic analysis are demonstrated, with an illustration of some of the results attained.

During the last five or six years, the technical problems relating to the production and exhibition of motion pictures have been changed very greatly by the introduction of the recording and reproduction of sound. The introduction of sound recording has, indeed, influenced every part of the motion picture industry, from the nature of the original material selected for presentation to the architectural design of the motion picture theater. Any attempt to consider within the confines of a single paper the whole of the changes resulting from that introduction would necessarily lead to a very superficial result, but a brief and general discussion of the photographic

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

problems which arise in connection with the recording and reproduction of sound may have some interest and value for the general scientific public.

Since 1928, a very considerable amount of study has been devoted to these photographic problems, and a general understanding has been reached as to the principles involved and the conditions which produce satisfactory quality in the sound reproduced. This paper represents a summary, therefore, of the general conclusions which have been reached by those interested in the subject, attention being directed especially to the technical methods of sound recording which have been developed in the United States.

FIG. 1. Variable-density sound-track on film.

Many of the investigations which are summarized here have been carried out by my colleagues in the Kodak Research Laboratories, and my thanks are due to them and especially to Dr. Otto Sandvik for their assistance in the preparation of this paper.

The sound record on a film is contained in the *sound-track*, a narrow strip occupying an area between the picture area and the perforations of the film, as is seen in Fig. 1. This sound-track contains a photographic record so prepared that when it passes through a very narrow beam of light during the projection of the picture, the intensity of the light transmitted by it varies rapidly and continuously in the same sense as the air-pressure representing the sound by which the record was produced. By means of a photoelectric cell, the transmitted light is converted into electrical energy which, after amplification, actuates a loud speaker and reproduces the sound. The cycle of operations concerned in the recording and reproduction of sound therefore may be visualized somewhat as is shown in Fig. 2.

The desire to make a simultaneous record of sounds and actions is not new; it was, indeed, the objective toward which Edison strove in his early work on both the cinematograph and the phonograph. But its practical realization depended upon the discovery of some method of increasing the amount of energy corresponding to a given sound, and this in turn depended upon the interchangeable conversion of sound energy into electrical energy and upon the possibility presented by the electrical valve tube of increasing or *amplifying* electrical currents. Thus, in Fig. 2, a source of sound, *I*, emits pressure waves which the microphone, *II*, converts into electrical energy. This is amplified and operates a galvanometer of special type, *IV*, so designed that the variations in electrical intensity are transformed into variations in the intensity of a beam of light. These variations

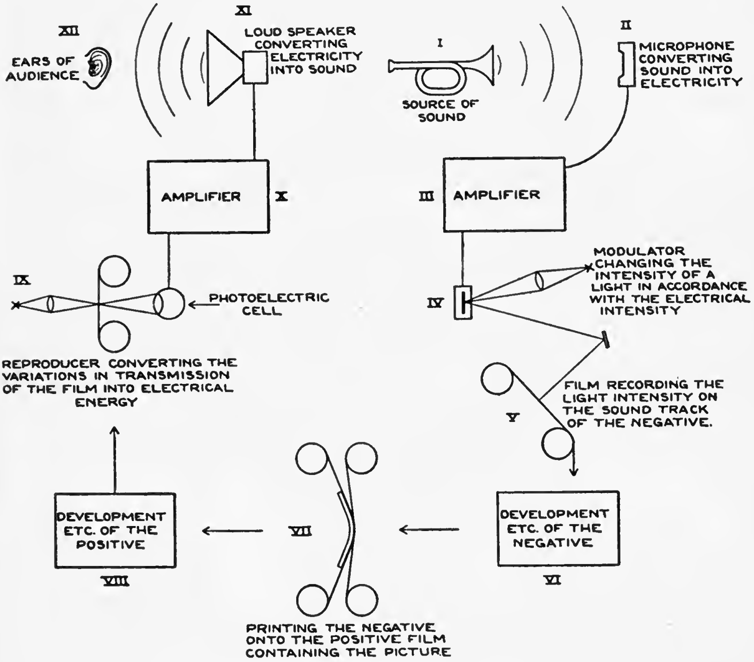


FIG. 2. Cycle of operations used in sound recording.

are recorded on a moving film at *V*. The film is developed, *VI*, and printed on a positive film, *VII*, which is developed and then in the projector controls the intensity of a beam of light from a lamp, *IX*. The light transmitted by the film falls upon a photoelectric cell and is converted into electrical energy. This energy, after amplification, operates the loud speaker, *XI*, which reconverts the electricity into sound. The reproduction thus takes place through six transformations: The sound is (*1*) converted into electricity, the modulations of which are (*2*) transformed into variations of light intensity; this then (*3*) undergoes the chemical transformation of the photographic process, which takes place in the four stages *V*, *VI*, *VII*, and *VIII;* in *Stage IX*, (*4*) the silver deposit produces changes of light intensity, which are (*5*) transformed into electrical variations, and these, finally, (*6*) into sound by the loud speaker.

For ideal reproduction, the sound reaching the audience, *XII*, should be of exactly the same character as that reaching the micro-

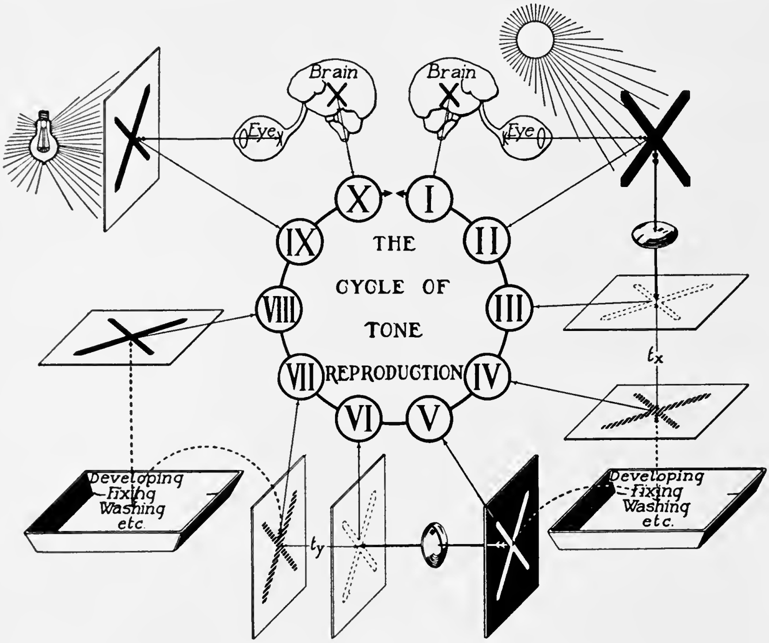


FIG. 3. Cycle of operations in tone recording.

phone, *II*, the intensity, of course, being adjusted by appropriate control of the amplifier. The sound will consist of a complex mixture of simple sounds varying particularly in the frequency and relative intensity of the different components; and in order that the quality of reproduction shall be satisfactory, it is necessary that the relative intensities of the different frequencies, and also the actual form of the pressure waves shall be preserved within certain limits through the series of transformations. This involves many problems in the design of the acoustical and electrical apparatus and circuits, but the discussion of these is beyond the scope of this paper. I need only state that within certain limits, which limits may be regarded as very satisfactory for most practical purposes, the necessary conditions can be fulfilled. This paper is concerned with the conditions which are necessary for the operation of stages *V*, *VI*, *VII*, and *VIII;* that is, with the properties of the negative and positive photographic films and with the conditions under which they must be used in order to ensure satisfactory reproduction of the sound.

Now, the positive film which carries the sound-track from which reproduction is achieved also carries the pictures showing the movement with which the sound is synchronized; and in order that the pictures shall be of satisfactory quality, it is necessary that certain conditions shall be achieved.[1] The cycle of operations necessary to produce a photographic reproduction is depicted in Fig. 3, which I owe to Dr. L. A. Jones. In the top right-hand corner will be seen a black cross illuminated by the sun, which will serve as a symbol for any photographic subject. This is reproduced in the left-hand top corner as an image on film for projection. The accuracy with which the picture duplicates in the brightnesses of its tones the different parts of the original subject corresponds to what is generally called the *objective phase of tone reproduction.*

Let us consider the steps of the photographic process by which the object is translated into the print. The first step is the projection of the object by means of a lens upon the sensitive material, where it forms an optical image and, after the duration of a given time, produces a latent image. This is developed, the material is fixed, washed, and dried, and we obtain a negative. This negative is printed either by contact or projection upon the positive material, producing first an optical image, then a latent image, and then, upon development, a positive print.

When the image falling upon the sensitive material is transformed into a negative, the accuracy of the tone reproduction depends upon the shape of the well-known curve shown in Fig. 4, which represents the growth of density in a photographic material as the exposure is increased. This shows what is known as the *characteristic curve* of an emulsion. There are three fairly well defined regions of the curve: Thus, from A to B we have the initial part, convex to the log E axis, which may be termed the region of *underexposure*[3]; between B and C, known as the region of *correct exposure*, the increase of density is practically constant for each increase of exposure; and in the third region, from *C* to *D*, this arithmetical increase fails, until the density becomes constant; this is the region of *overexposure*. By prolongation of the straight-line portion of the curve, the log *E* axis is cut at a point which Hurter and Driffield termed the *inertia*, which, when divided into a factor, gives the *speed* of the film. The slope of the straight line is known as γ (gamma). Tone reproduction will be correct only over the straight-line portion of the curve, and in order to get correct tone reproduction, therefore, the straight-line portion must be sufficiently long to cover the entire scale of brightnesses oc-

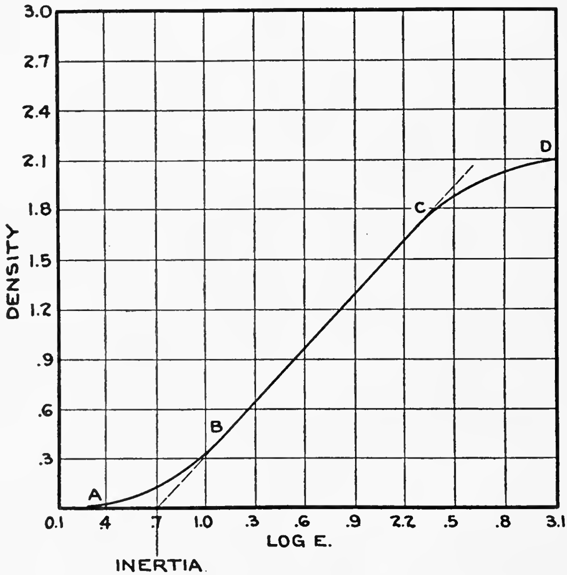


FIG. 4. Characteristic curve of negative material.

curring in the subject, and the exposure must be such as to place the lowest tone of the object at the beginning of the straight line of the characteristic curve. With modern materials and careful judgment of exposure, there is no difficulty in accomplishing this; and it may be said that there is no difficulty, provided the exposure is calculated correctly, in obtaining a negative in which the scale of brightnesses of the original will be rendered in correct proportion as a corresponding density scale in the negative. The absolute value of this scale depends upon the time of development of the negative, the contrast increasing as the time of development is prolonged, so that the scale may be contracted or expanded in the negative by varying the time of development without, however, affecting the proportional reproduction of the relative brightness values.

When negatives are developed for various lengths of time, the straight-line portions of the characteristic curves usually intersect approximately at the inertia point (see Fig. 5), so that the differences between them can be expressed simply in terms of the numerical value of γ. If, now, the value of γ be plotted against the time of development, an exponential curve is obtained, of which an example is shown in Fig. 6. The maximum value of γ is known as γ_∞ (gamma infinity), which is the γ obtained when development is in-

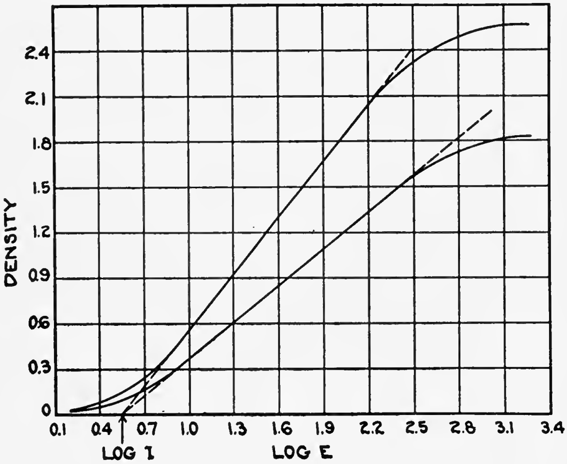


FIG. 5. Characteristic curves of negatives developed for two different times.

definitely prolonged. In practice, it is convenient to express the contrast of a given material in terms of γ_∞ and of the γ obtained by a fixed time of development in a given developing solution.

In making a motion picture, the negative is printed upon positive film, for which the characteristic curve is shown in Fig. 7. The straight-line portion of this curve is of sufficient length to cover the full range of brightnesses occurring in practically all scenes photographed, so that, provided exposure and development are correct, the brightness of the tones in the projected picture will be proportional to that of the tones in the scenes reproduced. We can follow through the tone reproduction by means of a diagram designed by

Dr. Jones (Fig. 8). In the right-hand lower quadrant of this diagram is plotted the characteristic curve of the negative material. Along the top of this quadrant are plotted the brightnesses occurring in the subject. In order to make the operation plain, two values of brightness have been selected and are indicated by broken lines; these produce corresponding densities upon the negative material. In the left-hand bottom diagram, the characteristic curve of the positive film is plotted, with its density at the bottom of the diagram and its exposure scale on the left-hand side. The original brightnesses translated into densities in the negative can now be transferred on to this curve by the broken lines shown. They thus appear as brightnesses of the print. In order to compare the bright-

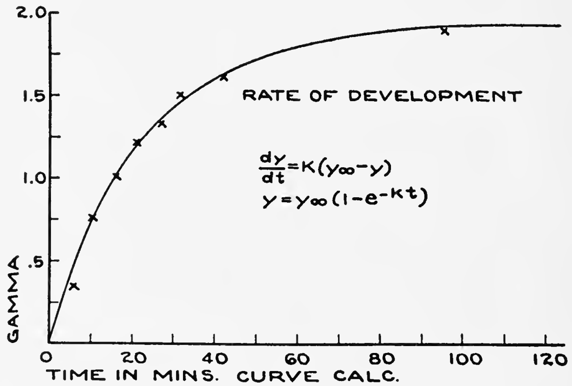


Fig. 6. Relation between gamma and time of development.

ness values of the print with those of the original scale, we draw new lines at right angles and transfer the reproduction of the brightnesses obtained through the two characteristic curves into the right-hand top quadrant, using the line *C*, drawn at 45 degrees in the left-hand top quadrant, to transfer the values to the point where they reach the vertical lines drawn from the original brightnesses. The intersections of all the original brightness values with the reproduced brightnesses of the print transferred in this way plot out the curve *D*, which represents the accuracy of reproduction of brightnesses throughout the photographic process. The straight-line portion of this corresponds to correct reproduction, and the curved portions to the errors introduced in the reproduction by the curved portions of the characteristic curves of the materials used.

In practical *sensitometry*, as the study of the characteristic curves of photographic materials is called, it is usual to measure the *density* by diffused illumination. The density was defined by Hurter and Driffield as:

$$D = \log \frac{1}{T} = \log \frac{I}{I_1}$$

where T is the transmission; I, the light incident; and I_1, the light transmitted by the silver deposit. Now, a silver deposit not only

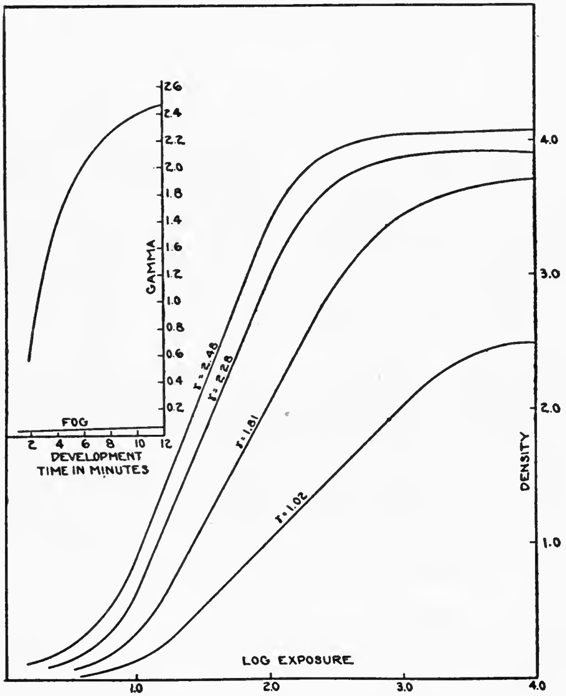


FIG. 7. Characteristic curves of positive film.

absorbs light—it also scatters it; so that if a parallel beam of light falls upon such a deposit and passes on to a lens, part of the light is lost to the lens by absorption and part by scattering (Fig. 9). The density of the deposit

$$D_{||} = \log \frac{I_{||}}{I_1}$$

where $D_{||}$ is the density measured by parallel light of intensity $I_{||}$, and the transmitted light *reaching the lens* has the intensity I_1. If, on the other hand, the density of the deposit is measured by completely diffuse illumination (as by placing opal glass in contact with the density) and the total light transmitted is effective (as in contact printing), then

$$D_{\#} = \log \frac{I_{\#}}{I_{\parallel}}$$

where $D_{\#}$ is the density measured by diffuse illumination, $I_{\#}$ is the incident diffuse illumination, and $I_{\parallel}$ is the total intensity of the light transmitted.

Callier[2] introduced this terminology, and the ratio $\frac{D_{\parallel}}{D_{\#}}$ is known

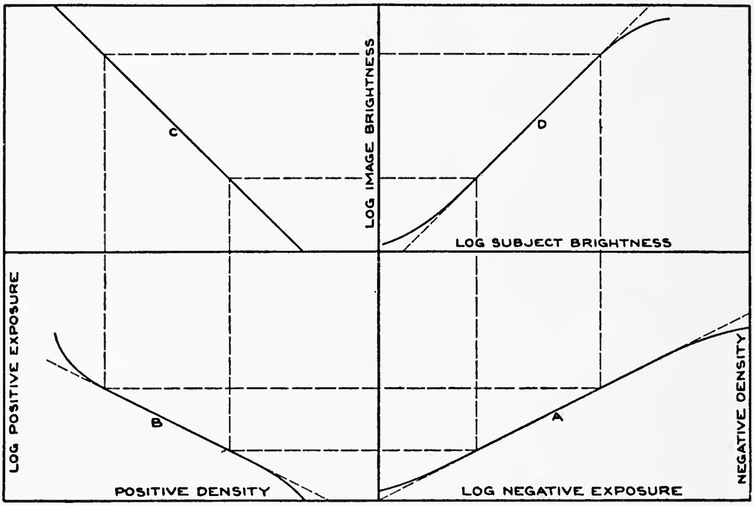


FIG. 8. Graphic solution of tone reproduction.

as the *Callier coefficient, Q*. For motion picture positive film, Q has a value of approximately 1.4.

In order that the reproduction shall be exact for the straight-line portion of the curve, and not merely proportional, the condition to be fulfilled is

$$\gamma_{\text{neg.}} \times \gamma_{\text{pos.}} = 1$$

provided that the densities in all cases are measured in the same way. In motion picture photography, however, $\gamma_{\text{neg.}}$ is measured by diffuse illumination since the negative is used for contact printing, but the γ of the positive effective in projection is increased because the positive is illuminated by a condenser and projected by a lens, so that this equation should be corrected to read

$$\gamma_{\text{neg.}} \times \gamma_{\text{pos.}} = \frac{1}{1.4}$$

where 1.4 is the value of Callier's Q for positive film and the density measurements are made by diffuse illumination throughout.

In motion picture practice, it is found that this produces too flat a picture, owing to flare in projection and some psychological factors, and it is usual to give the *virtual* or *over-all gamma* ($\gamma_{\text{neg.}} \times \gamma_{\text{pos.}}$) a value of 1.2 (densities being measured throughout by diffuse illumination). In order to keep graininess at a minimum, it is usual to develop the negative to a gamma of 0.60 and the positive to a gamma of 2.0.

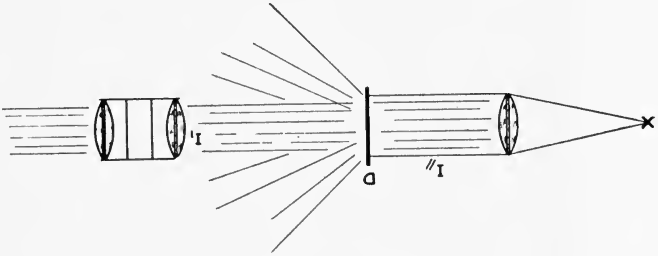


FIG. 9. Illumination of a positive for projection.

In the reproduction of the sound according to the cycle shown in Fig. 2, stages *V*, *VI*, *VII*, and *VIII* are the photographic operations with which we are concerned. These involve the following factors which are at our disposal for the control of the process:

(*A*) The choice of the film used for making the sound record.
(*B*) The amount of exposure given to the film.
(*C*) The development of the sound record.
(*D*) The choice of the positive film.
(*E*) The exposure used for printing the sound record upon the positive film.
(*F*) The development of the positive film.

Of these factors, *D* and *F* are involved in the processes used for the production of the picture, and must therefore fulfill the conditions necessary for the correct reproduction of the tones of the picture. They are consequently more or less fixed, and are not free variables available for the control of the sound record. For this purpose, there are available, therefore, factors *A*, *B*, *C*, and *E*, the positive film being of the standard type of emulsion known as *motion picture positive film* and its development being normally such as to give a gamma of 2.0, these conditions being set by the practice of the motion picture industry for the production of pictures.

Before considering the factors mentioned and their relation to the practice of sound recording, certain general matters must be dealt with. In the first place, there are in use two distinct types of sound record: These are known as the *variable-density* and *variable-width* types, respectively.

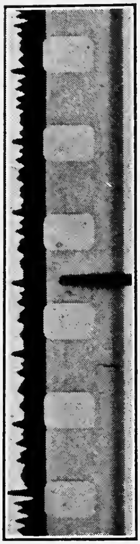


Fig. 10. Variable-width sound-track.

The *variable-density* type of record is illustrated in Fig. 1. In this type, the density is uniform across the sound-track but is made to vary along the length of the track by variations in exposure which correspond with variations in the pressure produced by the sound at the microphone. A glow-lamp or a string galvanometer operating as a light modulator is a familiar example of suitable apparatus for this purpose.

In the *variable-width* type of record, the exposing light is of constant intensity and the sound record, therefore, of constant density; but the width of the track illuminated varies in accordance with the sound pressure at the microphone. An oscillograph whose mirror is adjusted to illuminate half of the sound-track when there are no sounds at the microphone will produce this type of record (Fig. 10).

The physical phenomenon which we term *sound*, consists in rapid variations in atmospheric pressure. These pressure variations are ordinarily produced by the vibration of mechanical parts or by the vibration of columns of air, as in wind instruments. If the rate of vibration lies between about 16 and 20,000 cycles per second, the result is a note of audible frequency.* From a mathematical standpoint, the simplest type of variation in sound pressure is a simple sine wave, as is shown in Fig. 11. This may be represented by

$$p = P_0 + P \sin \omega t \qquad (1)$$

* The exact limit of audibility is dependent upon the intensity of the source and the characteristic of the observer's ear. For most practical purposes, it is sufficient to reproduce all frequencies between 20 and 10,000 cycles per second.

where P_0 represents the average atmospheric pressure upon which is superimposed a sinusoidal variation of amplitude P. Although a simple sine wave of this sort is rarely produced by any musical instrument, we may always analyze any musical note into a fundamental sine variation plus a number of harmonics or overtones.* Each of these, however, is itself a simple sine wave whose rate of variation is an integral multiple of the fundamental. The quality, or timbre, of a musical instrument depends upon the relative amplitudes of these harmonics.

If a perfect microphone and amplifier are used in recording, the current i in the last stage of the amplifier may be represented as

$$i = I_0 + I \sin \omega t \tag{2}$$

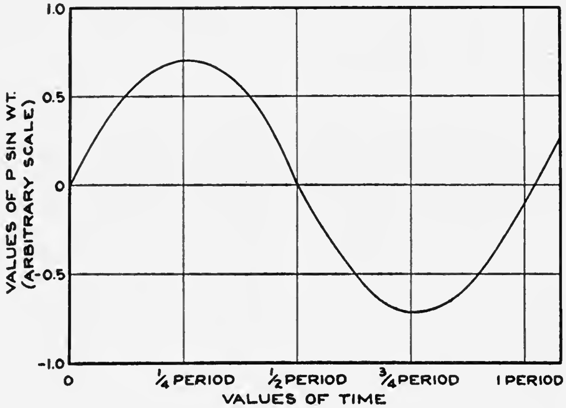


FIG. 11. A simple sine wave.

There is a concept in sound recording which is very useful and which arises from this equation. Since the maximum value of $\sin \omega t$ is $+1$ and its minimum value -1, the maximum value of i is $I_0 + 1$, the minimum value is $I_0 - 1$, and the average value is I_0. The *modulation, m,* is defined as

---

* Consider the case of a musical instrument playing the A below middle C. The fundamental frequency of this note is a little more than 200 cycles per second, for simplicity, let us assume it to be exactly 200 cycles per second. In general, this note will consist of the fundamental 200-cycle variation, plus a harmonic with a frequency of 400 cycles per second, plus a third harmonic with a frequency three times the fundamental, or 600 cycles per second, and so on, the amplitude falling off rather rapidly in the higher harmonics.

$$m = \frac{i_{max.} - i_{av.}}{I_{av.}} = \frac{i_{av.} - i_{min.}}{i_{av.}} = \frac{I}{I_0} \quad (3)$$

Since the amplifier current can never be less than zero, the value of m can never exceed unity.

If, now, the variations in the exposure of the film are proportional to the variations in the current I, the exposure of the film may be represented by equation 4:

$$e = E_0 + E \sin \omega t \quad (4)$$

where e is the value of exposure corresponding to a sound pressure, P_0; E_0 is the value of exposure when there is no sound before the microphone; and E is the maximum value of the sinusoidal variation of exposure.

The condition for correct tone reproduction in the photographic phase of the problem is simply that the current in the photoelectric cell of the reproducer be expressible by an equation in the form of equation 2:

$$i' = I_0' + KI \sin \omega t \quad (5)$$

The constant term I_0' in eq. 5 is independent of the constant term I_0 in eq. 2. However, the amplitude of the variable term in eq. 5 must be proportional to the variable term in eq. 2, as indicated by the proportionality constant K; that is, the transmission of the positive sound-track must be linearly related to the exposure of the negative. The transmission of the positive sound-track will vary, therefore, from an average value, T_0, to a maximum value, $T_0 + T$, and a minimum value of $T_0 - T$, and T/T_0 is the modulation.

In the case of a variable-width record, the modulation is proportional to the width of the track covered by the silver deposit, the average transmission being that where half the width is occupied; the maximum transmission where all, or nearly all, the track is clear; and the minimum transmission where all, or nearly all, is covered. This average transmission in either type of sound record exists when no sound strikes the microphone. The transmission of the film, however, is not absolutely constant owing to surface imperfections, such as dirt, dust, scratches, *etc.*, and also to the granular structure of the silver deposit. These changes in transmission cause a certain minimum of modulation which, when converted into sound, is known as *ground-noise.*

Sound has three attributes, namely:

(*1*) Loudness.
(*2*) Frequency or pitch.
(*3*) Wave-form, quality, or timbre.

Now, for perfect reproduction of sound, the reproduction should be perfect in respect of all these three attributes. As to loudness, the maximum intensity can be achieved by simple amplification (within the capacities of the electrical system and the loud speaker), but this amplification will also increase the minimum intensity due to *ground-noise;* so that the intensity range is limited primarily by the ground-noise, and secondarily by the modulation which is permissible before the wave-form becomes sufficiently distorted to be noticeable to the ear.

As to frequency, there is no photographic limit at low frequencies, but the reproduction of high frequencies is limited by the *resolving power* of the photographic film as well as by the optical and mechanical systems. As to wave-form, the reproduction will be dependent upon the fulfillment of certain specific requirements in the photographic operations.

In systems in which sound is reproduced by means of electrical circuits, it is usual to express the relative loudness or intensity in terms of the electrical transmission unit, the *decibel.* If, in a circuit, the electrical energy is diminished to one-tenth of its input level, the loss is stated to be ten decibels, the decibel being defined as one-tenth of the logarithm of $\frac{\text{power input}}{\text{power output}}$. Correspondingly, if one sound has twice the energy of another, it is said to be three decibels (10×0.30; *i. e.*, $10 \times \log 2$) louder; if it has ten times the energy, it will be ten decibels louder; one hundred times the energy, twenty decibels, and so on.

A change of one decibel is just about the smallest change in loudness which the ear can recognize, *i. e.*, about 12 per cent. The intensity of sound is usually stated as the number of decibels above the *audibility threshold*, corresponding to an acoustical energy of about 4×10^{-16} watts per square centimeter. A soft whisper at a distance of three feet would be 15 to 20 decibels above this threshold; speech, 60 to 80 decibels; the range of an orchestra from 40, for a single instrument *pianissimo*, to 115 for the whole orchestra *fortissimo*.[3]

Now, as has already been mentioned, the maximum intensity of the sound produced from a given track can be increased to any extent within reason by increasing the amplification between the photoelectric cell and the loud speaker, but this amplification will proportionately increase the minimum intensity of sound, or *ground-noise,* and the ratio between the maximum and the minimum intensity will remain constant. This ratio can, however, be increased by the methods known as *noiseless recording,* which will be discussed shortly.

The ground-noise is the sound heard from the loud speaker when the film is running through the projector, but there is no change in transmission of the sound-track except that due to parasitic modulation. When a well adjusted projector is running without any film at all and the amplifier is adjusted to give the desired loudness from a

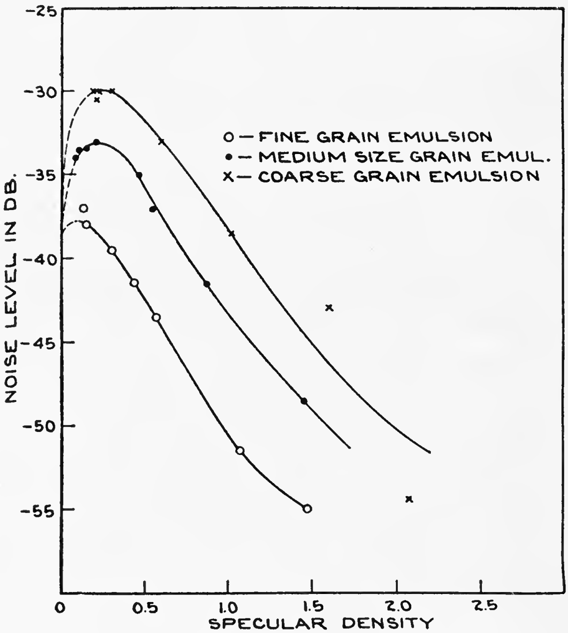


FIG. 12. The relation between ground-noise and density.

normal sound record, there is a slight residual noise arising from the photo-cell and electrical system, the level of which, however, should not be greater than 55 decibels below the maximum level of the sound record. If a perfectly clean film is allowed to run through the projector, the ground-noise increases about 6 decibels. If, now, the film carries a photographic density such that it transmits one-quarter of the light (this is the density normally used for an unmodulated variable-density sound-track) and if the amplification is increased to compensate for the reduced illumination of the cell, the noise level will increase three more decibels even if the utmost care has been taken to preserve the film-track from extraneous dirt. This increase in the noise level is due to the grain structure of the photographic deposit.

Fig. 12 shows the relation between ground-noise and the specular density of the photographic deposit. It shows also that the noise increases with the increase in the emulsion grain size. The ground-noise, however, increases when the film is run through the projector, as it accumulates microscopic scratches and specks of dust, and although cleaning will reduce the ground-noise somewhat, a film in active service in the theater which has been run some fifty times (on the whole, a favorable condition for a first-run film) has its average value of noise level raised by about 6 decibels. The apparent increase in ground-noise is much greater than is indicated by this figure because of its character.

In view of this great interest in the ground-noise, due to unavoidable handling of the film, any attempt to reduce the ground-noise due to the granularity of the silver deposit does not seem to be worth while, in view of existing theater conditions; although if some way of avoiding the ground-noises due to other causes could be found, a reduction of the granular structure of the film is not impossible and might in that case be of value.

It is obvious that ground-noise is most noticeable when the signal level is low and is of negligible importance when the recorded sound is loud. Since the ground-noise is due chiefly to dirt, dust, scratches, oil spots, and finger prints on the film surface, and since these surface imperfections produce a larger percentage change in the photoelectric cell illumination through a film which has a high transmission than through one which has a low transmission, it is evident that the ground-noise could be diminished if the average transmission of the film decreased with a decrease in the sound level. In the case of variable-density recording, this could be accomplished if the positive sound-track were denser when the modulation was low and became lighter as the sound increased. This method is utilized in the Western Electric system of "noiseless" recording.

In this system of recording, the exposure on the negative film is made through a light-valve whose ribbons are normally spaced 0.001 inch apart, giving a certain fixed unmodulated density in the sound-track of the negative and, in turn, of its print. This ribbon spacing is sufficient to permit the movement of the ribbons required by the loudest sounds and is, therefore, considerably greater than necessary for the weaker sounds.

In noiseless recording, the mean spacing of the ribbons is not constant but is reduced to some predetermined value during silent passages or during periods of weak signals. This reduces the density of the negative unmodulated track and, consequently, increases the density of the positive unmodulated track, decreasing the groundnoise. As louder and louder sounds arrive at the microphone, increasing the valve modulation, the mean spacing of the ribbon increases sufficiently to accommodate the increased modulation of the valve without bringing the ribbons together.

Fig. 13(*B*) illustrates the behavior of the ribbons in a normal light-valve. In the normal method of recording, the ribbons have

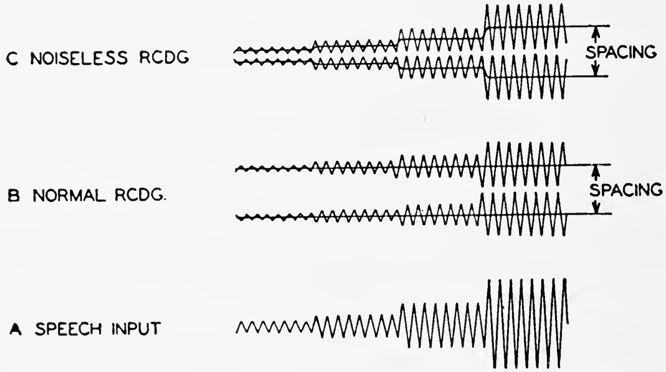
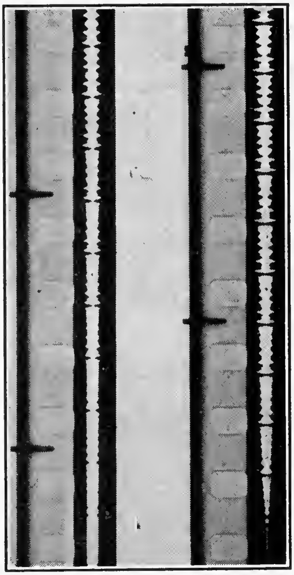


FIG. 13. Diagram illustrating the use of "noiseless recording."

a constant average spacing and their movement is essentially simple, corresponding to the variations of the sound-current only. In the method of noiseless recording, the ribbons may be regarded as having two motions: first, the motion due to the sound-currents only, exactly as in the normal method of recording; and, second, a superimposed, slower movement which follows the envelope of these sound-currents. This is shown in Fig. 13(*C*). This control of the ribbons is effected by a special electrical circuit which supplies to the ribbons, not only the sound-currents, but another current at a slower period corresponding to an average value or envelope of the sound-currents, which are shown in Fig. 13(*A*). As a result, the exposure through the light-valve on the negative film is reduced during periods of silence, while at the same time provision is made for increasing the exposure automatically with increasing modulation of the light-beam by the light-valve ribbons. It follows that the density of the resulting negative sound-track will be a minimum during silent intervals and will rise to a maximum value with increasing input, while the density of the print made from this negative will be a maximum during silent intervals and will decrease to a fixed minimum with increasing output from the film. By this system, an effective noise reduction of approximately 10 decibels can be attained.

Turning to the variable-width system of recording, the same result is achieved if the width of the clear or unexposed portion of the positive sound-track is less when the modulation is low and becomes wider as the modulation increases. In the latest type of RCA recording system, the galvanometer is so arranged that when a current such as the amplified microphone current flows through it, its mirror vibrates about a horizontal axis. Associated with this galvanometer mirror are a source of illumination and an optical system which image an illuminated equilateral triangular area in the plane of the slit. The base-line of this triangle is parallel to the major axis of the slit, and a perpendicular line drawn from the apex of the triangle to its base passes through the midpoint of the slit. The height of the illuminated triangle is large compared to the height or the width of the slit opening, so that at any one time only a small fraction of the light falling within the boundary of the illuminated triangle passes through the slit opening.



(A) (B)

FIG. 14. Normal and "noiseless" variable-width tracks.

For normal recording, the mean position of the triangle is adjusted so that the center of the slit opening lies at a distance from the apex equal to one-half its maximum amplitude. Thus, when no sound strikes the microphone, the negative receives a uniform exposure. The strip of the negative exposed is centrally located in the sound-track, and its width is equal to half that of the fully modulated sound-track. When sounds strike the microphone, the triangular area vibrates up and down; thus illuminating more or less of the slit opening, causing a corresponding increase and decrease in the length of the slit image upon the film, with the corresponding widening and narrowing of the exposed area of the sound negative, which when developed and printed, results in the sound-track shown in Fig. 14(*A*). In the case of normal recording, the average position of the triangle is fixed, and the exposure through the slit opening results in a clear portion in the positive sound-track sufficiently wide to accommodate full modulation, and it is therefore much wider than that required for low modulation.

It is entirely permissible to reduce considerably the width of the clear portion of the track during periods of no sounds or weak sounds if, in the presence of louder sound, the width of the clear portion of the track is in some manner increased sufficiently that the amplitude of the sound record does not exceed the width of the clear track. This is accomplished by adjusting the position of the illuminated triangle with respect to the slit so that when the modulation is zero, the apex of the triangle extends just beyond the slit opening. Thus, the negative receives a very narrow line of exposure along the middle of the track which, when developed to a negative and printed, results in the sound-track in Fig. 14(*B*). Now, as the modulation increases, the position of the triangle changes so that the mean position of its apex is farther and farther away from the slit opening. When the modulation is complete, the distance between the slit opening and the mean position of the apex is equal to one-half its maximum permissible amplitude.

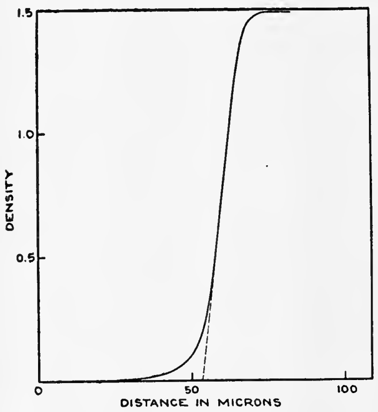


FIG. 15. Curve showing the sharpness of a record at an edge.

It will be seen, therefore, that in the normal method of recording the illuminated triangle has constant average position and its movement is essentially simple, corresponding to the variations of the voice-currents only. However, in the method of noiseless recording, the triangle may be regarded as having two motions: first, the motion due to the sound-current only, exactly as in the normal method of recording; and, second, a superimposed, slower movement which follows the envelope of these sound-currents.

THE REPRODUCTION OF FREQUENCY

The extreme range of frequencies audible to the normal ear is from approximately 16 cycles per second to nearly 20,000 cycles per second. The last two octaves, however, are of very little importance when considered as pure sounds; that is, a simple wave having a frequency greater than 5000 cycles is rarely met with, but frequencies between 5000 and 10,000 cycles are of considerable importance as representing the harmonics (or overtones) of sounds of lower frequency and thus as modifying the character of the sound. In speech, for instance, the sibilants and especially the consonants can be reproduced correctly only if frequencies in this range are available. The older type of equipment used in the theaters, and especially the loud speakers, limited the maximum frequency in reproduction to 5000 to 6000 cycles. At this frequency loss due to insufficient resolving power in the film is practically negligible. More recently, however, both the recording and the reproducing equipment have been improved so as to operate effectively with frequencies up to 10,000 cycles. This high-quality reproducing equipment has already been installed in many of the first-class theaters, so that the use of a photographic material of somewhat higher resolving power would be desirable.

The resolving power of a photographic material is limited by the scattering of the silver halide grains for the incident light. Consider a beam of light incident upon a film and limited by a sharp edge. The light falling upon the film will be reflected from the silver halide grains and scattered into the shadow, the extent of the scattering depending upon the reflecting power of the grains, their size, and the absorption of the emulsion for the scattered light. The edge of an image, therefore, is not infinitely sharp, and the sharpness of the developed image at an optically sharp edge takes the form shown in Fig. 15, which is of the same form as the characteristic curve of the emulsion. Sharpness is defined numerically as the slope of the straight-line portion of the sharpness curve.

In practice, the resolving power depends not only upon the sharpness but also upon the graininess of the emulsion, and is usually measured directly by photographing a series of very small grating test objects, the resolving power being expressed in terms of the number of lines per millimeter which are visibly resolved when the image is

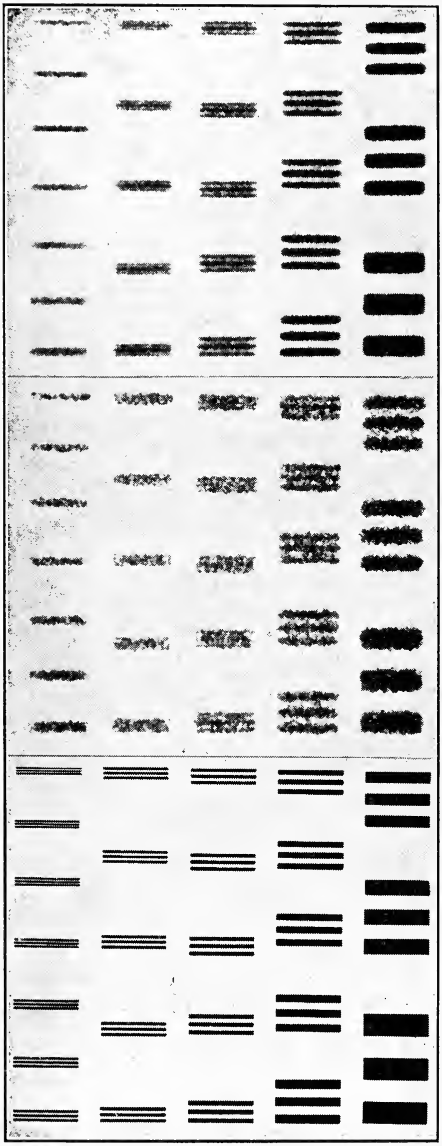


FIG. 16. Photomicrographs showing the measurement of resolving power.

examined under the microscope (Fig. 16). The resolving power of an emulsion is of an extremely complex nature, depending upon a number of variables such as distribution of intensity and contrast in the object, density of the photographic image, time of development, type of developer, quality (spectral composition) of the exposing radiation, and several other minor factors. It is impossible, therefore,

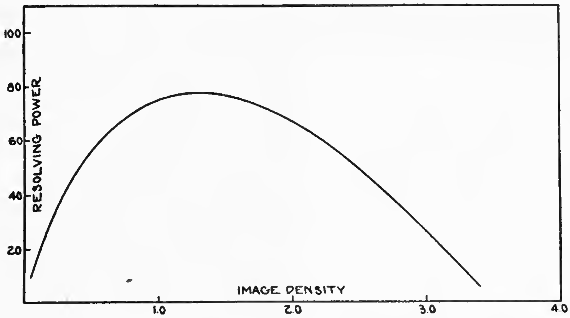


FIG. 17. Variation of resolving power with density.

with our present knowledge at least, to express the resolving power of an emulsion in terms such that one can calculate very closely the depression in volume of a sound record incurred by imperfect resolution. It may prove useful, however, to consider the nature and the effect of some of the above-mentioned variables. In order to sim-

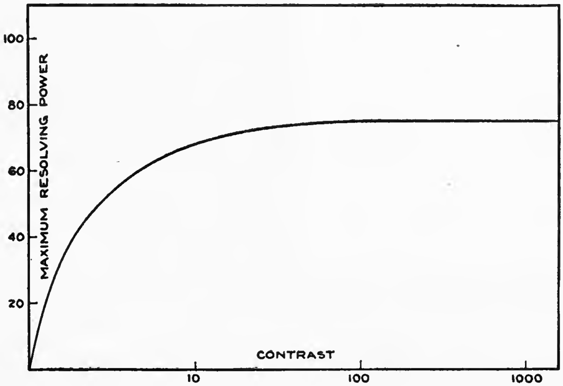


FIG. 18. Variation of resolving power with object contrast.

plify the problem as much as possible, we shall consider each variable separately:

Let us consider, first, the effect of a change in the image density keeping all other factors as nearly constant as possible. Fig. 17

shows a typical curve for motion picture positive film, the object being 1000; that is, the amount of light transmitted through the clear spaces is about 1000 times the amount of light transmitted through the opaque spaces, and the development time, 8 minutes in a standard positive film developer, this being a rather full development. This curve shows that the resolution increases from zero, at a density of zero, to a maximum value of 80, at an image density of 1.3. This density we shall call the *optimal density*. The general character of this curve is similar for any type of emulsion, although in general the lower the inherent contrast of the emulsion, the lower is the optimal density. Keeping the time of development constant and varying the object contrast, if we measure maximum resolving power, that is, resolving power at optimal image density, we obtain the curve shown in Fig. 18. The resolution increases with the contrast, finally reaching a limit. It is seen that motion picture positive emulsion very nearly reaches its maximum value when the object contrast is 1000. If, now, we vary the time of development, keep the object contrast 1000, and determine the resolving power for each time of development at an image density of 0.3, we obtain the curve shown in Fig. 19. It is interesting in this case to note the rapid decrease in resolution with increasing time of development. This is because the optimal density is greater than 0.3 and the entire curve shifts to the right as the time of development increases, thus depressing the low-density end. If both the image density and the development time vary, we obtain a family of curves, and if the object contrast varies as well, the resolving power is represented by a family of complicated surfaces.

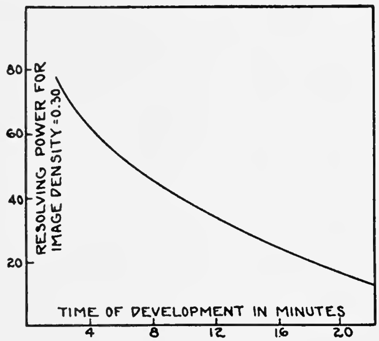


FIG. 19. Variation of resolving power with time of development.

To determine the resolution obtainable in a given practical case requires an integration of the effects due to these several variables. This is not possible, with our present knowledge, at least. It is probably a fair assumption to make, however, that an emulsion having a maximum resolution of 80, when correctly used with a high-quality optical system, will give excellent rendering of tone and form at frequencies well above the highest frequencies now used, and that the volume at those frequencies will not be materially reduced due to lack of definition. As a matter of fact, it is possible to record frequencies of 13,000 to 15,000 cycles and obtain excellent definition. In order to do so, the adjustment of focus has to be carried out with the utmost care. A displacement of the objective lens imaging the slit upon the film by a small fraction of a millimeter causes a change from excellent definition, that is, a high modulation in the density, in one case, to a practically uniform density in the other. Fig. 20 is a photomicrograph of a variable-area sound record of 10,000 cycle frequency. The definition is not perfect, yet the volume depression at this frequency from that cause certainly would not be very large.

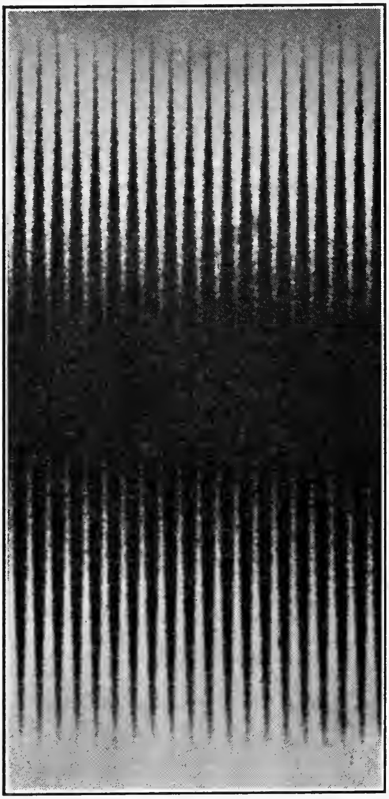


FIG. 20. Photomicrograph of a 10,000-cycle record.

While, however, the resolving power of the emulsion is sufficient to record very high frequencies, the spread of the image does involve some loss in modulation. This is illustrated in Fig. 21, which shows the loss of output level (in decibels) plotted against the frequency, the relative output levels being measured by a microdensitomer. In practice, a greater loss results owing to the width of the slit of the reproducer. A loss is also introduced if any slippage between the negative and the positive films occurs in the printer, which will happen unless the perforation spacing of the positive and negative films at the time of printing is exactly that for which the printer was designed. For the printer most generally used, the diameter of the printing sprocket is such that the negative should

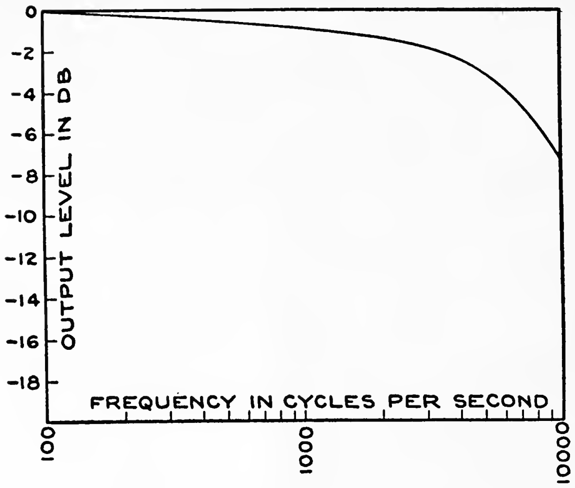


FIG. 21. Loss of output level with increase in frequency.

be 0.3 per cent below standard pitch when printed on standard positive film. This represents the normal shrinkage of the sound nega-

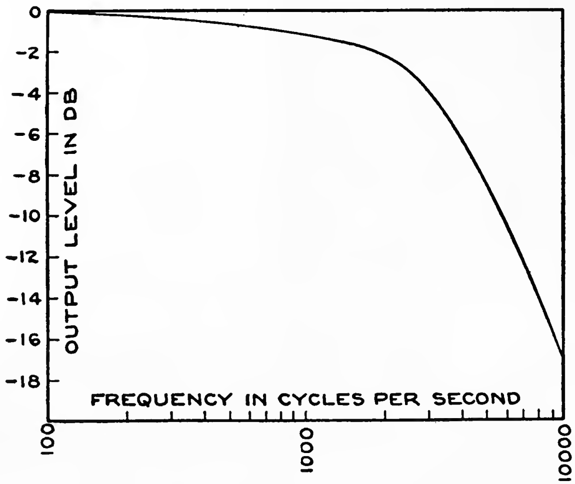


FIG. 22. Output plotted against frequency.

tive film during the time which elapses between the processing of the negative and the printing of the bulk of the release positives. The over-all characteristic actually obtained in good practice, as measured by the output from a standard reproducer head plotted against frequency, is shown in Fig. 22.

THE REPRODUCTION OF WAVE-FORMS

In order that the original wave-form may be retained, it is necessary that the transmission of the positive sound-track shall be linearly related to the exposure of the negative. The photographic conditions can be analyzed by the tone reproduction diagram, for which graphic solutions have been discussed. Inasmuch, however, as the current of a photoelectric cell is linearly related to the transmission of the positive, it is convenient to use linear coördinates and to plot

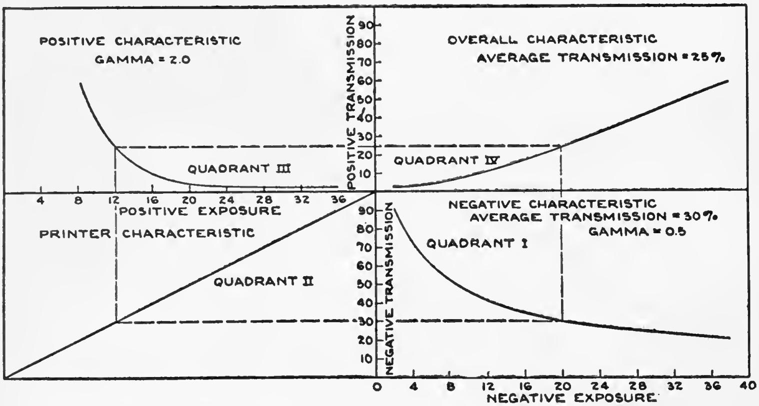


FIG. 23. Schematic reproduction diagram for sound recording.

transmission against exposure instead of plotting density against the logarithm of exposure, as is customary in general photographic work.

A schematic reproduction diagram is shown in Fig. 23. In quadrant *I*, the transmission of the negative when developed to a gamma of 0.5 is plotted against the exposure. In quadrant *II*, the straight line is drawn at an angle which defines the exposure on the positive film in the printer. The characteristic curve of the positive film developed to a gamma of 2.0 is plotted in quadrant *III*, the transmission being plotted against the exposure. Vertical lines for each exposure point in the negative in quadrant *I* now meet horizontal lines drawn through the corresponding positive exposures on the positive curve in quadrant *III*, and their intercepts trace out the curves shown in quadrant *IV*, which represents the reproduction curve of the process.

So far as this reproduction curve in quadrant *IV* is linear, undistorted reproduction should be obtained.

It is clear that the effect of modification in the photographic process, use of different film, different exposures, or different times of development can be computed, and this was done some years ago by several workers; but in view of the complexity of the problem, it seemed desirable to make a direct experimental study of the subject. To this end, three special instruments were designed.

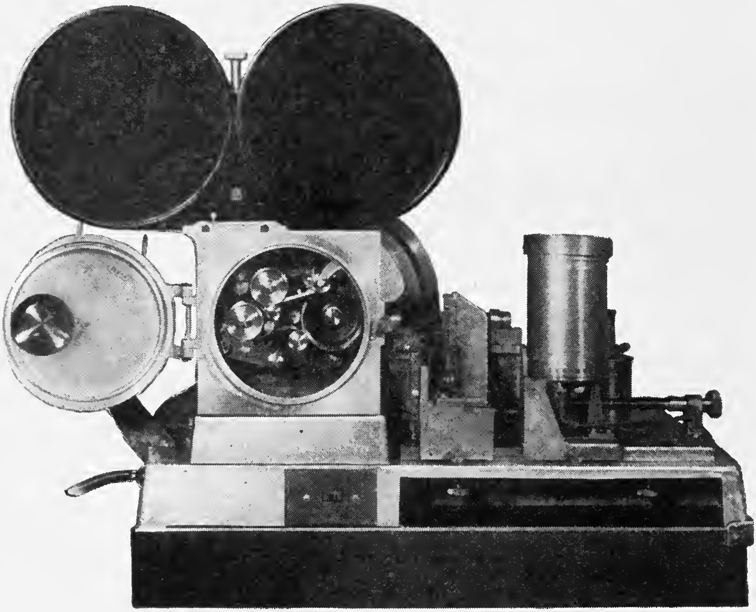


FIG. 24. Variable-slit sensitometer.

The first was a variable-slit sensitometer. The instrument is shown in Fig. 24. It consists of a camera moving the film at a uniform speed of 90 feet per minute past an exposing slit of variable width. The light-source is a tungsten ribbon filament lamp. The lamp filament is imaged upon the variable-width slit, which in turn is imaged upon the moving film at two to one reduction, as shown in Fig. 25. The width of the slit is varied automatically by the rotation of a precision screw which is actuated by a cam mechanism. There are sixteen stops on the cam, so arranged that the width of the variable slit is changed by steps from a slit-width of 4 mils to about

0.016 mil. This range of variation is more than sufficient to cover the normal exposure range occurring in practice. With this instrument, film can be exposed under exactly the conditions of time of exposure and intensity of light which prevail when sound is recorded.

The second instrument is a sound-track densitometer, shown in Fig. 26. This instrument is so designed as to approximate closely the conditions of a standard sound reproducer except that the film instead of being moved at a speed of 90 feet per minute by a rotating sprocket, is moved step by step past the scanning slit by the rotation of a very accurate screw mechanism. This instrument is used chiefly to measure densities photoelectrically; since the ratio of radiation

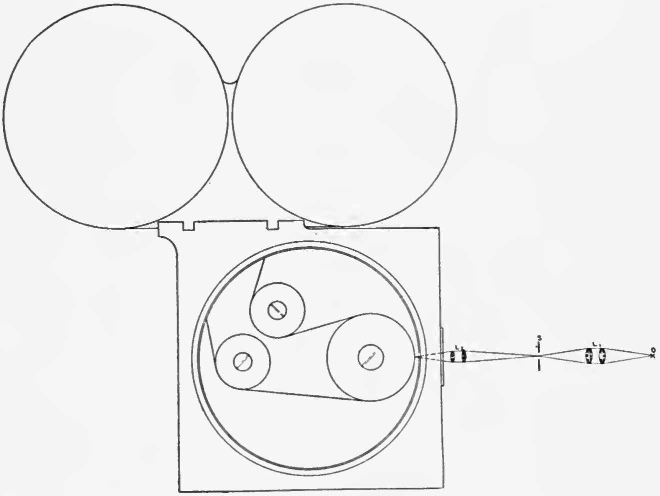


FIG. 25. Diagram of optical system of slit sensitometer.

transmitted to that incident upon a given photographic image depends upon the degree of collimation or diffusion of the incident radiation and upon the size of the cone angle of the transmitted radiation intercepted by the receiving element, it is necessary in connection with the sensitometry of sound recording emulsion that densities should be measured to conform with the optical conditions which obtain in practice, the densities attained being of the same order as those defined by Callier as $D_{\|}$, and not the $D_{\#}$ values used in ordinary sensitometry.[4]

The third instrument is a microdensitometer of rather special design, by which continuous microdensographs can be obtained from the sound-track. In this instrument, a microscope objective projects an enlarged image of the sound-track upon a slit, behind which is a lens imaging the principal plane of the microscope upon the photoelectric cell surface. This insures a uniform distribution of illumination on the photoelectric cell surface at all times. The cell operates into a strictly linear d-c. amplifier whose power output actuates a galvanometer of fairly low period. The microscope stage carrying the film is driven at a constant speed by means of a train of gears and a precision screw. The image of the sound-track moves across the

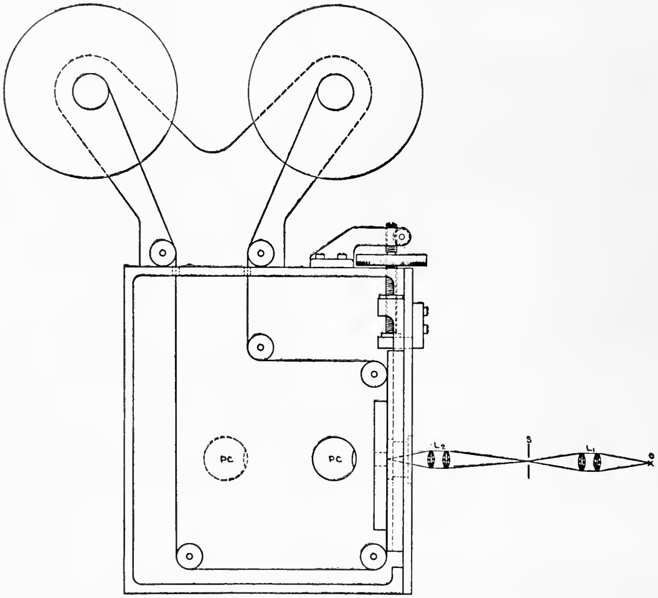


FIG. 26. Diagram of sound-track densitometer.

slit, varying the illumination of the photoelectric cell and, therefore, its current output, in accordance with the transmission of the sound-track. The amplified photoelectric current actuates the galvanometer whose angular movements are recorded upon a continuously moving strip of film $6^1/_2$ inches wide and driven at a constant ratio of speed with respect to the sound record. The ratio of sound-track speed to recording film speed is adjusted so that the amplitude and the wavelength of the record are each about five inches, a convenient size to handle and sufficiently accurate for all purposes. One such record is shown in Fig. 27. Superimposed upon the curve are shown points obtained when the same record is run through the sound-film densitometer containing a standard reproducer optical system and photoelectric cell. The photoelectric cell current can then be read directly on the galvanometer at various points along the curve. The results of measurements made on the two instruments agree well.

The results obtained with these instruments are studied by the use of a harmonic analyzer of the Henrici type, made by Coradi. It normally gives the first five terms of the Fourier series, although the next five terms may be obtained by a second set of readings, giving, in all, the first ten harmonics. A complete description of this instrument is given by D. C. Miller.[5]

The microdensitometer records are enlarged to a standard wave-length of 40 centimeters, this being the required base-line for the

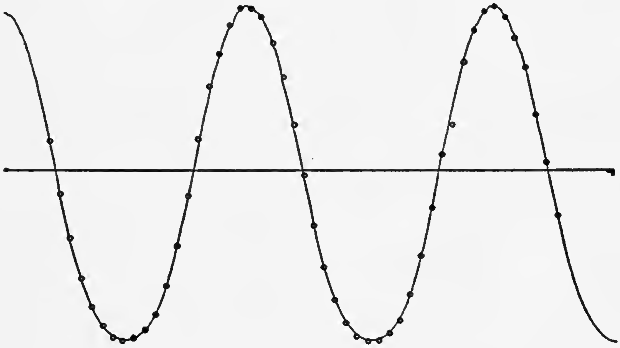


FIG. 27. Microdensitometer record.

harmonic analyzer. The results are accurate with a single tracing of the curve to the order of 0.5 mm. of amplitude for the lower harmonics, and a slightly greater accuracy can be attained for the higher terms because the repetition of the values gives a better average. Since the curves are about 300 mm. in amplitude, the harmonics are determined with a maximum error of about 0.2 per cent. In order to decrease accidental errors, the average of four successive cycles was used in most of the work. This was found to be sufficient to give the required accuracy of analysis of the wave-form even when the modulation was low. In order to correlate the two fundamental quantities of *modulation* and *harmonic* content, the amplitude was measured on the identical cycles of the wave.

Fig. 28 shows the results of analyzing a very distorted sound-wave, the negative having an average density of 1.00 (diffuse) at a gamma of 1.25. The print shown has an average density of 0.60 and on analysis was found to have the relative amplitudes of harmonic shown. Components as far as the sixth harmonic have been drawn, although

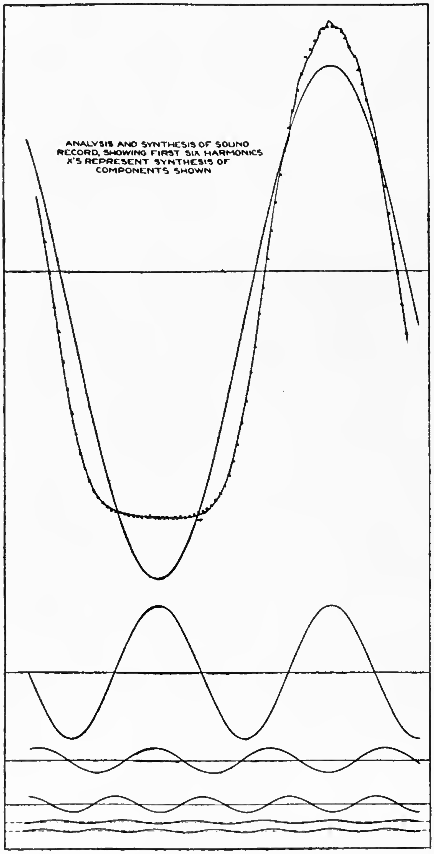


Fig. 28. Analysis and synthesis of sound record.

the amplitudes of the fifth and sixth are only 0.7 per cent that of the fundamental, corresponding to 43 decibels down.

The tone reproduction diagram shown in Fig. 23 and referred to briefly above will now be considered in more detail. In quadrant *I*, the exposure follows along the axis from an average value indicated by the broken line. The exposure varies equally in the direction of increasing and decreasing exposures. The average or unmodulated exposure results in an average transmission, while the maximum and minimum values depend upon the *modulation.* Using the arbitrary value of *20* as average exposure, the maximum modulation occurs when the light decreases to zero on the decreasing half of the cycle and increases to *40,* on the increasing half. In terms of the light-valve, this maximum means that the valve ribbons close completely, or clash, on the one hand, and open to double their average value, on the other. In terms of a glow-lamp, the lamp is extinguished and

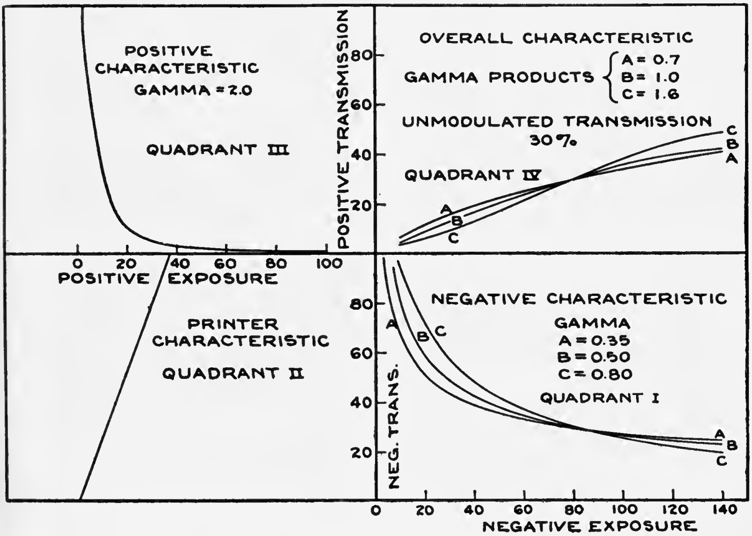


FIG. 29. Effect of negative development upon reproduction.

goes to double its average intensity on the two halves of the cycle. In general, the amplification between the sound-waves striking the microphone and the recording device is so adjusted that this maximum is never reached, because the limits of the curve can not be utilized without introducing a considerable amount of distortion. If the modulation is limited to 80 per cent, corresponding to about 2 decibels below the overload point, the remaining distortions can be balanced out, as can be seen by following through the diagram.

The straight line in quadrant *II* defines the positive exposure. The exposure of the positive material used for printing will be proportional to the transmission of the negative, the coefficient of proportionality depending upon the intensity of the exposing lamp. Zero *transmission* of the negative always leads to zero *exposure* of the print, so a family of straight lines through the origin represents all possible printing conditions.

Quadrant *III* shows the *positive characteristic* drawn for a gamma of 2.0. This is similar to the negative curve.

Quadrant *IV* shows the final curve of *positive transmission* against *negative exposure.* This curve is obtained by following negative exposures through to the corresponding positive transmission. As

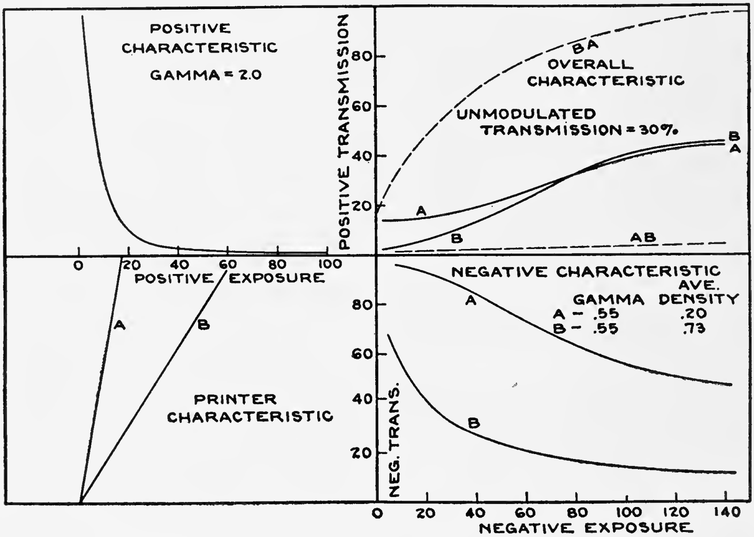


FIG. 30. Effect of negative density upon reproduction.

can be seen, the final curve is relatively straight, the curvatures of the two photographic materials used having compensated for each other.[6] Now, since the photoelectric cell current in the reproducer is proportional to the transmission of the film, it follows that, for the photographic process to be correct, there must be a straight-line relationship between positive transmission and negative exposure. It is also true that *any* straight line gives correct sound tone reproduction. The steepness of the line determines only the amount of modulation necessary in recording, while its vertical projection determines the amount of *change* in photoelectric cell current and hence the amount of voltage developed in the first stage of the amplifying system. Control of these factors does not lead to any distortion corresponding to that produced by a wrong over-all gamma in the pictorial case, where the picture becomes either too contrasty or too flat. The analog of pictorial contrast is loudness, which can be controlled by adjustment of the amplifiers.

As can be seen from the figure and by comparison with the H&D curve, much of the negative and positive exposure range is in a region corresponding to the toe of the H&D curve, while a part is on the straight line. Since the relationship actually utilized is the linear one, it is difficult to interpret the results on the basis of considerations

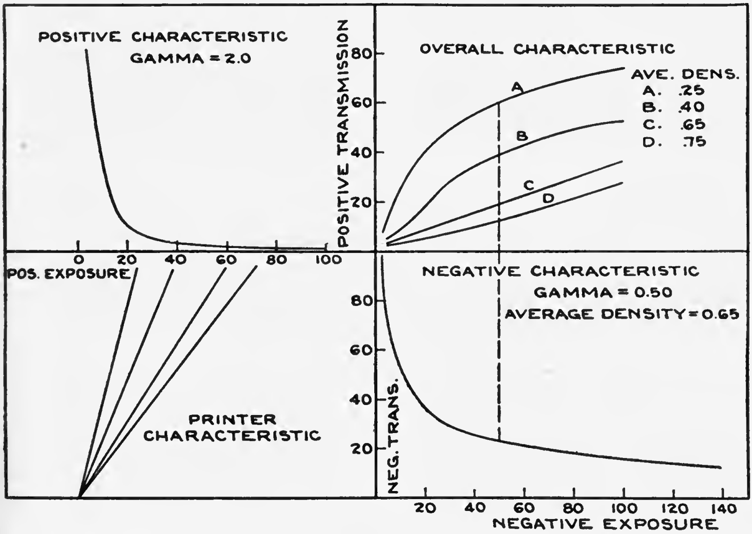


FIG. 31. Effect of positive transmission upon reproduction.

of the straight-line portion of the curve. In actual practice, only peaks of waves reach to a high enough density to be on the straight line of the H&D curve of the positive.

So far, the limitations on the straight line of quadrant *IV* have not been mentioned. There would be no problem of tone reproduction if it were not of importance to keep the amplification to a minimum in order to keep down the ground-noise. The amplification necessary depends directly upon the range of transmission used. This points to the desirability of using 50 per cent as the average transmission of prints, as the light modulation in reproducing can then be from 0 per cent to 100 per cent; that is, the absolute maximum.

Consideration of ground-noise leads to the practical adoption of lower values of transmission, and these are compatible with satisfactory tone reproduction, as shown in the next figures.

Fig. 29 shows the effect of variable negative development upon the final reproduction. Gamma is given on the curves to indicate extent of development. It can be seen from quadrant *IV* that curve *C* has the greatest vertical height of straight-line portion, and this corresponds to the greatest negative development. In general, the change of quality with negative development is not very rapid.

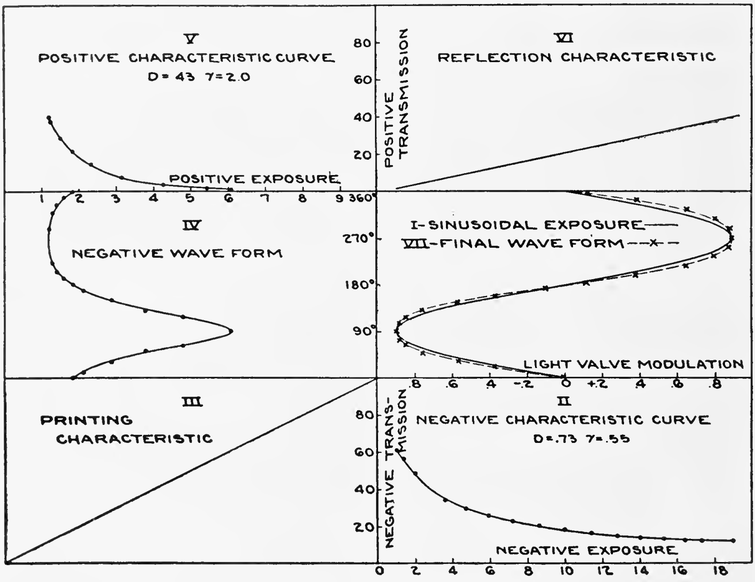


Fig. 32. Reproduction of a sinusoidal wave.

Fig. 30 shows the effect of varying negative density, the extent of development being constant. The *printer characteristic* was changed to adjust the different transmissions of the negatives to the same positive transmission. The negatives used are extremes, and an intermediate value would give fairly good sound reproduction, as the curve would lie between *A* and *B* in quadrant *IV*. Printing the low-density negative to a high positive density gives *AB* with practically no change in positive transmission and hence very low photo-cell current modulation, while printing the high-density negative to a low-density print gives *BA*, a record with sufficient change in transmission, hence sufficient volume, but very bad distortion, as indicated by the curvatures.

Fig. 31 shows the effect of variation of positive transmission, the negative being constant, and the change made by varying the printer lamp intensity. The family of curves in quadrant *IV* shows a progressive change with increasing positive density from a characteristic very concave to the exposure axis, *A* to *D*, which is convex to the exposure axis. Curve *C* is practically a straight line and would give satisfactory reproduction with a positive density of 0.65. The am-

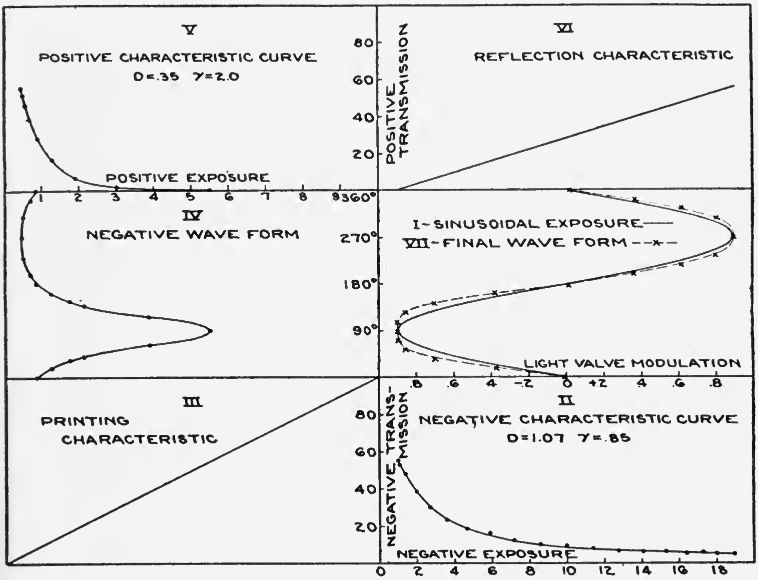


FIG. 33. Reproduction of a sinusoidal curve introducing distortion.

plitude of reproduction measured by the vertical projection corresponds to 33 per cent modulation of transmission, which is also satisfactory from the standpoint of freedom from ground-noise.

Fig. 32 shows graphically the steps in the photographic sound recording process as applied to a sinusoidal sound-wave. The cycle of operation begins in the right-central compartment with the solid line showing a simple sine wave of sufficient amplitude to modulate the light-valve 90 per cent; that is, from the normal value of 0.001 inch to a value of 0.0001 inch on the low-exposure side, and to a value of 0.0019 inch on the high-exposure side. This modulation, in terms of exposure units, results in the negative curve in the lower right-hand compartment. The actual wave-form of the negative is in compartment *IV*. The curved characteristic indicates the presence of large distortion. This distorted wave is printed on to the positive characteristic of compartment *V*. A straight line is used in compartment *VI* to adjust the amplitude of the print to equal that of the original wave. The flattening at the crest and the trough indicates the presence of some third-harmonic distortion.

Fig. 33 shows the same type of diagram as Fig. 32. This shows that a combination of high negative density and long time of development leads to a considerably more distorted final wave-form. The

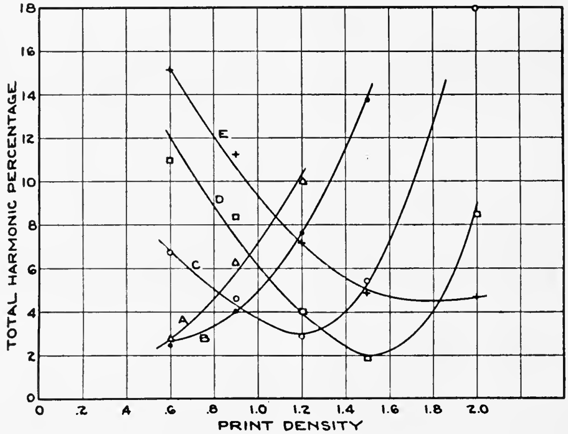


FIG. 34. Distortion as a function of print density in variable-width recording.

excessive flattening in the region corresponding to low exposures indicates that in this record there is appreciable second-harmonic distortion as well as third.

By means of diagrams of this kind, the distortion in wave-form of the recorded sound can be determined. Actual analysis of many records shows that considerable latitude in the exposure processing conditions is allowable, as the harmonic distortion does not change rapidly with the change of these negative or positive conditions. The ear is not critical of small amounts of harmonic distortion.

Turning to the variable-width method of recording, it can be seen that, with this type of record, faithfulness of reproduction is primarily a matter of reproducing a geometric form. The optical system is so adjusted that when no sound reaches the microphone, a part of the sound-track is illuminated to a fixed intensity, leaving the remainder of the track unexposed. When sound strikes the microphone, the moving part in the recorder optical system—that is, the galvanometer mirror—is caused to vibrate and vary the width of the illuminated portion of the track. The exposure of whatever fraction of the width of the track is illuminated is at all times constant. The wave-form of the recorded sound suffers a certain amount of distortion due to lack of sharpness at the boundary of the exposed area. This lack of sharpness is due in part to scattered light in the optical system, a fraction of which reaches the part of the sound-track lying

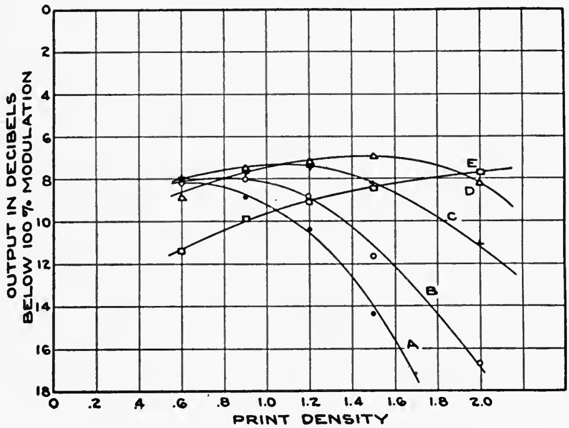


FIG. 35. Modulation of cell current as a function of density in variable-width recording.

without the geometric boundary of the image, and is also due to light scattered by the emulsion itself, giving rise to a finite gradient at the edge of the photographic image.

Many analyses have been made of these records and typical results are shown in Figs. 34 and 35. Fig. 34 shows the harmonic distortion as a function of print density for a series of negative densities. Electrical currents for modulating the galvanometer were derived from a beat frequency whose output was a pure sine wave. The curves show that over a wide range of negative and print exposures the total harmonic content is below the maximum allowable value. The curves show also that for each negative density there is a print density giving a minimum harmonic content. This minimum occurs at approximately equal negative and print densities. Fig. 35 shows the modulation of the photoelectric cell current as a function of print density for the same series of negative densities as those in Fig. 34. This also shows that over a wide range of conditions the volume obtained is within 2 decibels of the maximum. The conditions for maximum modulation and minimum harmonic distortion are approximately at the same point. The optimal conditions may vary with the particular optical recording system used, since this would affect the amount of stray light scattered into the unexposure part of the track. The point of minimum distortion occurs when the lack of sharpness, due to light scattered by the optical system and by the photographic emulsion in the recording process, is compensated for by a corresponding spreading of the image in the printing process. As stated above, a change in the characteristics of the recording system may vary the amount of distortion in the negative sound record. It would, therefore, be necessary to change the printing conditions to obtain the maximum amount of compensation in the printing process.

Improvements in the reproduction of sound by photographic means will depend, in the future as in the past, upon intensive scientific research in relation to sound, electricity, and photography. I believe that this account of the work which has been done on the photographic aspects of the subject will show that research in that field is being prosecuted with energy. The same is true of the work which is being done upon sound and upon electrical apparatus. We may expect, therefore, that the quality of the sound heard in the motion picture theaters will improve steadily, and that eventually it will leave nothing to be desired by the most critical audiences.

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CERTAIN PHASES OF STUDIO LIGHTING*

C. S. WOODSIDE**

Summary.—*Certain technical phases of studio lighting are discussed, including the new line of Mazda lamps for photographic purposes; new materials and contours for reflectors; an analysis of the several means of achieving diffusion; and the projection of shadows upon backgrounds.*

During the course of preparation of a film for use by amateur cinema clubs we had occasion to study several phases of studio lighting. Of vital importance to the amateur and of considerable interest to the professional is the quantity of photographically effective light that can be squeezed out of a single unit. The operation of lamps above their rated voltage was discussed in 1933 by Beggs and Palmer.[1] Since that time a series of Mazda lamps has been designed to operate at very high temperatures and correspondingly high photographic efficiencies. Table I gives their important characteristics.

TABLE I

Characteristics of High-Temperature Incandescent Lamps

Service	†Watts	Volts	Bulb	Base
No. 1 Photoflood	250	105–120	*A*-21	Medium Screw
No. 4 Photoflood	1000	105–120	*PS*-35	Mogul Screw
Movieflood	1000	105–120	*PS*-52	Mogul Screw
Movieflood	1500	105–120	*PS*-52	Mogul Screw
Movieflood	2000	105–120	*PS*-52	Mogul Screw
General‡	1000	115	*PS*-52	Mogul Screw

	Finish	†Lumens	†Color Temp.	†Life Hours	Light Center Length (inches)
No. 1 Photoflood	I. F.	8,875	3450°K.	2	3 3/8
No. 4 Photoflood	I. F.	33,900	3400°K.	10	7
Movieflood	Clear	32,500	3360°K.	15	9 1/2
Movieflood	Clear	49,050	3370°K.	15	9 1/2
Movieflood	Clear	69,200	3430°K.	15	9 1/2
General	Clear	20,500	2990°K.	1000	9 1/2

† Watts, lumens, color temperature, and life are given on the basis of operation at 115 volts.

‡ Shown for purposes of comparison.

* Presented at the Spring, 1934, Meeting at Atlantic City, N. J.

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

The figures of Table I indicate the great increase of illumination that results from operating the lamps at high temperatures. The spectral quality of this high-temperature illumination is different from that of general service lamps. Fig. 1 illustrates the manner in which the radiation in the blue-green section of the spectrum increases with the temperature. This, of course, increases the photo-

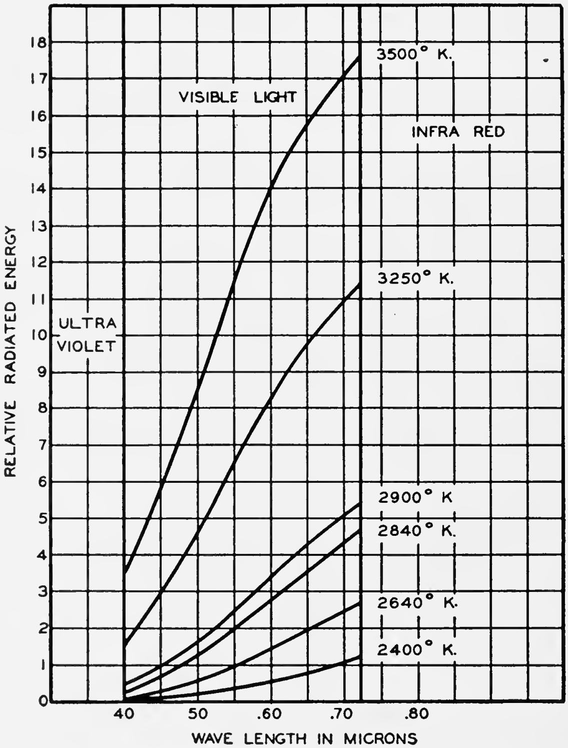

Fig. 1. Distribution of visible energy radiated from tungsten filament.

graphic effectiveness of the light source, as indicated in Fig. 2. Whereas panchromatic film is only slightly more sensitive to light of a high color temperature, the gain with orthochromatic film is from 25 to 50 per cent.

As a practical example, a broadside unit employing two 1000-watt general service lamps could be relamped with two 1000-watt photoflood lamps, with an increase in photographic effectiveness of 70 per cent for panchromatic film and 90 per cent for orthochromatic film. This increased effectiveness is attained with no increase of power or of radiant heat. Radiant heat is an important factor which may cause considerable discomfort on the set. An effective method of eliminating the radiant heat consists in placing a greenish blue glass cylinder over the lamp. The Macbeth Daylighting Company has made an exhaustive study of this subject, and is equipped to provide glasses of various heat-absorbing characteristics. Some of the glasses will remove 90 per cent of the radiant heat while absorbing only 20 per cent of the light. The heat is of course re-radiated from the cylinder, and should be removed by a blower or air duct. The effect

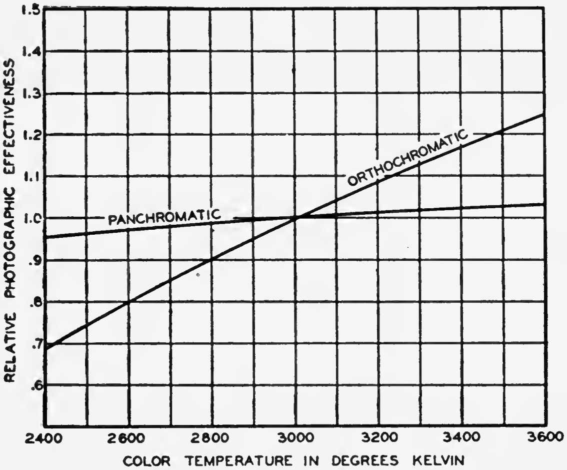

FIG. 2. Relation of photographic effectiveness *vs.* color temperature of incandescent tungsten.

upon the set, however, is a complete absence of discomfort from heat.

Reflecting Equipment.—Recent developments in reflecting equipment have included both contour changes and new materials. In addition to the customary silver, chromium, nickel, and porcelain enamel, we now find rhodium plate, and the Alzak processed aluminum. Rhodium is nontarnishable, and the plating process involved permits contours of extreme accuracy. The Alzak processed aluminum, fabricated by a new electrolytic process, has a very high reflection factor and is available in polished or matte finish. Manufacturers will undoubtedly produce some effective light-weight equipment using this material.

TABLE II

Reflection Factors of Commonly Used Materials

Material	Surface	Reflection Factor
Silvered Glass	Specular	0.90
Alzak Aluminum	Specular	0.83
Alzak Aluminum	Matte	0.85
Rhodium	Specular	0.75
Chromium	Specular	0.64
Nickel	Specular	0.64
Aluminum	Matte	0.65
Porcelain Enamel	Semi-matte	0.75

Table II gives the reflection factors of the materials commonly used in projection. Specular reflection is important in equipment designed to produce high-intensity beams and highlights. Diffuse reflection is important in broadside units for general illumination.

The usual reflector contours employed in the past have been spherical or paraboloidal. The newest equipment for spotlighting employs an ellipsoidal contour. Since this subject forms the basis of another paper we will not discuss it here.

Diffusion.—Inside frosted lamps combined with specular reflectors produce smooth beams of moderate concentration. Where a more highly concentrated beam is required it is necessary to use a clear lamp with a concentrated filament. Even with the biplane filament lamps, the source of which is nearly solid, the projected beam reveals filament striations. To remove the striations a certain amount of diffusion is needed. The two general methods of attaining diffusion are, first, to change the reflector characteristics by stippling, faceting, or employing a series of concentric rings; and, second, by placing a diffusing screen in front of the housing. By the first method the beam is produced by a series of paraboloidal surfaces and a series of surfaces slightly off the theoretical curve. The beam intensity is decreased and the spread increased. Table III shows

TABLE III

Characteristics of Deep Parabolic Reflectors

Surface Characteristic	Beam Intensity (per cent)	Beam Spread (inches)
Smooth	100	26
Concentric Rings	45	62
Stippled	21	72

results produced by deep parabolic reflectors of identical dimensions and material. The loss of beam intensity is serious unless a number of projectors are to be used, when the overlapping beams will produce approximately the same average intensity as the same number of smooth-surfaced reflectors.

The second method has been used in many forms by both amateur and professional. Silk, tracing-cloth, figured glass, spread lenses, wire netting, and other materials have found employment. In an effort to find a suitable screen that would have the minimal effect upon the beam and yet display sufficient diffusing power to avoid objectionable streaks, we came across several materials that proved satisfactory. The new ellipsoidal reflector spotlight with objective lens produces a uniform spot of adjustable size. The older type of spot-

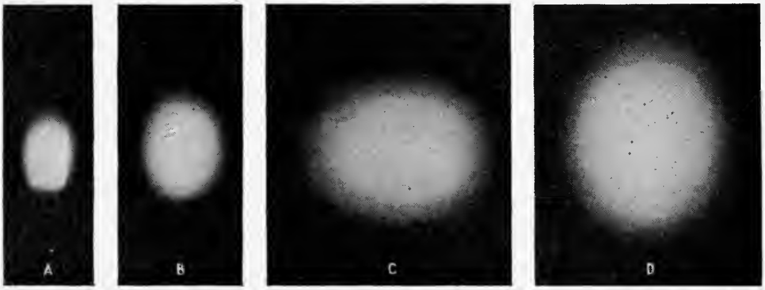

FIG. 3. Modification of spot by various diffusers: (*A*) no diffuser; (*B*) 2-degree circular spread lens; (*C*) Luminex glass; (*D*) Velvex glass.

light, employing a spherical mirror and condenser lens, is limited in focusing positions. Drawing the spot to a sharp focus produces fila-

TABLE IV

Diffusion Test: 2000-W., 115-V. Biplane Lamp; 8-Inch Condenser in Spotlight 17 Feet from Screen

Diffusing Medium	Foot-Candles on Screen	Width of Beam (inches)
None	450	16
2° Circular Lens	380	22
2° Horizontal Spread Lens	310	29
Bubble Glass	320	25
Luminex Wired Glass	225	32
Velvex Wired Glass	215	33
Silk	13	156

ment striations and chromatic aberrations. Any one of several diffusive media will correct this condition. Fig. 3 shows the change of appearance of a spot when such a diffuser is used. Under ordinary conditions the lamp is thrown out of focus to produce a smoother spot. A test made under these conditions with a 2000-watt 115-volt biplane filament lamp in a spotlight with an 8-inch condenser located 17 feet from the screen produced the results shown in Table IV.

The 2-degree spread lens is not available in sizes greater than 9 inches in diameter, and hence can not be used with the larger size floodlights and spotlights. With this equipment the wired sheet glasses, such as Velvex or Luminex, are recommended, since the danger from broken glass is eliminated. When using high-wattage lamps it may be necessary to split the glass into strips to provide for expansion. The heat-absorbing glass cylinder previously mentioned will provide some diffusion and consequently serve a double purpose.

Fig. 4. Wide-angle spotlights are effective in projecting shadows.

Projection of Shadows.—It is frequently required to project a shadow upon a background. A point-source such as a bare lamp will produce a sharply defined shadow, but the wattage required to produce sufficient intensity is usually prohibitive. A more satisfactory method consists in using a focusing type of spotlight in which the lamp is located as far in front of the focus as possible. Such an arrangement acts virtually as a point source, affording good definition and at the same time sufficiently high intensity. It is, of course, necessary to shield the background from the foreground lighting so that the shadow is not blotted out. This can be done by using overhead lights of the concentrating type, as shown in Fig. 4.

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HISTORICAL NOTES ON X-RAY CINEMATOGRAPHY*

R. F. MITCHELL** AND L. G. COLE†

Summary.—*The history of the various attempts to make x-ray movies is briefly traced. In the beginning there was only visual examination. When it became possible to take still x-ray photographs, the next step was to "animate" them by producing a series of stills showing different phases of movement.*

With improvements in x-ray apparatus and reinforcement screens the time of exposure was reduced so that it became possible to take a series of x-ray photographs on a long strip of film. Speeds up to four pictures per second have been reached, though one experimenter claims speeds up to fourteen frames a second.

The "frames" so taken are copied on 35-mm. or 16-mm. film and shown in regular equipment. The 16-mm. display device described attracted great interest at the Chicago Century of Progress Fair and has since excited like interest at other popular expositions.

The methods employed to animate x-ray films are not only of historical importance, but were of considerable legal importance in connection with patent litigation on regular motion picture animation processes.

The subject of this paper was originally prompted by the great interest aroused by the display device illustrated in Fig. 4 exhibited at the Century of Progress Fair at Chicago, Ill., 1934. The historical background has been worked out in what is believed to be a comprehensive and impartial manner, although no claim is made as to its legal accuracy. It is felt that this survey is of historical value for the records of the Society.

In 1896, Hammeter of Baltimore and Wolf Becker in Europe, made attempts to use opaque solutions to render visible the lumen of the hollow viscera.

On July 24, 1897, before La Société de Biologie, Roux and Balthazard[1] presented their first reports of the use of opaque bismuth meal‡ in the study of the motor function of the stomach. Their full report was published in 1898. They seem to have been the first to conceive the possibility of x-ray cinematography of the gastro-intestinal tract,

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* Presented at the Fall, 1934, meeting at New York, N. Y.

** Bell & Howell Company, Chicago, Ill.

† Cole Laboratories, New York, N. Y.

‡ A paste of water and bismuth sulfate.

and the first to accomplish it with frogs. Their efforts merit considerable prominence in view of the time it took for x-ray motion pictures, as such, to become an accomplished fact.

H. P. Bowditch, Professor of Physiology at Harvard University, suggested to W. B. Cannon, then a medical student, that the x-rays be used as a means of studying deglutition under normal conditions. Cannon, in 1896, used free bismuth in studying the stomach of a cat. F. H. Williams, of Boston, deserves a good deal of credit for his efforts in this type of work. Williams, assisted by Cannon, on September 23, 1899, performed further experiments[2] of this type.

Then for almost half a decade there was a silent era broken only by the contributions of O. Kraus and Lommel.

In 1903–04, as a result of gradual improvements in apparatus, the time of exposure had been reduced to fifteen or twenty seconds, so that roentgenograms could be made of the kidney stone while its motion due to respiration was stopped. Sufficiently rapid exposure to avoid the motion of gastric peristalis, however, continued to be impossible. Roentgenographs of the stomach were so blurred that they were of little or no diagnostic value. Methods of exciting the x-ray tube, however, were such as to enable one to observe fluoroscopically the size, shape, and position of the stomach, as well as some of the grosser lesions of the stomach, when present.

In the United States, the resurrection and further development of gastro-intestinal roentgenology dates from 1905. In that year, Hulst, who had visited Rieder in Munich, informally presented roentgenographs of the gastro-intestinal tract at a meeting of the American Roentgen Ray Society in Baltimore. The following year he presented an illustrated comprehensive paper on the roentgenographic method of examination of the gastro-intestinal tract before the American Roentgen Ray Society, which was so complete that it furnished a new impetus to the method Williams had suggested seven years previously. At the same meeting (American Roentgen Ray Society, 1906) Snook[3] first presented the electrical facts upon which he developed and made practicable the transformer that superseded the static machine and coil. Snook developed the transformer in 1906, and this, with the improvement and application of the intensifying screen, enabled exposures to be made in a fraction of a second: thus the blur due to movement of the stomach was eliminated.

Medical men differed concerning the efficiency of diagnosis from a single plate as compared with fluoroscopic examination, because the various roentgenograms of the same stomach differed so much in appearance that a conclusion could not be drawn from the evidence on a single plate. The proponents of the morphologic basis of x-ray diagnosis, particularly Cole[4] and his associates, proceeded to obviate this objection by making a series of plates in as rapid succession as possible. This method was called "serial roentgenography."

During the years 1905 to 1909, fluoroscopic exploration of the gastrointestinal tract became very popular on the European continent.

The experiments of Roux and Balthazard were resumed by Levy-Dorn in 1905, and in 1907 by A. Kohler. These men took a large number of radiograms at a maximum rate of about one per second, and then combined the images in a series.

Levy-Dorn, for instance, radiographed 20 to 22 phases of movement in 20 seconds, and each phase was repeated twice, one after another.

In 1908, Eijkmann succeeded in obtaining x-ray cinematographs of the act of deglutition. The slight thickness of the organs of the throat had enabled him to take instantaneous radiographic poses, that is, poses corresponding to an opening of the primary current of the Ruhmkorff coil. Unfortunately, his process, which was easy to carry out with suitable electrical controls and very small plates, laid the operator open to all the dangers connected with the excessive use of x-rays, causing the hair to fall and provoking erythema. In addition, it could not be used for large organs such as the stomach and the heart. This would have necessitated enormous intensities of x-rays for radiograms of such short duration, and such intensities were not available in those days.

But great improvements soon began to be made in radiological apparatus, which, with the elimination of the closing currents, gave a very high intensity ray, namely, 100 or more milliamperes.

In 1910, at the same Congress where Groedel had presented his roentgenocinematographs of the heart, Biesaldski and A. Kohler illustrated a process, worked out by Kohler during the previous year, consisting in the cinematographic photography of moving images as they appear upon the fluorescent screen. This brilliant idea occurred again, later on, in 1911, to two French radiologists, Lomon and Comandon. Their technic, which was used for the first time in the Physics Laboratory of Professor Broca of the Faculty of Medicine of Paris, also consists in cinematographic photography, with a special lens, of the images on the fluorescent screen.

Until 1909, Austria and Germany led the world in this work; among the leaders were Holzknecht, Strauss, Rieder, Schwarz, Kreuzfuchs, Groedel, Albers-Schonberg, Haenisch, and Kienbock.

In 1910 Cole and his associates[5] developed the idea, and regularly made a series of x-ray pictures to which they gave the name "serial roentgenography." To these roentgenograms some 10 or 12 pictures were made at intervals from 4 to 10 seconds apart, so that in this series all the phases of the gastric motor phenomenon were depicted.

In 1909, Kaestle, Rieder, and Rosenthal[6] made roentgenocinematographic films of the stomach under the term "bioroentgenography." They assembled roentgenograms of a normal individual made on 18 × 24-cm. plates, exposure 20 to 22 sec., 30 to 60 milliamperes at 220 volts. These were reproduced cinematographically to illustrate the normal motor phenomena of the stomach.

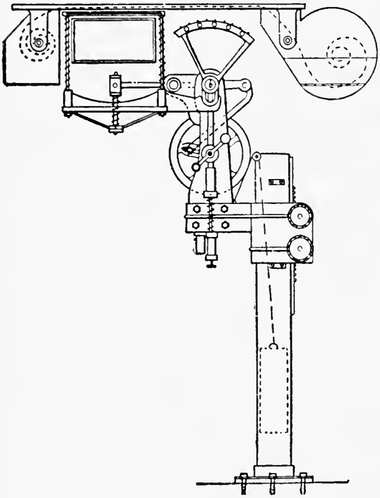

FIG. 1. Drawing of roentgenocinematographic apparatus.

One of the most notable improvements was the development of the reinforcement screen by Gehler of Leipzig. The reinforcement screen is formed of a plate that is very easily penetrated by the x-rays; it is covered on one side by a salt that transforms the rays into ordinary light. If this covered side is closely attached to the sensitive surface of the photographic plate, it is possible to make much shorter exposures than would be necessary otherwise, using the same intensity of ray, with excellent results. It was thus possible to reduce considerably the time required to make a good radiograph.

In 1909 Groedel, making use of radiographic films placed between two reinforcement screens, instead of photographic glass plates, was able to obtain, at 60 to 70 cm., radiograms of the thorax and abdomen in one-fifth to one-twentieth of a second. By means of this improvement and of a special mechanism for changing the plates, Groedel made a film of the movements of the heart, which he obtained by a series of 6 radiograms per second. This he presented before the Congress of Internal Medicine, held in that year at Berlin. Some question has been raised, however, as to whether those films were true x-ray motion pictures or an assembly of a series of stills. Groedel's use of film instead of plates and the use of two reinforcement screens was later improved on by Luboshez, who was instru-

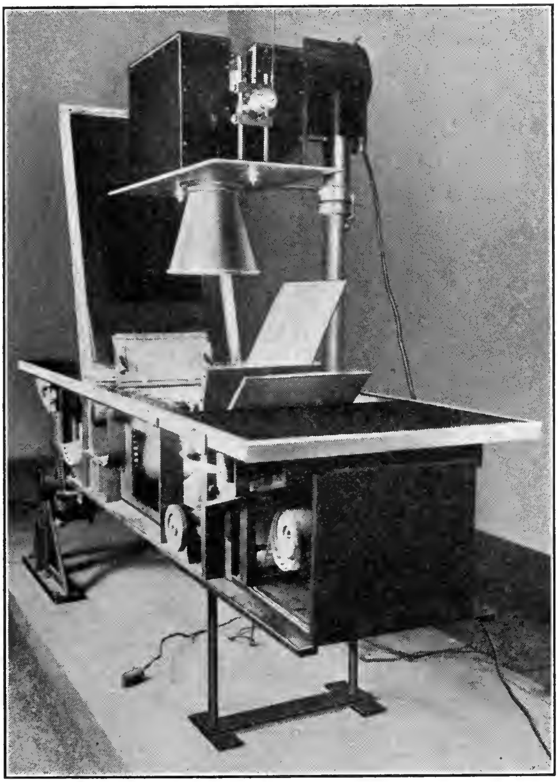

FIG. 2. Roentgenocinematographic apparatus designed to move film 10 inches wide: installed in the Joseph Purcell Memorial Laboratory at the Fifth Avenue Hospital, New York, N. Y.; apparatus opened for threading.

mental in promoting the commercial development of the double-emulsion film used between two reinforcement screens, a system still in use today. The invention of the method is ascribed by Fuchs to M. Levy in 1897.[7]

An x-ray motion picture machine developed by Cole was demonstrated at Detroit, Oct., 1910. It moved a film 8 inches wide, and had a relatively narrow gate, 5 inches. Further experiments with x-ray cinematography on this basis were conducted by Cole[8] with the apparatus shown in Fig. 1, and conclusive results regularly obtained by 1913. The equipment was further improved to the form of the elaborate apparatus shown in Figs. 2 and 3, now in use at the Purcell Memorial Laboratory, Fifth Avenue Hospital, New York, N. Y. This latest machine employs the principle of the regular motion picture machine. It uses film 10 inches wide, perforated in a special perforating machine, in exactly the same manner in which a standard motion picture camera moves a smaller film. With this apparatus we are able to make true motion pictures of the stomach at speeds up to four "frames" per second. The unused film is contained in a magazine, and is shown under the near end of the table. After passing around wheels with sprockets the film is threaded between intensifying screens and then through rollers back into another magazine. In this photograph the apparatus is opened for threading. A worm-gear at the far end of the table enables it to be used in either the horizontal or vertical position, or at any desired angle. The same reflecting mirror that was employed on the serial tables enables one to observe the action of the stomach both prior to making the film and during the time that the film is actually being exposed.

Fig. 3 shows the roentgenocinematographic apparatus closed and ready for action. The tube is enclosed in a ray-proof box. The timing of the exposures is accomplished by a switch at the top of the tube stand, which may be used to break either the secondary or the primary current. The motor that drives the mechanical parts is observed in the foreground; and just behind it is a speed-changing device, similar in size and shape to the gear-shift of an automobile, which enables us to make a continuous roentgenographic film at various speeds. The film is exposed in the special x-ray "camera" which has a gate 10 inches long and 9 inches wide, allowing $^1/_2$ inch of film on each side for the perforations. The film is developed in large tanks somewhat after the manner of developing film from aerial mapping cameras. Each individual "frame" is then copied on one frame of 35-mm. or 16-mm. film for showing in a regular projector.

A wide roll of film was used by H. E. Ruggles[9] for x-ray cinematography of the heart. An account of the heart study made by Ruggles was presented by Chamberlain and Dock,[10] who describe the frames as 8 by 10 inches in size, and taken at the rate of 15 a second.

Lomon and Comandon were able to obtain instantaneous photographs on ultra-sensitive films, illuminating the fluorescent screen by means of very powerful beams of x-rays (corresponding to 300 ma. of a Coolidge therapy ampule on 80 kv.), using specially made fluorescent screens, and employing an $f/1.55$ lens (designed by C. E. Florlian, then engineer to the firm of Lacour-Berthiot). The lens, which is the essential part of the apparatus, was calculated for

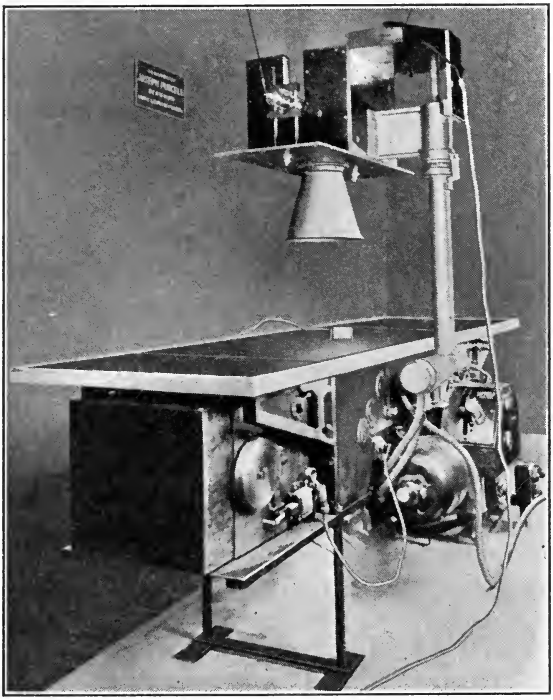

FIG. 3. Another view of Fig. 2; apparatus closed and ready for use.

photographing a flat surface emitting ultra-violet rays, and was therefore composed of substances that were transparent to them, namely, quartz, uviol glass, and glycerine. The cinematograph apparatus of the Pathé firm was so modified as to increase as much as possible the time of the exposure in relation to the time of obturation. The fluorescent screen and the cinematograph apparatus were made solid and firmly fixed on a rigid frame, which in its turn was fixed to the ground. The focusing was very difficult on account of the slight depth of the field of the lens, and once determined accurately, was fixed permanently. Among the various fluorescent screens examined, Lomon, after many trials, chose those of calcium tungstate, like those used for reinforced screens, but coarse-grained.

Three seconds is sufficient time in which to obtain at least two revolutions of the heart, and therefore that period was not exceeded for cinematographing them. The method has not been widely used on account of the danger either to the apparatus or to the patient (x-ray burns).

Direct cinematography of the fluoroscopic screen was attempted by Caldwell in New York in 1910 and by Kay in England, who did extensive work in this connection.

B. E. Luboshez, at the Italian Congress of Medical Radiology described in 1928 a system of direct photography in the center of the fluorescent screen. His first apparatus differed from the regular type by the use of a special lens having the exceptional speed of $f/0.625$, invented by himself.

In 1930, Busi[11] described before the Medical Society of Bologna a method of taking one-quarter of a radiographic frame (24 × 30 cm.) of a double-emulsion photographic plate between reinforcement plate and screen. However, the method had been widely employed in this country for a considerable period prior to 1930.

R. Janker, of Boon, described an apparatus in 1931 in which the film, turning rapidly, passes between two strips of reinforcement screen, which also run with the same speed and the same stops as the film, but in the opposite direction; so that the new film is continually being placed between fresh and rested sections of the reinforcement screen, that is to say, sections in which the fluorescent light is already extinguished. Janker used his method with excellent results, but, it is believed, only on animals: the danger of lesions to man is still too serious.

A newer apparatus shown in 1932 by Luboshez at the National Congress of Medical Radiology at Parma, has, among other improvements, four object glasses or lenses, instead of one. The apparatus demonstrated at the International Congress of Educational and Teaching Cinematography, April, 1934, uses 16-mm. films and takes pictures at normal as well as at an accelerated speed. It works electrically and automatically with the cardiological apparatus; it has a device for counting the meterage for a film 30 meters long and for a duration of five minutes per reel. Finally, it is complete for every form of photographic manipulation, and can be loaded or unloaded in the light. For a normal picture exposure of several seconds it is sufficient to feed the Coolidge type ampule with 50 ma. at 75 kv.: a modest regimen representing the greatest safety for the apparatus and the patient.

We have now reached the logical point where we can discuss the

FIG. 4. Continuous display apparatus, exhibited at the Century of Progress Exposition, 1934, at Chicago; the mirrors and path of the light rays are shown in the left-hand view.

film shown at the World's Fair at Chicago in connection with the "Blonde Lady in Black"; the display is illustrated in Fig. 4. The arrangement involves a continuous projector with a small mirror placed just ahead of the projection lens, the pictures being reflected to another mirror located directly behind a transluscent screen in the position shown. When the projector is switched off, little or no trace of the screen is evident. However, as soon as the button on top of the box is pressed, a picture of very satisfactory brilliance is visible through the thin black material employed. To the layman the model is interesting as illustrating the size and shape of the stomach and its movement when digesting foods. To the medical student it illustrates accurately the several distinct motions that constitute the complex gastric motor phenomena. To the motion picture engineer it is interesting because of the manner in which the various scenes were made.

The first sequence of the film to be shown was made by assembling and copying x-ray plates that had been taken at various intervals in the order of progress of the cycle. Early motion picture films illustrating the movement of the stomach had been made in that manner. This crude cinematographic presentation of what was called serial roentgenograms established that the then-prevalent idea that the stomach held food for several hours until it was digested and then rapidly evacuated it was erroneous.

The first motion picture films that we made were made with an early motion picture projector used as a camera, installed in the wall of a dark room. The regular projection lens was used to photograph a series of x-ray plates assembled in the proper order. The film in the projector was moved past the gate by hand as each succeeding phase was placed before the illuminating box. The x-ray films were registered by arranging them according to the progress of the peristaltic wave, placing one plate upon another, and making two dots on each plate. The dots were then registered by hand on a given spot on the illuminating box. This procedure of making cinematographic films of x-ray plates did not exactly constitute animation, although it was very close to it.

In one case, however, prints were made of a set of x-ray films, and cut-outs were made of the outline of the stomach, showing accurately its size and shape, and the peristaltic waves. The prints were then reversed, so that the plain white cardboard back of the cut-out was photographed, instead of the picture on the cut-out. These were photographed on a film as described before and the film was shown in Detroit in the early part of October, 1910. This procedure of photographing the white cardboard cut-out of the stomach probably was the first attempt at animation, and this film, therefore, is of interest from a historical standpoint as it has already become of interest from a legal standpoint, in that it antedated, by approximately a decade, the animation of *Felix the Cat* by Pat Sullivan. This early animation of x-rays has been of great significance in connection with patent litigation covering animation of regular motion picture films.

The second section is an animated film, consisting of 88 line-drawings made by Cole without a peg-board and without intermediates. Beginning at one end of the cycle and going right through the 88 drawings, there is only a slight backlash on the greater curvature in one short period of the cycle. These drawings were based on an intensive study of innumerable sets of roentgenograms showing the complexity of the gastric motor phenomenon.

The line-drawings were filled in with black by Carpenter and Goldman, and photographed by them. The scene was the final scene of a two-reel animated film, illustrating and analyzing the complexity of the gastric motor phenomenon, and showing the various types of stomach. This film, entitled *The Complex Gastric Motor Phenomenon*, was shown at Chicago in 1923.

The third section is a more accurate presentation of advanced studies made by Cole in the late twenties. Having learned the tricks and science of animation from Carpenter and Goldman, these were applied to a more accurate presentation of the advanced studies that had been made of the gastric motor phenomenon. This film also shows more accurately the altered shape of the cap to conform to the stages of pyloric systole (contraction of the pyloric end of the stomach).

The fourth section is a true roentgenocinematographic film, made of various phases of the same cycle, and was first shown at the Third Radiological International Congress at Paris, in 1931. In proof of the fact that this is a true roentgenocinematographic film, the rapid movement of the small intestine is shown on the same film showing the slow movement of the stomach, proof positive that these are not assembled films of various cycles. The modern machine with which this film was made is shown in Figs. 2 and 3.

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DISCUSSION

DR. COLE: This motion picture projector is perhaps of historical interest in indicating the crude way in which this work was done. I obtained it about 1906, but I am not sure of the date. We set the camera into the wall of the dark room. We turned the crank steadily by hand and moved the film along; then we set up the next one, and so obtained our first animated movies. There were only 20 cut-outs, I believe, and they were repeated over and over again.

Referring to Figs. 2 and 3, the table may work either horizontally or vertically, so that the patient may be x-rayed lying on his abdomen or in the erect posture showing the change in the position of the stomach and the relation of the viscera to each other. The principle of the machine is essentially the same as that of the motion picture camera. We used the Geneva movement. First the film goes through the typical sprockets with the Geneva movement, and comes up over the rollers just beneath the bed of the table, and out, where it is picked up by the second line of Geneva movements which shift it and stop it. It is taken up in a casette or box at the other end. Each time the film moves (it must come to a standstill, of course) it must be registered. Then the intensifying films must be separated—the suction must be overcome. We even use compressed air to aid in separating the film.

The gear box, about the same in size, shape, and characteristics as the gear-shift of an automobile, has four or five shifts enabling us to take an exposure every two seconds, every second; one a second, two a second, three a second and four a second.

One of the greatest difficulties that we had to overcome was registration. It was accomplished by means of an accessory punch. Two punches perforate the film accurately and the film is then positioned so that the punch holes fit firmly over tapered pegs.

MR. CRABTREE: What is the width of the film?

DR. COLE: Ten inches. It is registered approximately to a thousandth of an inch.

MR. CRABTREE: What is the advantage of this scheme over photographing the image on a fluorescent screen?

DR. COLE: The stomach just can't be photographed on the fluoroscopic screen; or at least I won't say it can't be done, but it hasn't been done as yet. The detail obtained by such photographing of the screen is not sufficient for diagnosis, even of the heart and lungs, and detail is the essential factor in the diagnosis of both gastro-intestinal and lung lesions, the heart less so.

MR. CRABTREE: What has been the advantage of the motion picture as compared with the still, from a diagnostic standpoint?

DR. COLE: From organic lesions probably nothing. It has, however, been very essential in proving the accuracy of the complex motion of the stomach. The action of the stomach is made up of seven motions, which we had recognized in the still pictures; enough stills had been taken at random and set up so that we could study them. The ultrascientific man said, "Yes, but that isn't a true motion picture. You haven't proved a systole and diastole of the pyloric end of the stomach."

I wanted to prove that these contentions, as far as the physiology and motor phenomena of the stomach were concerned, were correct. It would be of value in the study of nervous indigestion, functional derangements of the stomach, and so forth. But in the prosperous days, we didn't have functional derangements of the stomach; and now that we don't have prosperous days, we don't have money enough to buy the films. A roll of film like this costs about $50, and we don't get $50 for an examination, especially for nervous indigestion. We might get it for cancer, but it isn't necessary for that.

MR. CRABTREE: How close to the danger limit are you going in exposure? How long an exposure can the patient withstand with safety?

DR. COLE: I believe he could stand at least four cycles of 20 seconds each—a minute and twenty seconds—provided we had filters. It must also be understood that the exposure is not continuous. It is intermittent, whereas with the photographing of the screen, the x-ray is going through the patient continuously. With this method, it is only a flash and then you have to have the period for moving the film.

SYMPOSIUM ON CONSTRUCTION MATERIALS FOR MOTION PICTURE EQUIPMENT*

APPLICATIONS OF STAINLESS STEELS IN THE MOTION PICTURE INDUSTRY

W. M. MITCHELL**

Summary.—*The development of the stainless steels is related with the important position they have assumed in chemical and other industries because of corrosion resistance and unique properties. The steels suitable for use in motion picture industries are classified into two groups: steels for structural purposes, and steels for resistance to corrosion. A brief description of these steels and their possible applications in the industry are given.*

The stainless steels are a group of ferrous alloys notable for high resistance to corrosive attack and for freedom from tarnishing when exposed to the atmosphere. Their commercial prominence began about 1914 with the introduction by H. Brearley, of the Brown-Firth Laboratories, Sheffield, England, of cutlery made from stainless steel; so-called because it did not discolor when in contact with acids of fruits and vegetables, as did the cutlery previously used. For some years applications were restricted to cutlery and cutting tools of various kinds, due, to a certain extent, to the inherent hardness of the alloy and the difficulty of producing it in various forms. But a softer modification, with equal corrosion resistance, was introduced about 1920. This was followed a few years later by the extensive use by one of the larger chemical concerns of the softer stainless steel for the construction of a plant for the manufacture of nitric acid.

At about the same time iron-chromium-nickel stainless steels, which had been developed some years earlier by Strauss of the Krupp Gun Works, were intoduced from Germany. These possessed somewhat higher corrosion resistance, were more easily workable, and at once came into popular use. Since that time development has progressed with great rapidity, and today there is scarcely an indus-

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try that has not benefited in some way through the introduction of this group of metals. Chemical industries have received perhaps the greatest benefit, since here corrosion and its toll are greatest. But equally important applications have been found in the food-handling industries and for architectural ornamental work; and very recently, stainless steel and the light-weight construction made possible by it give promise of reduced operating costs of equipment for railroads and other agencies of transportation.

Corrosion, the destroyer of metals, has always been with us. But until comparatively recent years its destructiveness was accepted as unavoidable, and the losses in various industries were absorbed as a part of the final cost of the manufactured product. This has naturally stimulated research and investigation, with the result that many new metals and alloys have been developed and brought into commercial use, affording in many cases considerable saving and economy. The most important of these are the group of stainless alloys or steels which depend for their corrosion resistance upon the considerable proportion of the metal chromium that enters into their composition.

Since the invention of stainless steel by Brearley and the iron-chromium-nickel steels by Strauss, development has been rapid. Various modifications in the original compositions have been made to produce alloys or steels more suited for particular purposes, so that there are now some 50 varieties of what we are pleased to call "stainless steel" in more or less regular production. Whether or not they should all be classed as "steels" may be open to question, since not all of them are hardenable on sudden cooling from a high temperature and, incidentally, the exact definition of the word "steel" is still a subject of discussion among metallurgists. However, they are all alloys of iron, and comply in general with the mechanical and metallurgical characteristics of what we mean by steel; hence the use of the term "stainless steel" for any or all of this group of alloys.

The outstanding characteristic of this group is their high resistance to corrosive attack; and with this are combined excellent mechanical properties of strength, ductility or hardness depending, obviously, upon the composition of the particular steel. Varying with the composition, we have steels ranging from those capable of great hardness and wear resistance to steels that have virtually no hardening capacity whatever and are suitable for cold forming, bending, and similar operations.

For applications in the motion picture industry the stainless steels can be divided into two groups: those suitable for structural applications where strength, wear resistance, or hardness is required; and those for applications where resistance to corrosive attack is essential. It will be appreciated that these groups are not necessarily mutually exclusive and that certain steels find application for both structural and corrosion resisting purposes.

Consider first applications for structural purposes. By structural we understand those applications where the mechanical properties of strength, hardness, wear resistance, *etc.*, are desired. Some of them may be used for parts of machinery that must be maintained bright and free from rusting and at the same time possess the strength to withstand strains and sudden stresses and to be wear-resisting for a long life without frequent replacement—that is, for shafts, levers, screws, gear-wheels, ratchets, *etc.*, and the various parts that make up the mechanism of the modern motion picture camera. Those members of the stainless steel group that seem particularly suitable for this purpose are the following:

(1) The original stainless cutlery steel of Brearley. Its composition is approximately 12 per cent chromium, 0.35 per cent carbon, with the balance essentially iron. This is a true steel in that it may be made hard by sudden cooling from a high temperature. It is a very hard, strong, wear resisting material, suitable for parts that must withstand much wear and abrasion. It may be machined with reasonable success in the softened (annealed) condition but must be heat-treated (hardened) to develop proper hardness, strength, and corrosion resistance. As with all stainless alloys its surface must be properly polished for maximum resistance to rusting and tarnish. Table I gives average physical properties.

TABLE I

Properties of 12% Cr, 0.35% C Stainless Steel

	Heat Treated	Annealed
Ultimate Strength (lb./sq. in.)	252,000	99,950
Yield Strength (lb./sq. in.)	210,000	65,000
Elongation in 2″ (per cent)	9	27
Reduction in Area (per cent)	24	59
Brinell Hardness	490	175

(Values between these extremes may be attained by variations in heat treatment)

(2) An alloy that might be called "mild stainless steel." This has the same chromium content as the preceding steel, but because of

definitely lower carbon content (usually 0.10 per cent or less) is a softer and more easily workable steel. It is suitable for screws, bolts, nuts, shafting, or other mechanical parts not subject to the most severe service. This steel is produced in two modifications: regular and "free-machining." In the latter, other elements (usually zirconium sulphide) are added in small proportion to render the steel free-cutting so that it may be used in automatic screw machines for rapid production of small parts in quantity, such as screws, nuts, studs, *etc.*

This steel is also produced in flat rolled products as sheets, plates, and strip, but its corrosion resistance to chemical agents is rather moderate, so it is not recommended for applications that demand highest corrosion resistance. Table II gives average physical properties.

TABLE II

Properties of "Mild Stainless Steel"

	Heat Treated	Annealed
Ultimate Strength (lb./sq. in.)	198,000	85,000
Yield Strength (lb./sq. in.)	179,000	55,000
Elongation in 2″ (per cent)	19	30
Reduction of Area (per cent)	50	72
Brinell Hardness	395	170

(3) The next steel to consider contains a higher proportion of chromium than either of the preceding, namely 16–18 per cent, and carbon is maintained less than 0.10 per cent. The low carbon with the higher chromium results in a softer and more ductile alloy. This steel might be called stainless "iron" in that it has virtually no hardening capacity and in that respect more nearly resembles an iron in its softness and ductility. It is to be understood, however, that it is by no means a weak material. Its comparative softness is responsible for its use in sheet or strip form for the manufacture of articles and parts that are formed by bending, pressing, and deep drawing. It

TABLE III

Properties of Annealed, High Chromium, Low-Carbon Steel

Ultimate Strength (lbs./sq. in.)	80,000
Yield Strength	55,000
Elongation in 2″ (per cent)	30
Reduction of Area (per cent)	55
Brinell Hardness	165

possesses high corrosion resistance, and the properly polished surface presents a beautiful silvery luster that is untarnishable when exposed to the atmosphere. Table III gives average physical properties.

(4) The last steel to be considered for structural applications is "18-8." Although this steel should more properly be classed in the corrosion resisting group, it may equally well be used for machine parts that require high resistance to corrosive attack. It is producible in all desired forms—sheets, bars, plates, strip, seamless and welded tubing, wire, *etc.* For various applications there are small variations in analysis, and we may recognize three types: regular—used chiefly for corrosion resistance; free-machining—a special analysis containing a small percentage of selenium to impart easier machining qualities, as this steel will sometimes prove difficult to handle in machining, drilling, *etc.;* and a "stabilized" analysis containing a small percentage of titanium, and used practically entirely as a corrosion-resisting metal for tank work, which must be fabricated by welding.

This steel has high ductility and toughness as shown by its physical properties, which average as in Table IV.

TABLE IV

Properties of "18-8" Steel

Ultimate Strength (lb./sq. in.)	85,000
Yield Strength (lb./sq. in.)	40,000
Elongation in 2″ (per cent)	60
Reduction of Area (per cent)	70
Brinell Hardness	135

Freedom from tarnishing in the atmosphere is one of the important characteristics of the stainless steels. This holds true in the salt air of the seashore and the moist air of the tropics, as well as in less severe surroundings. It should be emphasized that this property is inherent in the metal itself, and that it is tarnish resistant "all the way through." It is thus not a mere surface coating, as produced by electroplating operations, which may peel or be worn off in service. This is a fundamental property, and one that gives these steels an outstanding position in this respect. Another important fact to be noted is that all varieties of stainless steel are superior to regular carbon steel in resisting heat, both from the standpoint of resistance to scaling and maintenance of strength; hence, they are particularly applicable to the construction of projection apparatus.

In considering the second group of applications, namely, for corrosion resistance, we shall disregard chemical plant operations which are concerned with the manufacture of motion picture film, silver halide emulsions, *etc.*, as this is a phase of the industry which is more chemical than photographic.

Corrosion-resisting applications in the motion picture industry are mainly concerned with equipment for fixing and development of positive and negative film. Such equipment consists of tanks, shafting, and various intricate devices that convey the film through the processing solutions and drying chambers. There are several alloys suitable for the manufacture of this equipment, *viz.*, "18-8" and "18-8" with molybdenum.

(1) *"18-8."* The 18 per cent chromium, 8 per cent nickel steel already mentioned. This is produced by steel mills in sheets, plates, strip, seamless and welded tubing, wire, bars, *etc.* As this steel can can be formed by pressing, bending, and deep drawing, and fabricated by all methods, it is possible to construct from it virtually any kind of equipment or apparatus that is desired. It has higher corrosion resistance than any of the straight chromium steels previously mentioned. General resistance is against nitric acid and oxidizing agents, sulphur and many of its compounds, and to many organic acids and their salts. The publication of data derived from laboratory corrosion tests is considered inadvisable, as such tests rarely reproduce actual working conditions and hence are limited in ability. A better method of determining the value of any alloy for corrosion resisting purposes is by test under actual working conditions, and such tests can usually be made economically and with reasonable convenience.

Actual experience with the usual developing baths containing pyro, metol (elon), and hydroquinone, alone or in combination, shows that "18-8" is unattacked by these solutions. In consequence, this steel is now practically standard throughout the larger studios for construction of developing machines and parts.

For bleaching solutions containing potassium ferricyanide and for toning solutions, "18-8" has not been altogether satisfactory when the solutions are allowed to stand in trays exposed to the air for indefinite periods. The same applies to fixing baths under certain conditions, where attack may take place at the air-liquid surface. For such chemical media a still more corrosion resisting steel may be required, such as "18-8 Mo."

(2) *"18-8 Mo."* This steel was also developed by Strauss of the

Krupp Gun Works, and was originally applied to the sulfite pulp industry, where corrosion is particularly severe. The addition of some 2–4 per cent molybdenum to the "18-8" analysis confers additional resistance to a variety of chemical media, particularly acids, both organic and inorganic. In consequence, this steel is rapidly coming into use in many industries, and so far it has given excellent results. "18-8 Mo" is produced in flat rolled products, as sheets, plates, and strip, and also in bar stock and in castings. The production of seamless tubing is, however, difficult and has not yet reached the commercial stage.

Another steel, also containing molybdenum, which may be considered a modification of "18-8 Mo," has the composition 27 per cent chromium, 3.5 per cent nickel, and 1.5 per cent molybdenum. It has the advantage of easier workability and has successfully been produced in seamless tubing. It is quite probable that either or both these stainless steels with molybdenum will be found resistant to bleaching and toning solutions and to fixing baths. Either can be welded satisfactorily, and as molybdenum acts as a "stabilizing" agent, heat-treatment of welded equipment after fabrication will probably not be required.

(3) The U. S. Steel Corporation has recently placed a new product on the market which is particularly well suited for construction of developing tanks. This is a stainless veneered steel, to which the trade-name *Plykrome* has been given. It is essentially a composite metal made up of a plate of carbon structural steel to which has been bonded a relatively thin coating of stainless steel of the "18-8" analysis. These are perfectly united by a patented process, and will remain so under all ordinary fabricating operations. Compared to solid stainless steel plate, which is corrosion resistant on both sides, Plykrome is corrosion resisting on one side only. As it may be welded, with proper technic, so that the weld is as corrosion resistant as the rest of the surface, it may be fabricated into tanks of all kinds. Its base price is about one-half that of solid "18-8" plates of the same thickness. Thus, it is possible to effect a saving of from 25 to 40 per cent more, depending upon labor cost, over the cost of solid stainless tanks of identical dimensions, by the use of Plykrome.

DISCUSSION

CHAIRMAN CRABTREE: How do the corrosion resisting properties of free machining steel compare with those of 18-8? How is it made free-machining?

MR. MITCHELL: By adding a small amount of selenium. Selenium is analogous to sulphur, chemically. It makes the steel, I won't say easy to cut, but easier to cut then the ordinary 18-8.

CHAIRMAN CRABTREE: What are its corrosion resisting properties?

MR. MITCHELL: Virtually the same. The difficulty of machining 18-8, as those of you know who have had any experience with it, is due to the work-hardening properties of the metal. The metal hardens rather severely when worked cold, and if the tool is at all dull, the surface of the metal will become hardened and glazed so it becomes impossible to cut through it.

To avoid that, the tool must be sharp, have ample clearance and "lip-rick," as we say, and plenty of power behind it. The free-machining variety, of course, is of more use for work in automatic screw machines where large numbers of small parts are to be made.

CHAIRMAN CRABTREE: I understand that when you weld the 18-8, unless particular precautions are taken to anneal the weld, the weld will corrode more rapidly than the material proper. Do I understand that there is a new variety which is more satisfactory for welding and which is not open to this objection?

MR. MITCHELL: Yes. The difficulty is not corrosion at the weld itself but in the region adjacent to the weld. It can be avoided to a certain extent by specifying a material of low carbon content. The difficulty is caused by the precipitation of chromium carbide which takes place at certain temperatures in regions adjacent to the weld. The formation of chromium carbide absorbs chromium from the solid solution of the steel, so lowering its corrosion resistance. This occurs particularly along the borders of the crystalline grains, so that the material will be disintegrated completely under certain conditions. That can be overcome by using a very low carbon material, or by heat-treating the entire piece, which is very often impracticable because of the general size or shape. This difficulty has also been overcome by adding a small quantity of titanium or columbium. Carbon has greater affinity for titanium or columbium than for chromium, and under favorable conditions there will be precipitation of titanium or columbium carbide instead of chromium, and the corrosion resistance of the metal is not destroyed thereby.

This material is called "stabilized" because it is given a special heat-treatment which stabilizes it against change during welding. It has been found to be quite successful and obviates the former difficulty of corrosion alongside the welds in the regular 18-8.

CHAIRMAN CRABTREE: With the low carbon content material, what do you sacrifice by lowering the carbon? In other words, why not always use low carbon?

MR. MITCHELL: The sacrifice is on the part of the steelmaker, because the low carbon is more difficult and more expensive to produce.

CHAIRMAN CRABTREE: Can you say a little more about the properties of the 18-8 with molybdenum? You say it is more resistant to corrosion. Is it more difficult to machine?

MR. MITCHELL: I should not say it is any more difficult to machine. Molybdenum was introduced originally for the sulfite pulp industry, to provide better resistance against the sulfurous acids and other conditions encountered in the digester and pipe lines. There it has given very good service. Due to the fact that it has better resistance to dilute mineral acids than the straight 18-8, it has found various applications in chemical plants. Also it has been used successfully in the textile industry, where dilute acid solutions are used in connection with dyeing.

I don't know whether it has been used at all in photographic work, but it would seem to me that due to its higher corrosion resistance than the straight 18-8, it should be a good material to consider for fixing-tanks and so forth, where there has been trouble with 18-8.

CHAIRMAN CRABTREE: What happens when you weld it?

MR. MITCHELL: It can be welded as satisfactorily as 18-8, and there is very little difficulty from carbide precipitation; it must be used also in the low carbon form. It has excellent physical properties, is amply strong for any requirements, and can be obtained in the form of sheets or bars, *etc.* Seamless tubing is rather difficult to produce, and is not generally available. The price of 18-8 with added molybdenum is about one-third more than the regular 18-8.

LAMINATED BAKELITE IN THE MOTION PICTURE INDUSTRY

R. L. FOOTE*

Summary.—*The nature, manufacture, and applications of laminated bakelite are described briefly, and reference is made to its current and possible uses in motion picture work.*

Laminated bakelite has a definite set of unusual physical and chemical properties quite unlike those of any other material. It will be shown later, how certain of those properties combine to make laminated bakelite a material of unusual versatility and value in mechanical applications.

In the manufacture of laminated bakelite a base material such as kraft paper, cotton rag paper, cotton duck of various thicknesses, asbestos paper or asbestos fabric, is first impregnated with a dissolved or liquid phenol formaldehyde synthetic resin. This is a continuous process in which the base material is handled in rolls and is continuously impregnated and dried.

During the coating operation, it is necessary to maintain careful laboratory control of the specific gravity of the resin and finish with an exact degree of dryness. If the equipment that is used is modern and accurate, and the operating personnel careful and conscientious, the resulting product will be a strong, uniform, stable, moisture-resistant and free-machining laminated bakelite. Inferiorities in

* Synthane Corp., Oaks, Pa.

either equipment or men will result in material that may readily absorb moisture, machine poorly, warp badly, have low shock-resistance or—perhaps most serious of all—be subject to change of state; that is, the material will show definite changes in its properties after shipment and when subjected to normal service conditions.

For the production of laminated bakelite sheet, the coated sheet material is next cut to size. The desired number of coated sheets are stacked between polished stainless steel finishing plates and placed in a hydraulic press having steam-heated platens. The stack or make-up, as it is called, is then cured at a temperature of about 325°F. under a pressure of 2000 pounds per square inch.

Though nearly dry, the synthetic resin in the coated sheets will soften under the influence of heat. It is however, thermo-setting; that is, the continued application of heat causes a chemical change to occur, when the resin becomes a hard, infusible, insoluble substance that is definitely not thermoplastic. The heavy pressure causes the "make-up" to compress as the resin softens, and to have a minimal cross-section when the chemical change, or "kick-over," as it is termed, occurs. This results in the product known as laminated bakelite sheet. Similarly, curing the coated stock after first winding it upon a mandrel of the desired size and shape, produces tubular laminated bakelite. The resulting product may be sawed, turned, drilled, punched, milled, shaped, or threaded. Any of these machining operations may be performed with comparative ease, and should be done at relatively high speed.

In the motion picture industry many uses of laminated bakelite are already common practice. Throughout the sound equipment field, laminated bakelite is widely used for insulation, in both recording and reproducing apparatus. In addition, gears, pinions, shims, and bushings for cameras and projectors are at times made of this material.

With quietness becoming an increasingly important factor in such equipment, still better silent gear materials are required. Some refinements have already been made, but still greater improvement is possible. Materials quite in advance of anything commercially available are now possible in the laboratory and will soon be offered for these purposes.

In the processing equipment field, the usual electrical applications to panels, insulating washers, and so forth, are to be found, of course. Much less common, but of great importance, are the purely mechanical applications recently developed. Laminated bakelite combines high ratio of strength to weight, ready machinability, and quite complete resistance to the action of all chemicals thus far encountered in film processing. Thus, it is an ideal material to use for stationary parts in contact with otherwise corrosive chemicals. These parts have so far included various bushings, spacers, frame members, pipe fittings, and other stationary parts. In addition, laminated bakelite makes an ideal bearing or journal when lubricated with water or whatever chemical solution might be present. Free-running and long-wearing bearings and idler rolls are being applied more and more widely.

Some doubts have existed as to the material's ability to resist the action of caustic soda. Due, however, to the low concentrations generally employed, the development of caustic resistant resins, and improved technic in manufacture and application, this difficulty has been completely overcome.

Laminated bakelite possesses several other interesting features. As compared with metals, it is nearly non-resonant. To improve its sound and vibration absorbing qualities still further, a method of laminating sheet rubber into the make-up has been developed. This results in an almost completely non-resonant material, yet one that retains the physical strength of laminated bakelite. It is possible also to treat the surface sheet so as to imitate wood grains, leather surfaces, pebble finish, or even weather-beaten shingles.

It is probably impossible permanently to remove all noise from a rotating mechanism, such as a gear train. Refinement of the mechanism soon reaches a point of commercial impracticability. But if we wish completely to silence a camera or projector mechanism of this sort, why not house it in a non-resonant case of this material with a surface finish of imitation morocco leather or pebble grain?

Laminated material can be molded in irregular cross-sections, and yet retain high impact strength. In order to stiffen a simple beam or cantilever section, it is possible to bury a metal insert in the section Again, with some limitations, we may combine the strength and stiffness of metal with the corrosion-resisting properties, permanent finish, and, perhaps, eye-appeal of laminated bakelite.

DISCUSSION

MR. MACOMBER: How does bakelite withstand caustic soda, sulfuric acid, and acetic acid, as compared with rubber?

MR. FOOTE: Sulfuric acid, up to about 20 per cent concentration, shows no effect, and is not materially detrimental. I know of no case where acetic acid has shown any effect upon a good piece of laminated stock. As to caustic soda, if we are not interested in the surface appearance, and the concentrations used are not too high, it is quite satisfactory. For example, we have some heavy-duty bearings working in about 14 per cent caustic and at very high unit loads and low speeds. After a year or so of service, they look perfectly awful when they are taken out, but are entirely serviceable as bearings.

It is now possible to produce material that is approximately ten times as caustic-resistant as, let us say, the ordinary garden variety of laminated bakelite was a year or so ago. Whereas we used to make a piece that would last two years, we can now make it last ten times as long, according to tests.

CHAIRMAN CRABTREE: With regard to ordinary photographic solutions, that is, developers and fixing solutions, these materials are surprisingly resistant. In cases where slight possible distortion or expansion of the material is not important, I believe the material is a very promising one for such equipment.

INCONEL AS A MATERIAL FOR PHOTOGRAPHIC FILM PROCESSING APPARATUS

F. L. LAQUE*

Summary.—*The chemical and physical properties of the alloy Inconel are described, with especial reference to the requirements of film processing equipment. Examples of applications of Inconel in motion picture film handling apparatus are given. As a background to the use of Inconel, the more familiar properties and uses of monel metal and pure nickel with photographic solutions are discussed briefly.*

Inconel is an alloy first made commercially available by the International Nickel Company, Inc., in 1931. Since it is one of the newest of the corrosion-resisting materials, a brief description of its general characteristics will be given before a discussion of its usefulness in connection with film processing.

COMPOSITION AND MECHANICAL PROPERTIES

Inconel contains approximately 80 per cent of nickel, 14 per cent of chromium, and 6 per cent of iron. Its principal constituents combine the acid and alkali resistance of nickel with the passivating effect of chromium to provide resistance to the attack of a wide variety of corrosives, including those encountered in film treatment processes. It is pertinent to the present discussion that nickel, the principal con-

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stituent of Inconel, has for many years been used to protect films and emulsions from harmful metallic contamination during their manufacture. Typical of such use of nickel is the emulsion strainer illustrated in Fig. 1.

The mechanical and physical properties of Inconel are given in Tables I and II, from which it will be seen that the alloy is exceptionally strong and ductile, and that the range of both strength and ductility provide an opportunity for selection of a combination

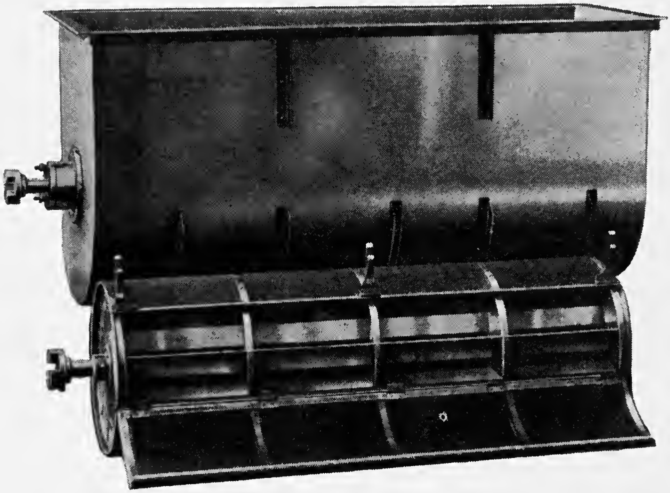

Fig. 1. Pure nickel photographic emulsion strainer.

best suited to particular needs. Thus, for example, the ductility desirable for sheet fabrication is as readily attained as the high strength required for springs. The strength and hardness properties of Inconel give it good resistance to wear, which is often needed for

TABLE I

Mechanical Properties of Inconel

	Tensile Strength (lbs./in.²)	Yield Point (lbs./in.²)	Elong. (per cent)	Red. in Area (per cent)
Sheet and strip				
Annealed	80–95,000	30–40,000	45–55	
Rod				
Annealed	80– 95,000	30–40,000	45–55	65–75
Cold Drawn	100–115,000	80–95,000	20–30	
Wire				
Annealed	80– 95,000	30–40,000	45–55	
Spring Temper	175–200,000			

TABLE II

Physical Constants of Inconel

Density	8.55
Coefficient of expansion	
100°–200°F. range	
per °F.	0.0000064
per °C.	0.0000115
100°–1400°F. range	
per °F.	0.00000696
per °C.	0.0000161
Heat conductivity	3.5% that of copper
Specific heat (77°–212°F.)	0.109
Melting point	
°F.	2,530
°C.	1,388
Modulus of elasticity	32,000,000
Modulus in torsion	10,300,000

parts rubbed by rapidly moving film. The high value of the modulus of elasticity indicates exceptional rigidity; and the low coefficient of expansion, which, incidentally, is about the same as that of steel, is useful in welding operations (by reducing buckling) and in operating equipment subjected to wide or frequent changes of temperature.

The widespread use of springs in cameras, projectors, and film developing equipment makes the excellent spring properties of Inconel especially interesting. These properties are given in Table III, which includes also, for convenient reference, data on some other

TABLE III

Spring Properties of Inconel

Metal	*S* Torsional Elastic Limit (lbs./in.²)	*G* Torsional Modulus	*S–G* Deflection Index	*S²G* Stored Energy Index	Maximum Operating Temperature (°F.)
Ferrous					
Music wire	140,000	12,000,000	0.012	1640	200
Carbon steel	125,000	11,500,000	0.011	1360	400–430
Chrome vanadium	110,000	11,500,000	0.0096	1050	400–430
Tungsten steel (high alloy)	110,000	11,500,000	0.0096	1050	700
Stainless Steel	100,000	10,000,000	0.010	1000	500–600
Nonferrous					
Inconel	100,000	10,300,000	0.0097	960	600–700
Monel Metal	70,000	9,000,000	0.0072	540	400
Phosphor bronze	70,000	6,500,000	0.011	750	Atmospheric
Brass	50,000	5,500,000	0.0091	450	Atmospheric

commonly used spring materials. The torsional elastic limit of Inconel given in Table III refers to coiled helical springs after solid compression; as coiled, the springs have a torsional elastic limit of 65,000–75,000 pounds per square inch.

Inconel is available in all the usual forms, such as sheets, bars, rods, tubes (seamless and welded), and wire. It is amenable to fabrication by all common methods and can be welded, soldered, and silver-brazed. Its corrosion resistance is not adversely affected by the heat of welding, and welded parts do not require heat treatment to assure corrosion-resistance.

GENERAL CORROSION-RESISTANCE

The corrosion-resistance of Inconel is, of course, of greatest interest to motion picture engineers. The alloy was developed primarily to resist corrosion and staining by organic acids such as are found in fruits and other food products. To illustrate its resistance to dilute acetic acid, commonly used in film processing solutions, specimens of Inconel were exposed to vinegar containing 10 per cent of acetic acid in a storage tank for 240 days. The indicated rate of attack upon specimens subjected to both continuous and intermittent immersion was equivalent to penetration at a rate of less than one ten-thousandth of an inch per year. In boiling 2 per cent acetic acid the rate of corrosion of Inconel was found to be less than one-thousandth of an inch per year. Data on the resistance of Inconel to sulphuric, hydrochloric, and nitric acids are given in Table IV.

TABLE IV

Rates of Corrosion of Inconel by Sulfuric, Hydrochloric, and Nitric Acids

Acid	Rate of Corrosion in Inches Penetration per Year*	Conditions of Test
5% Hydrochloric	0.125	Cold, fully aerated, 16 ft. per minute flow
5% Sulfuric	0.125	Cold, fully aerated, 16 ft. per minute flow
5% Sulfuric	0.009	Cold, air free, 16 ft. per minute flow
5% Sulfuric	0.200	Hot, fully aerated, 16 ft. per minute flow
5% Nitric	0.22	Cold, fully aerated, 16 ft. per minute flow
25% Nitric	0.002	Cold, fully aerated, 16 ft. per minute flow
45% Nitric	0.001	Cold, fully aerated, 16 ft. per minute flow
65% Nitric	0.003	Cold, fully aerated, 16 ft. per minute flow

* The depth to which uniform corrosion would penetrate a surface of the metal exposed to the corroding solution continuously for a year.

Inconel possesses sufficiently good resistance to sulfuric and hydrochloric acids to enable its use where these acids may be encountered. However, the availability of such other materials as monel metal or nickel, whose resistance to these acids is superior to that of Inconel, would not justify its use, simply because of its resistance to sulfuric or hydrochloric acids. At the same time, the fact that Inconel withstands such a highly corrosive solution as aerated 5 per cent hydrochloric acid as well as it does, is impressive evidence of its inherent resistance to chemical attack.

It will be noted also in Table IV that the resistance of Inconel to concentrated nitric acid is superior to its resistance to the dilute (5%) acid. Consequently, if nitric acid should be used for cleaning Inconel film processing equipment, it would be preferable to use acid of 25 per cent strength or stronger.

Because of its high nickel content Inconel is, of course, strongly resistant to attack by alkaline solutions, while its chromium content increases its resistance to sulfur compounds. Consequently, it would be expected that Inconel would be highly resistant to alkaline sulfur compounds. That this is the case was demonstrated by a test in a boiling concentrated (50%) solution of sodium sulfide, where the indicated rate of attack was equivalent to penetration at a rate of only about four one-thousandths of an inch per year. The resistance of Inconel to straight caustic corrosion was indicated by a test in which specimens were exposed for thirty days within a vacuum evaporator producing caustic soda of 70 per cent strength at 260°F. The results showed that Inconel was practically free from attack, the rate of penetration being less than one ten-thousandth of an inch per year.

RESISTANCE TO DEVELOPING SOLUTIONS

It is not only necessary that a material used in contact with photographic solutions be resistant to chemical attack by them, but it is also requisite that the material be free from detrimental effects upon the properties of the solutions themselves. The advantage of nickel and high nickel alloys in this respect has already been mentioned in connection with the manufacture of photographic film.

Of probably greatest importance from the standpoint of metallic contamination of film processing solutions is the well-known effect of certain elements in inducing fogging action in developers. This subject has been investigated in considerable detail by Crabtree and Matthews[1] who found that copper and tin and alloys containing these elements were most active in inducing chemical fog in developing solutions. A notable exception to this general conclusion was that monel metal, although containing copper, did not fog the developing solution. These investigators found also, by adding metal salts to a typical developer, that tin and copper had a fogging action, but that, among other elements tested, nickel and iron—constituents of Inconel—had no fogging effect. Similar data on chromium, the third constituent of Inconel, are lacking, but sufficient experience has been obtained to show that chromium, as it is present in Inconel, at least, has no detrimental effect upon developing solutions.

Quantitative data on the resistance of Inconel to developing solutions are not available, but results of qualitative tests and practical use of the material in the form of containers for such solutions have demonstrated that corrosion is practically nil. This is not surprising, in view of the widespread use of monel metal and nickel for handling developing solutions, and the fact that the resistance of Inconel to the chemicals used in developers is at least as good as that of either monel metal or nickel.

Typical of results of practical experience with Inconel in contact with developing solutions is the following quotation from a report from the first user of Inconel for photographic solutions: "For the past six months we have been using trays made of chrome nickel (Inconel) for developing prints, and find that they are very satisfactory indeed. The developer forms a deposit upon the inside surface of the tray, but this deposit is very easily removed with 28 per cent acetic acid, and there is no corrosion whatever of the surface of the tray." On several occasions Inconel has been tested as to its suitability for use with developing solutions, with uniformly satisfactory results, as indicated by the following examples of such tests:

A specimen of Inconel was exposed for more than six weeks in a standard solution of Eastman-prepared x-ray developer at the University Hospital, University of Michigan. This sample showed not the slightest evidence of corrosion after this test. Specimens of Inconel were exposed to developing solutions (elon-hydroquinone and pyro-soda) at Wright Field, Dayton, Ohio, for more than ten months, without any evidence of corrosion. Tests in the laboratories of a large producer of photographic equipment demonstrated that Inconel is satisfactory for use with developing solutions. Of direct interest to motion picture engineers is that at least four of the largest motion picture companies on the Pacific Coast have made exhaustive tests on the suitability of Inconel for use with developing solutions and all have found it to be entirely satisfactory.

FIXING SOLUTIONS

Probably the most important property of Inconel, so far as equipment for film processing is concerned, is its resistance to the complex corrosive effects of wholly, or partly, exhausted hypo fixing solutions. It is a well-known fact that most metals and alloys will precipitate silver from such solutions. Such precipitation of silver is always accompanied by a certain amount of corrosion, part of which is due to the direct solution of an equivalent amount of the material to replace the silver plated out, and part to complex galvanic and concentration cell effects that follow the deposition of silver and the entrapment of fixing solution beneath loose deposits. Crabtree, Hartt, and Matthews[2] have shown that such silver deposits are not protective to the underlying metal.

It has been found that under ordinary conditions of use no silver will deposit upon Inconel in fixing solutions, and thus the corrosion is practically nil. This property is also important in connection with moving parts, the dimensions of which must be maintained within very close limits and where the deposition of silver may cause mechanical difficulties as well as corrosion.

There is some indication from tests in the laboratories of a film producer that the deposition of silver on Inconel which does not occur in fixing solutions at ordinary temperatures may occur at higher temperatures. In some tests in a used fixing bath at 110°F., a slight amount of silver was plated out upon an Inconel tray used to hold the solution, but there was no appreciable corrosion of the tray.

It is interesting to note that the first piece of Inconel used for photographic equipment was made up into a welded container for a hypo solution. This container has been in practically continuous use for about three years, and has remained bright and free from silver deposits and shows no evidence of corrosion. A specimen of Inconel was exposed for more than six weeks in a standard hypo fixing solution at the University Hospital, University of Michigan. It remained clean and bright, and free from deposited silver. A sample of Inconel that had been continuously immersed in hypo for ten months, in the film developing department of the International Nickel Company's Research Laboratory at Bayonne, N. J., also showed no signs of corrosion or deposited silver.

Most of the larger motion picture studios have tested Inconel in contact with hypo fixing solutions, and all have reported that it has withstood their tests satisfactorily. A typical result of such a test follows:

A specimen of Inconel in the form of a sheet measuring $2^1/_4$ by $3^1/_2$ in. was suspended in the reservoir tank of the hypo circulation system in the film developing laboratories of Consolidated Film Industries, Fort Lee, N. J. It was so located that part of the time it was immersed in the solution and part of the time exposed to the air. The sample was weighed before exposure, after eight days in the tank, and

Fig. 2. Monel metal shafting, gears, bolts, and screws in main channel of film-developing unit.

at the end of the test period of one hundred and fifty-four days. The loss of weight during the first eight days was only 0.7 mg., and the total loss of weight during the whole test was only 2.5 mg., or less than 0.0001 oz. That such a rate of corrosion is insignificant can be readily appreciated when it is considered that it would account for penetration of a sheet to a depth of only 0.000003 inch per year.

Its better behavior in fixing solutions is the principal reason why Inconel should be preferred to the older materials, monel metal and pure nickel, for film processing equipment. In fact, so far as developing solutions are concerned, both nickel and monel metal are entirely adequate, and it is doubtful whether Inconel or any other material could show an important advantage over them. The older materials are also suitable for fixing solutions in amateur work where the silver content of the fixing baths does not build up to as great an extent as in professional or commercial laboratories. Both monel metal and nickel are useful for wash-tanks. However, for hypo wash-tanks Inconel would have the advantage of remaining bright, whereas nickel and monel metal would gradually become darkened by silver and sulfur compounds.

Monel metal has been used successfully to a considerable extent for motion picture developing apparatus in the form of shafting, gears, rods, bolts, *etc.*, on automatic equipment such as is illustrated in Fig. 2. Other uses for both monel metal and nickel are trays, clips, *etc.*, such as illustrated in Fig. 3.

TONING, INTENSIFICATION, AND REDUCTION SOLUTIONS

Toning baths, as a class, appear to be much more corrosive to metals than either developing or fixing solutions. This is especially true of solutions containing potassium ferricyanide and salts of iron and uranium. Consequently, caution should be exercised in using them in equipment made of Inconel or other corrosion-resisting materials. At the same time, it is interesting to note that Inconel has been found to be much superior to monel metal for this service. An Inconel coil has been in use for several months for heating and cooling a sepia toning bath containing hypo, potassium alum, silver nitrate, and silver chloride in the usual proportions. It is true that the Inconel has suffered some corrosion, as evidenced by the accumulation of a scale of corrosion product plus some deposit from the solution, most evident at the liquid line. However, the rate of attack has been moderate, and the accumulated scale appears to have been somewhat protective. Glass coils which the Inconel replaced were less satisfactory because of occasional breakage and the resulting detrimental effects upon the prints being processed. It is significant that whatever corrosion of the Inconel occurred had no harmful effect upon the quality of the work turned out.

Solutions used for intensification, such as those containing bichloride of mercury, are also very corrosive to metals. Inconel is not recommended for use in contact with solutions containing appreciable percentages of bichloride of mercury.

Inconel should be satisfactory for use with bleaching solutions such as a mixture of potassium bichromate and sulfuric acid at atmospheric temperature. A sample of Inconel showed no evidence of attack after three days' contact with a solution made up to contain $3^3/_4$ oz. of potassium bichromate and 5 oz. of sulfuric acid in a gallon of water.

Solutions used for reduction also belong in the group that require caution in their use with metals. This is especially true of those containing free iodine, which should not be used in contact with Inconel or other metals. Data on the behavior of Inconel in contact with acid solutions containing potassium permanganate and ammonium persulfate are lacking, but in view of its good behavior in the test with the acid bichromate mixture mentioned earlier, it is possible

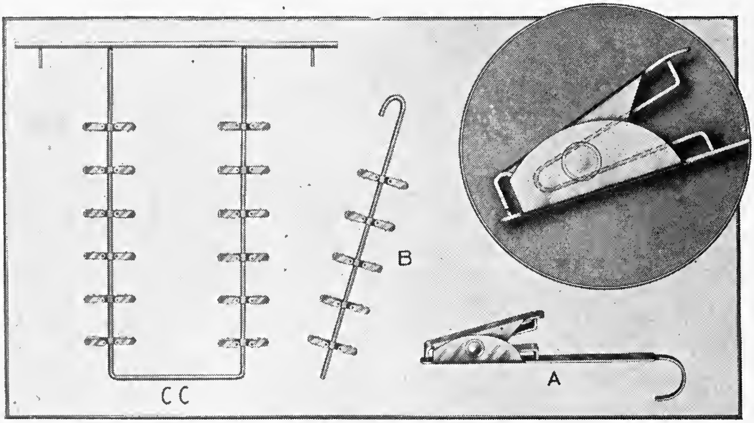

FIG. 3. Monel metal film developing clips.

that it will be found satisfactory for use with these other oxidizing acid solutions. However, it should be used with caution with these solutions until its suitability has been definitely established.

Data on bleaching solutions are contradictory, in that tests conducted in a film company's laboratories have indicated the unsuitability of Inconel for use with bleaching solutions containing potassium bromide and potassium ferricyanide, whereas reports from the field mention the replacement of less satisfactory materials with Inconel for parts of motion picture film processing equipment that are used in bleaching solutions.

GALVANIC BEHAVIOR

In view of the work done by Crabtree, Hartt, and Matthews[2] on the effect of electrolysis on the rate of corrosion of metals in photo-

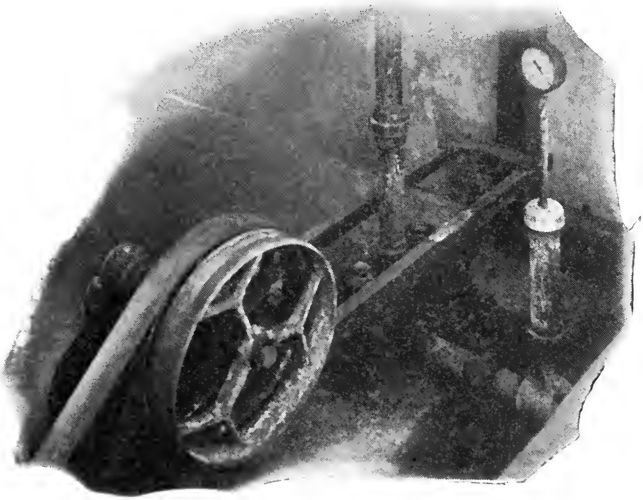

FIG. 4. Eight-inch plunger pump lined with Inconel for pumping hypo.

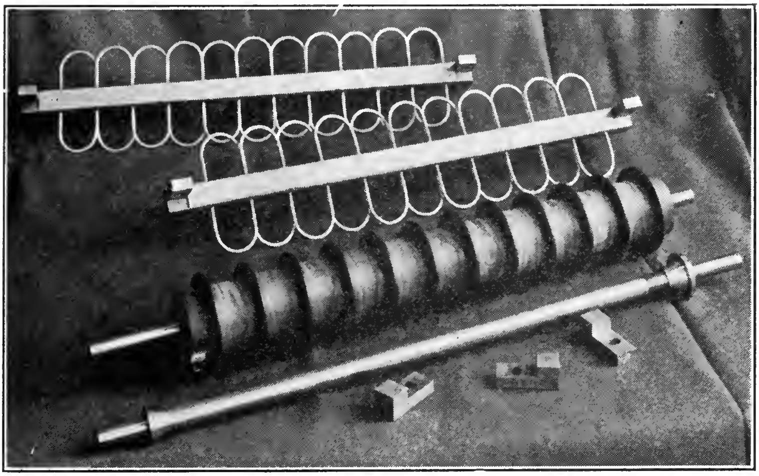

FIG. 5. Inconel spindle and spacers for film rolls in continuous developing equipment.

graphic solutions, it is desirable to establish the position of Inconel in an electromotive series referred to developing and fixing solutions. Inconel under ordinary conditions of use will occupy a position very close to silver in such a series. Since it does not precipitate silver from hypo solutions, it must be either very close to or more noble than silver in such solutions, although it may be less noble in other environments. In common with other high chromium alloys, such as the stainless steels, which owe their apparent nobility to what is most commonly believed to be an oxide film, destruction of this film may cause Inconel to occupy a position in the electromotive series near nickel. In setting up such a series, therefore, it is desirable to include the high chromium alloys in two locations, the one referring to the passive (passive film present), and the other to the active (passive film absent) state. It should, of course, be noted that for purposes and under conditions for which Inconel and the other high chromium alloys are generally used, the active state is only rarely encountered. Such a series, based upon many tests and practical experiences, is given in Table V.

TABLE V

Electromotive or Galvanic Series of Metals and Alloys

Corroded end (anodic)

Magnesium
Aluminum
Duralumin

Zinc
Cadmium

Iron
Chromium-Iron Stainless Steel (*active*)
Chromium-Nickel-Iron Stainless Steel (*active*)

Lead-Tin Solder
Tin
Lead

Nickel
Inconel (*active*)
Brasses
Bronzes
Monel Metal
Copper

Inconel (*passive*)
Chromium-Iron Stainless Steel (*passive*)
Chromium-Nickel-Iron Stainless Steel (*passive*)
Silver

Gold
Platinum

It will be noted that the materials are arranged in groups. There may be a rearrangement of positions within any group, depending upon the environment; but it is unusual for a change of position to occur from one group to another, except in the special case of the chromium alloys previously discussed.

A practical application of this series to photographic film developing processes is that all materials grouped above silver in the series will precipitate silver from exhausted or partially exhausted fixing solutions. The chromium alloys grouped with silver ordinarily will not precipitate silver except where they may have been rendered active by the destruction of their passive films. As has been shown earlier in the discussion of its behavior in hypo fixing solutions, Inconel tends to remain passive in these solutions, and consequently does not precipitate silver from them.

FIG. 6. Submerged type of pump with 2-inch Inconel pipe connections.

As Inconel is below the lead-tin solders and the high copper alloys in the galvanic series, combinations of these alloys with Inconel in developing solutions should be avoided, because these other materials may suffer accelerated corrosion, especially where the area of Inconel exposed is great as compared with that of the other materials. This is in accordance with the recommendation of Crabtree, Hartt, and Matthews[2] resulting from their investigations of the effects of dissolved copper and tin. Tin was found to cause fogging,[1] and copper to accelerate the rate of oxidation of a sodium sulfite solution[3] and thereby to shorten the life of a developer.

PRACTICAL APPLICATIONS OF INCONEL

The many useful properties of Inconel that have been described soon led to its adoption for the fabrication of film processing equipment, especially in the motion picture industry. Typical of such uses of Inconel are the following:

The plunger pump illustrated in Fig. 4 was lined with Inconel about a year ago. It is being used for pumping hypo fixing solutions at the West Coast plant of Consolidated Film Industries, Inc.

Paramount Productions, Inc., Los Angeles, Calif., is using Inconel with good success for such equipment as spindles and spacers for film

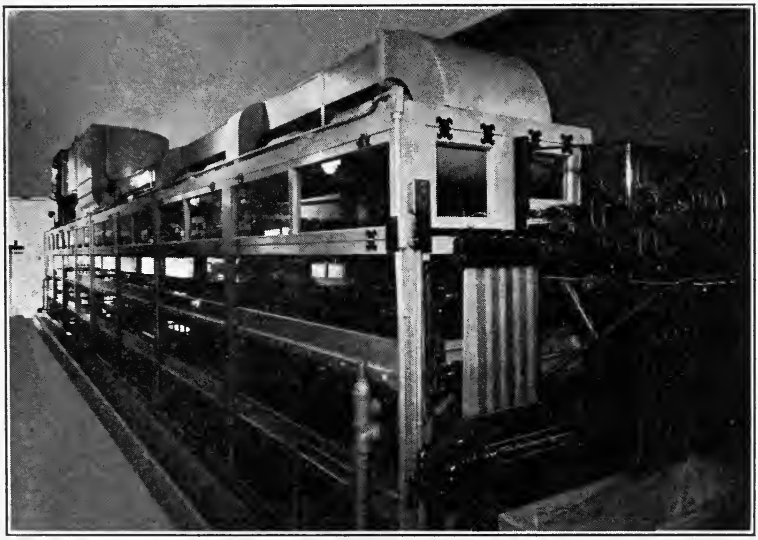

Fig. 7. Hunter-Pierce film development machine equipped with Inconel.

rolls in continuous film developing apparatus as illustrated in Fig. 5. The submerged pump shown in Fig. 6 has been equipped with 2-inch Inconel pipe for handling a hypo solution. The developing machine shown in Fig. 7 equipped with Inconel is in use at the Universal Pictures Company plant on the West Coast. One of the most interesting applications of Inconel is as a coil for controlling the temperatures of a hypo fixing solution in the plant of Cinecolor Pictures. This coil was put into service about ten months ago.

In addition to such applications as these in the motion picture industry, a considerable amount of Inconel has been used for film-developing equipment in x-ray and commercial laboratories. The success of these and other installations of Inconel confirms the results of the numerous tests that have demonstrated its resistance to photographic solutions. It is expected that its use for such purposes will increase as time goes on.

REFERENCES

[1] CRABTREE, J. I., AND MATTHEWS, G. E.: "The Resistivity of Various Materials toward Photographic Solutions," *Ind. & Eng. Chem.*, **15** (July, 1923), No. 7, p. 666.

[2] CRABTREE, J. I., HARTT, H. A., AND MATTHEWS, G. E.: "Effect of Electrolysis on the Rate of Corrosion of Metals in Photographic Solutions," *Ind. & Eng. Chem.*, **16** (Jan., 1924), No. 1, p. 13.

[3] CRABTREE, J. I.: "Chemical Fog," *Brit. J. Phot.*, **66** (Feb., 1919), p.97.

DISCUSSION

CHAIRMAN CRABTREE: What is the resistivity of welded Inconel?

MR. LAQUE: So far as we have been able to determine, neither the deposition of the weld nor the heat attending the deposition have any detrimental effect upon the corrosion-resistance, either in the weld itself or in the metal adjacent to it. We have subjected Inconel to the standard tests used to determine susceptibility, and it has come through the tests without any indication that such things occur.

MR. MACOMBER: What is the price of Inconel as compared with that of monel metal?

MR. LAQUE: In the form of sheets Inconel costs about fifteen cents more a pound than monel metal, and about twenty cents a pound in the form of a cubical. Castings are always a rule unto themselves.

CHAIRMAN CRABTREE: Do you find any greater degree of corrosion, at the air-liquid boundary?

MR. LAQUE: If corrosion will occur at all, that will be the place where it will begin. Whether it will begin or not in any given case is determined by a number of factors that are difficult to control. I should not be surprised that under the conditions of use of fixing solutions, where the temperature might be higher than normal for appreciable periods, you would find evidence of air-line attack. However, I don't believe it would be very serious; it would occur, but very slowly.

SPRING, 1935, CONVENTION

SOCIETY OF MOTION PICTURE ENGINEERS

HOTEL ROOSEVELT, HOLLYWOOD, CALIF.

MAY 20–24, INCL.

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MRS. W. QUINLAN	MRS. P. MOLE	MRS. F. C. COATES
	MRS. C. W. HANDLEY	

Headquarters

The headquarters of the Convention will be the Hotel Roosevelt, where excellent accommodations and Convention facilities are assured. Registration will begin at 9 A.M. Monday, May 20. A special suite will be provided for the ladies attending the convention. Rates for S. M. P. E. delegates, European plan, will be as follows:

Single: $2.50 per day; one person, single bed.
Double: $3.50 per day; two persons, double bed.
Double: $4.50 per day; two persons, twin beds.
Suites: $6.00 and $8.00 per day.

Technical Sessions

An attractive program of technical papers and presentations is being arranged by the Papers Committee, laying special emphasis upon the developments in the technic, equipment, and practices of the studios. Several sessions will be held in the evening, to permit those to attend who would be otherwise engaged in the daytime. All sessions will be held at the Hotel.

Studio and Equipment Exhibit

The exhibit at this Convention will feature apparatus and equipment developed in the studios, in addition to the usual commercial equipment. All studios are urged to participate by exhibiting any particular equipment or devices they may have constructed or devised to suit their individual problems, conform to their particular operating conditions, or to achieve economies in production, facilitate their work, or improve their products.

Those desiring to participate should communicate with the General Office of the Society, Hotel Pennsylvania, New York, N. Y. No charge will be made for space. Each exhibitor should display a card carrying the name of the particular studio or manufacturer, and each piece of equipment should be plainly labelled. In addition, an expert should be in attendance who is capable of explaining the technical features of the exhibit to the Convention delegates. Expenses incidental to installing and removing equipment, and the cost of any power consumed, will be borne by the exhibitors.

Semi-Annual Banquet

The semi-annual banquet of the Society will be held at the Hotel on Wednesday, May 22. Addresses will be delivered by prominent members of the industry, followed by dancing and entertainment. Tables reserved for 8, 10, or 12 persons; tickets obtainable at the registration desk.

Studio Visits

S. M. P. E. delegates to the Convention have been courteously granted the privilege of visiting and inspecting the Warner Bros. First National Studio (courtesy of the Electrical Dept.), the Fox Hill Studio of Fox Film Corp., and the Walt Disney Studio: admission by registration card only. A visit has also been arranged to the California Institute of Technology. All bus charges on studio and other trips will be assumed by the individual delegates.

Motion Pictures

Passes will be available during the Convention to those registering, to Grauman's Chinese and Egyptian Theaters, Pantages', Hollywood Theater, Warner Bros.' Hollywood Theater, and Gore Bros.' Iris Theater.

Ladies' Program

An especially attractive program for the ladies attending the Convention is being arranged by Mrs. E. Huse, *hostess*, and her Ladies' Committee. A suite will be provided in the Hotel where the ladies will register and meet for the various events upon their program.

Further details of the Convention will be published in the next issue of the JOURNAL.

Points of Interest

En route: the gigantic Boulder Dam project, Las Vegas, Nevada; Union Pacific Railroad.

Hollywood and vicinity: Beautiful Catalina Island; Zeiss Planetarium (Open May 1); Mt. Wilson Observatory; Lookout Point, on Lookout Mountain; Huntington Library and Art Gallery (by appointment only); Palm Springs, Calif.; beaches at Ocean Park and Venice, Calif.; famous old Spanish missions; Los Angeles Museum (housing the S. M. P. E. motion picture exhibit); Mexican village and street, Los Angeles; the California Pacific International Exposition at San Diego, Calif. (open May 29); Agua Calienta, Mexico; Tia Juana, Mexico.

Golf

Members attending the Convention have been extended the privileges, at the usual course rates, of the following courses:

Hollywood Country Club, North Hollywood
Oakmont Country Club, Glendale
Westwood Country Club, Westwood
Rancho Golf Club, Westwood

PROGRAM

Monday, May 20

9:00 A.M. *Florentine Room*
Registration

10:00 P.M. Society Business
Technical Papers Program

12:30 P.M. *New Supper Room*

Informal Get-Together Luncheon, for members, their families, and guests; short addresses by eminent members of the industry. Tickets obtainable at registration desk.

2:00 P.M. *Florentine Room*

Technical Papers Program

8:00 P.M. Visit to Walt Disney Studio.

Direction of Mr. W. Garity, Studio Manager; admission by registration card only; buses leave the Hotel promptly at 7:30 P.M.

Tuesday, May 21

9:30 A.M. *Florentine Room*

Technical Papers Program

1:30 P.M. Visit to Warner Bros. First National Studio.

Luncheon and inspection of studio; courtesy of the Electrical Department, under the direction of Mr. F. Murphy, Chief Studio Engineer; admission by registration card only; buses leave the Hotel promptly at 1:00 P.M.

7:30 P.M. *Academy Room*

Technical Papers Program

Wednesday, May 22

9:30 A.M. *Florentine Room*

Technical Papers Program

2:30 P.M. Visit to Fox Hill Studio.

Courtesy of Fox Film Corp.; direction of Mr. W. J. Quinlan, Chief Studio Engineer. Admission by registration card only; buses leave the Hotel promptly at 2:00 P.M.

7:30 P.M. *New Supper Room*

Semi-Annual Banquet of the S. M. P. E.

Addresses by several eminent members of the industry; dancing, and entertainment; tables reserved at the registration desk for 8, 10, and 12 persons.

Thursday, May 23

9:30 A.M. *Florentine Room*

Technical Papers Program

2:30 P.M. Visit to California Institute of Technology.

Direction of Dean F. W. Hinrichs, Jr.; inspection of astronomical, aeronautic, and high-voltage laboratories; admission by registration card only; buses leave the Hotel for Pasadena promptly at 1:30 P.M.—a beautiful scenic trip.

7:30 P.M. *Academy Room*

Technical Papers Program

Friday, May 24

9:30 A.M. *Florentine Room*

Technical Papers Program

2:00 P.M. *Florentine Room*

Technical Papers Program

Adjournment of the Convention

SOCIETY ANNOUNCEMENTS

ATLANTIC COAST SECTION

At the regular monthly meeting, held on February 20 at the Hotel Pennsylvania, New York, N. Y., Mr. Eddie Senz delivered a talk on the subject of "Make-Up for Motion Pictures," discussing the subject from both the esthetic and the photographic points of view. Miss Dean Fureau, of Paramount, kindly acted as model for Mr. Senz, who illustrated the technic of his art by making up Miss Fureau's face in exactly the same manner as it would be made up for actual motion picture production. The effects of various shadings and colorings of the features in order to accentuate favorable facial characteristics or to subdue unfavorable ones were demonstrated. Mr. W. Graff, of Hudnut's, New York, assisted by illustrating how the hair was dressed to suit the personality of the subject.

More than two hundred persons attended the meeting, and an interesting discussion followed the presentation. Lighting equipment was kindly supplied by Mr. M. W. Palmer.

PROJECTION PRACTICE COMMITTEE

The first meeting of the Committee under the new chairman, Mr. J. O. Baker, was held at the Paramount Building, New York, on March 6. Work on revising the projection room layouts originally published in the August, 1931, JOURNAL, was continued. It is planned to present the revised specifications and layouts at the Spring Convention at Hollywood in May.

PAPERS COMMITTEE

At a meeting held at the General Office of the Society on February 21, plans were laid for constructing the papers program for the coming Convention at Hollywood. Nine technical sessions will be held and there will be many interesting presentations and demonstrations. The program is under the direction of Mr. J. I. Crabtree, *Editorial Vice-President*, Mr. J. O. Baker, *Chairman* of the Papers Committee, assised in the Hollywood area by Mr. W. A. Mueller. Details of the Convention may be found on page 372 of this issue of the JOURNAL.

SECTIONAL COMMITTEE ON MOTION PICTURES UNDER THE A. S. A.

As reported previously in the JOURNAL, a Sectional Committee on Motion Pictures, organized according to the procedure of the American Standards Association, is in the process of being formed, with the S. M. P. E. as sponsor. The appointments thus far made by the various organizations and societies are as follows:

American National Committee for International Congresses of Photography	W. Clark
Acoustical Society of America	F. L. Hunt
Illuminating Engineering Society	R. E. Farnham
Fire Protection Group of the A. S. A.	A. R. Small
Amateur Cinema League	F. G. Beach
Eastman Kodak Company	L. A. Jones
Agfa Ansco Corp.	P. Arnold
Dupont Film Mfg. Corp.	N. F. Oakley
National Electric Mfr's. Assoc.	J. G. T. Gilmour
Theater Equipment Supply Mfr's. Assoc.	O. F. Neu
Bell & Howell Co.	J. A. Dubray
Akeley Camera Co.	J. L. Spence
Mitchell Camera Co.	G. H. Worrall
Electric Research Products, Inc.	C. Flannagan
RCA Manufacturing Co.	M. C. Batsel
International Projector Corp.	H. Griffin
National Carbon Co.	W. C. Kunzmann
Motion Picture Producers & Distributors of America	A. S. Dickinson
	D. Palfreyman
U. S. Bureau of Standards	E. W. Ely
Bell Telephone Laboratories, Inc.	H. M. Stoller
Independent Supply Dealers' Assoc.	J. E. Robin

Nine organizations have yet to designate their representatives, including the Society of Motion Picture Engineers. Additions to the list will be published in a subsequent issue of the JOURNAL. When complete, the list is to be approved by the Council of the American Standards Association, whereupon an organization meeting will be called and an agenda of projects for standardization drawn up. The chairman of the Committee is yet to be chosen; the secretary is S. Harris, of the General Office of the S. M. P. E.

PROGRESS MEDAL AWARD

At a recent meeting of the Board of Governors, the provisions quoted below referring to the Progress Medal Award of the Society of Motion Picture Engineers and known as Section 3 of "Administrative Practices" of the Board, were adopted. The Committee appointed to administer these provisions for the year 1935 consists of:

A. N. GOLDSMITH, *Chairman*

M. C. BATSEL C. DREHER
J. CRABTREE W. B. RAYTON

The design of the medal, recently approved by the Board, was the work of Mr. Alexander Murray, of Rochester, N. Y., and was generously donated by him to the Society.

A meeting of the Committee will be held on June 27, allowing sufficient time to determine the recipient of the Award before the Fall, 1935, Convention, at which time the award will be made. All Fellows and Active members of the Society are urged to consider this matter, and, if they have any concrete proposals, to forward them to the General Office of the Society at the earliest convenient date. A description of the medal follows:

Obverse: The center is a replica of the official emblem of the Society. Above and around the emblem are embossed the words "For Progress," and below are two laurel branches, Grecian symbols of achievement. A reproduction of film perforations forms a decorative motif surrounding the central portion of the design. Eleven concave panels fill the remaining area extending to the outer edge of the face, upon each of which the form of a bird in flight is embossed. Various movements of the flight are depicted, reproducing the work of E. Marey, a French scientist who, in 1886, designed a "photographic gun," using circular glass plates, for analyzing the movements of living things. Although it was not Marey's intention to reproduce motion, his plates embodied the essential elements of the motion picture and the representation of them is therefore symbolic of the early development of motion pictures.

Reverse: The central portion consists of a series of horizontal oblong panels

(*Obverse*) (*Reverse*)

The Progress Medal

arranged in a partial pyramidal form and bearing the embossed inscription "Awarded to (Name of Medalist) for Outstanding Achievement in Motion Picture Technology." Crystals of silver bromide, the light-sensitive salt used in most photographic emulsions, are reproduced in two of the panels. Below the inscription is engraved the year of the award. Above it is a small rectangular panel upon which is engraved a sensitometric curve, representing the classical researches of Hurter and Driffield, who laid down much of the fundamental theory regarding numerical specification of photographic emulsion characteristics. Sine waves, symbolic of sound and light, are embossed upon two curved panels to the left and right of the central pyramid. In a slightly inclined panel surrounding almost the entire outer edge, the name of the Society appears in embossed letters.

REGULATIONS

A medal shall be awarded in the year 1934, and may be awarded in subsequent years, to be known as the *Progress Medal,* and the sum of $185 is appropriated for the design and die of this medal. The medal shall be awarded to an individual in recognition of any invention, research, or development which in the opinion of the Progress Award Committee shall have resulted in a significant advance in the development of motion picture technology. The Progress Award Committee shall consist of not less than five Fellows or Active members of the Society, to be appointed by the President subject to ratification by the Board of Governors. The names of the persons deemed worthy of the award may be proposed and seconded in writing by any two Fellows or Active Members of the Society, and shall be considered by the Committee not later than the month of July. A written statement of the accomplishments shall accompany each proposal.

Notice of the meeting of the Progress Award Committee must appear not later than the June issue of the JOURNAL. All proposals shall reach the chairman not later than June 20.

A majority vote of the entire Committee shall be required to constitute an award of the Progress Medal. Absent members may vote in writing. The report of the Committee shall be presented to the Board of Governors for ratification at least one month before the Fall Meeting of the Society. The recipient of the Progress Medal shall be asked to present a photograph and pertinent technical biographical data of himself to the Society and, at the discretion of the Committee, he may be asked to prepare a paper for publication in the JOURNAL of the Society. These regulations, the names of those who have received the medal, the year of each award, and a statement of the basis for each award shall be published annually in the JOURNAL of the Society.

MID-WEST SECTION

A showing of the *American Cinematographer* prize-winning 16-mm. films was held at the March 14 meeting of the Section at the Bell & Howell auditorium, Chicago, Ill. The meeting was well attended, and the showing aroused considable interest. Other meetings of the Section are planned for April 4 and May 2.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXIV **MAY, 1935** **Number 5**

CONTENTS

JOURNAL
OF THE SOCIETY OF
MOTION PICTURE ENGINEERS

SYLVAN HARRIS, EDITOR

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

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A REVOLVING LENS FOR PANORAMIC PICTURES*

F. ALTMAN**

Summary.—*The panoramic lens described was developed at a time when such a lens seemed a desirable means of achieving the large angle of view required under certain conditions for the so-called wide film, the film width in question being 70 mm. The full-field angle across the film with this lens was nearly 50 degrees, as compared with about 28 degrees for standard 35-mm. film using the same focal length lens. The film is held in a gate curved horizontally, the curve facing the lens and of a radius approximately equal to the focal length of the lens. The lens revolves about its rear nodal center, so that the axis of the lens sweeps out the entire angle of the picture. Because of the design of the lens, and a special shutter revolving with it in a plane near the film, allowing only a limited portion of the field to be imaged upon the film at a given instant, a sharp picture results.*

The development of the lens that forms the subject of this paper was done some years ago when the interest in wide pictures made such a panoramic lens seem a desirable means of achieving the large angle of view required under certain conditions for this film. If the interest in a picture of the width here considered has passed, or if in the meantime ordinary lenses of sufficient aperture and with wider covering power than those then available have been developed, these facts may not make the present paper without some interest to the Society.

At the time this work was undertaken the 35-mm. film aperture had been reduced to make room for the sound-record, with the result that for a time, at least, the old proportions that had been standard for years had been disturbed. A difference of opinion as to exactly what width of sound-track would be necessary for properly recording the sound was, no doubt, one of the factors that gave the advocates of the wider film the opportunity for which they had waited.

Of the various widths of film considered at that time the 70-mm. was the one for which the present lens was developed. This film provided for a picture area of 46 × 23 mm., and for a sound-track of 250 mils. This picture area had a diagonal of 51.4 mm. and required

* Presented at the Fall, 1934, Meeting at New York, N. Y.

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

a half-angle slightly greater than 27 degrees to cover the corner of the picture with a 50 mm. lens. The full-field angle across the film with such a lens was nearly 50 degrees, as compared with a field of slightly more than 28 degrees with standard 35-mm. film using the same focal length lens. Longer focal length lenses were available that would cover this new larger aperture subtending a smaller angle of view, but studio practice seemed to demand the shorter 50-mm. lens for a great portion of the work.

Unfortunately, lenses have a limiting angle-of-field over which they will form a sharp image. This angle varies among different types, but few if any were then available that would meet the require-

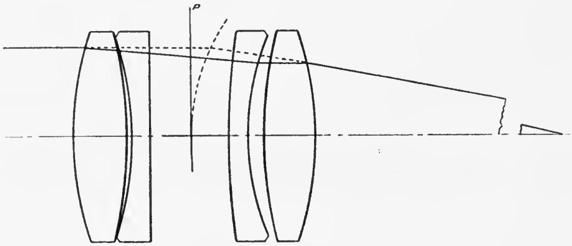

FIG. 1. Illustrating determination of "equivalent surface of refraction."

ments of the 46 × 23-mm. gate with a 50-mm. focal length. The light value of oblique pencils diminishes rather markedly at these extreme angles due to the trimming of the lens mounts. Both these factors set up limitations beyond which it is not practicable to go with the normal lens. Some other method of increasing the angle-of-view must be adopted.

Various efforts had been made prior to this time to produce a picture of larger angular dimensions, and some spectacular results had been achieved. Notable among them were the Widescope pictures, made with a two-lens two-film camera. In this attempt each lens recorded only half the field-of-view. These pictures were described and demonstrated before the Society by J. D. Elms in 1922.[1] Still another was the panoramic pictures made with a revolving lens by G. C. Ziliotto[2] and described before the Society in 1924.

The difficulties inherent in the Widescope pictures using two lenses and two films that must be properly synchronized in taking and projecting, as well as the difficulties in uniformly processing the two films, certainly would leave much to be desired, however satisfactory the final results upon the screen might be. The pictures made with a revolving lens by Ziliotto were spectacular in character, but since they were taken at the rate of eight frames per second the process was limited to still scenes.

Elms had continued his efforts to make a wide picture, and taking up the revolving lens as used by Ziliotto had attempted to increase the number of pictures per second by oscillating the lens. In a camera developed by him for this purpose, the lens was stopped at

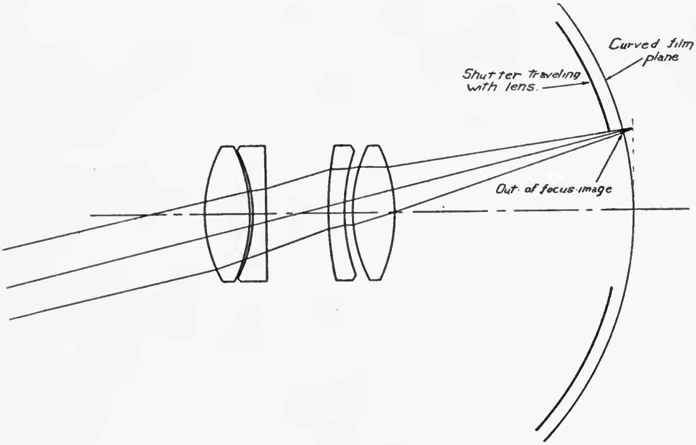

FIG. 2. Illustrating the action of the panoramic lens with curved film plane.

the end of the exposure of one frame and the direction reversed, thus sweeping out each succeeding frame by rotating the lens in the opposite direction. In this manner he was able to double the number of frames per second made by Ziliotto, but mechanical difficulties introduced by stopping and reversing the direction of the lens resulted in noise, vibration, and wearing of parts.

In 1927, Elms came to the Kodak Company with the proposal that they develop a panoramic lens that would take a picture equally well with the lens in a direct or reversed direction. This problem was taken up at the Hawk Eye Lens plant of the company, and the lens that is to be described was developed as a possible solution of the problem.

Lest there be any confusion as to the method of taking panoramic pictures in the manner here considered, let it be stated (*a*) that the film is held in a gate curved in the horizontal plane, the curve facing the lens and of a radius approximately equal to the focal length of the lens; (*b*) that the lens is revolved about its rear nodal center so that the axis of the lens sweeps out the entire angle of the picture; and (*c*) that because of the special design of the lens, and because of a special shutter revolving with the lens and in a plane near the film, allowing only a limited portion of the field of view to be imaged upon the film at a given instant of time, a sharp picture results. In this manner, the angle-of-view may be greatly increased over that possible with the orthodox type of lens. It is apparent also that the lens at all times is forming the picture with axial or near axial definition and with a full and unvignetted cone of light, so that definition and illumination are uniform over the entire picture.

Since the covering power required is then limited to an area defined by the height of the film and by the width of the exposure aperture (the later dimension being usually less than the height of the film), the demands for critical definition over this area are quite easily met in designing the lens. One exception was the correction for coma, which, because of the symmetry of the lens, proved troublesome. The solution of this problem lead to a rather unconventional design.

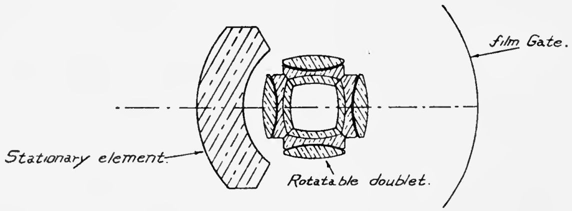

FIG. 3. The final form of the lens.

It might be well at this point to mention the several requirements that are to be fulfilled in designing a panoramic lens. We speak of a lens having a certain focal length, and some very carefully use the term "equivalent" focus without perhaps visualizing exactly what the term implies. In the case of a simple lens we would make no serious error in stating that the focal length was the distance from the lens to the point where light from a distant object was brought to focus. In the case of the complicated structure to which the modern anastigmat has so often developed, this surface-to-image distance would in most cases be in error. The opticians tell us that if we project parallel rays of light through a lens as though they were undeviated by the lens, until they intersect the extensions of the final refracted rays emerging from the lens, the intersections of the common pairs (the refracted and the unrefracted ray) will define a surface called an equivalent surface of refraction. (See Fig. 1.) It is as though the rays of light had continued through the lens undeviated until they encountered this surface, and that all refraction had then taken place at this point. If we were to reverse the lens and consider the same parallel rays entering the opposite end of the lens, a similar equivalent surface of refraction would be found.

FIG. 4. Early model of four-way lens in mounting.

The points where these equivalent refracting surfaces cut the axis of the lens locate the position of the nodal points or principal planes that are important in our present discussion. These principal planes as determined by the position of the nodal points are the basis of our calculation of focal length, object and image distance, and magnification. These nodal points have another important property: If a ray of light is directed to the first nodal point, it will leave the lens as though it came from the second nodal point, and the ray will be characterized further by having the same direction as it had before entering the lens. It is obvious, then, that if we revolve a lens about this rear nodal point, there will be no lateral shift of the image for any amount of rotation, provided the lens is free from distortion.

Thus far we have recorded two important requirements for a rotating lens. We must revolve it about the rear nodal center and the lens must be free from distortion. If we are to revolve the lens completely, however, and attempt to take a picture first with the lens in a direct and then in a reversed position, the conditions for freedom of lateral shift of the image requires that the front nodal point of the lens be also in the axis of rotation. It is, therefore, necessary that the two nodal centers be coincident and in the axis of rotation. Though it is not necessary that the lens be symmetrical, a consideration that succeeding pictures be identical in quality would lead to symmetry in design.

As previously mentioned, in taking a panoramic picture the film must be curved toward the rotation center of the lens with a radius of curvature approximately equal to the focal length of the lens. Before considering the design of the lens further, it might be well to visualize just what happens when we make a panoramic picture. In the vertical direction the film is flat, being curved only in the horizontal direction. Now if the field of the lens is flat and the film so curved, the image plane will be tangent to the film at succeeding points during exposure (Fig. 2); and if the exposure were limited by a very small slit, definition would be as perfect as though the image were formed upon a flat film. The requirements for exposure, however, necessitate a sizable width of exposure aperture, as indicated in Fig. 2. The size of the "out-of-focus" image resulting from the use of various shutter apertures, as well as the corresponding exposure obtained, are shown in Table I.

TABLE I

Exposure and Maximum Circle of Confusion with Various Shutter Openings

(Two-way lens; aperture ratio, $f/3.5$; 12 revolutions per sec.; 24 frames per sec.; shutter radius, 40 mm.)

Slit Size (mm.)	Angle of Slit (degrees)	Max. "Out of Focus" (mm.)	Circle of Confusion (mm.)	Circle of Confusion (inches)	Exposure Time
5	6	0.06	0.017	0.0006	1/720
10	12	0.27	0.077	0.0030	1/362
12	14	0.39	0.110	0.0040	1/300
15	21	0.87	0.250	0.0100	1/200
20	28	1.61	0.46	0.0180	1/150

In taking 24 frames a second with a two-way lens, the speed of rotation of the lens will be twelve per second. If we use an aperture in the shutter subtending 6 degrees, the exposure time will be $^1/_{60}$ th of the total, or $^1/_{720}$ sec. The table shows that the image due to the curvature of the film will be only 0.06 mm. out of focus at the beginning of the exposure of any given point; exactly in focus at the middle of the exposure time, when the image is formed upon the axis of the lens; and that it will be again out of focus by 0.06 mm. at the end of the exposure. If the lens is working at $f/3.5$, the circle of confusion on the film caused by these out-of-focus images will be 0.017 mm., or about 0.0006 inch.

With a slit subtending 12 degrees, the exposure time is $^1/_{360}$ sec., and the maximum circle of confusion of the out-of-focus image on the film will be 0.077 mm., or about 0.003 inch. We see that the increase of exposure by using a wider exposure aperture is achieved with a lowering of the definition. Definition is quite good even with larger apertures than those considered; because a large portion of the exposure, even in the case of wider apertures, is made with image sizes that constitute critical definition, and only a fraction of the exposure is made with "out-of-focus images" approaching soft definition. In practice, some compromise is made in the curvature of the gate which tends to reduce the maximum departure of the image from the focal plane of the film.

FIG. 5. Method of mounting revolving lens.

Since, however, there is this deterioration of the image as the shutter aperture increases—varying, as it does, with the cosine of half the angle subtended by the shutter aperture—it would appear that for a fixed rotation speed, the exposure might best be increased by increasing the lens aperture; for the reason that the "out-of-focus image" increases in size only in proportion to the diameter of the lens, whereas the exposure increases as the square of this value for a given focal length. Thus, if we make the lens $f/2.3$ instead of $f/3.3$, the exposure time will be increased by 100 per cent, whereas the out-of-focus image size would increase by only 40 per cent.

Another method of increasing the exposure without the attendant loss of definition presented itself and was successfully applied in designing this lens. If the lens system were so designed that the space between the front and the rear components was sufficient to allow an identical system to be placed in the same plane with its axis at right angles to the first, then four pictures could be made during each revolution, and the lens would revolve only six times per second to take twenty-four pictures; and with a constant exposure aperture, the exposure time would be increased 100 per cent over that of the two-way lens without any loss in definition.

This, then, was the course decided upon, and a symmetrical doublet having a central separation sufficient for mounting the lenses as described above was developed. As to the various aberrations that require correction in a lens system, they will merely be mentioned

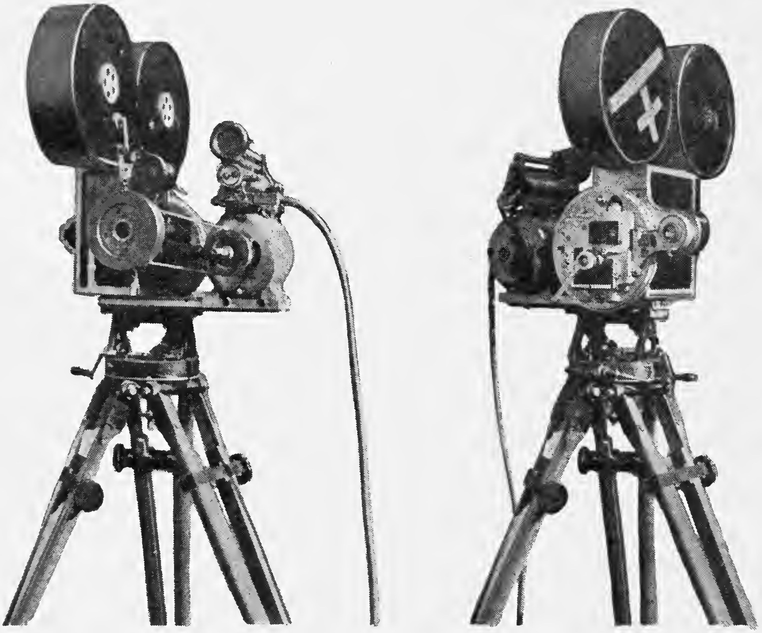

FIG. 6. Panoramic camera developed by J. D. Elms.

here. Color error on the axis and color difference of magnification depend for correction upon the powers of the elements, their positions with respect to each other in the system, and upon the dispersive values of the glasses used. Spherical aberration and astigmatism are corrected by altering the shapes of the various elements. Distortion, usually responsive to the distribution of power of the several elements, was not a factor in this lens, due to its symmetry. Field curvature is quite completely controlled by suitably choosing the glasses and the powers of the several components. Only one correction proved troublesome: the correction for coma.

Coma is manifest as a one-side blurring of oblique images, and is the result of spherical aberration of the oblique pencils of light. Coma of the character here considered is corrected by fulfilling certain conditions in the design of the lens into which we shall not go at this time. Let it be sufficient to say that this condition is satisfied in a symmetrical lens such as we have developed when, and only when, such a lens is working at unit magnification, when object and image are at equal distances from the lens. When such a symmetrical lens is used to image an object at a great distance, however, the condition for absence of coma no longer obtains, and to fulfill the necessary conditions for its correction some departure from symmetry must be made.

FIG. 7. Clipping of picture made under normal studio conditions, at 24 frames per second.

To render the lens system unsymmetrical so that this condition might be met, and yet provide for rotating the lens, the following expedient was adopted. To the symmetrical rotatable doublet already described was added a fixed or stationary member. This latter consisted of a negative meniscus element with surfaces concentric with the nodal center or axis of rotation of the rotatable doublet. Thus was achieved the lack of symmetry in the system as a whole which enabled the sine condition to be fulfilled, with consequent correction of the coma without disturbing the conditions necessary for rotatability previously established. The negative lens, having radii concentric about the point of rotation, would have not one optical axis as does an ordinary centered optical element, but innumerable axes, comprising all lines drawn through their common center of curvature. It is therefore seen that, regardless of the position of the symmetrical system in a plane containing its optical center and the optical center of the negative meniscus component, the complete lens would constitute a centered system. Both nodal points of the negative meniscus with concentric radii are at one and the same point, which is their common center of curvature; and since this point is made common with the nodal center of the symmetrical component, there is no shift of this nodal center when the negative is added to the system. The only effect is to increase the focal length of the system. Since in this case we are limited mechanically in the size of the lenses constituting the symmetrical components of the system, this resulted in reducing the effective aperture to $f/3.3$.

The correction of coma by the addition of the negative meniscus might be explained as a result of two definite conditions that now obtain. First, the negative lens forms a virtual image of a distant image at its own focal distance in front of the symmetrical component. This distance approximates so nearly the conditions for unit magnification for the symmetrical portion of the lens that this virtual image is imaged by the latter free from coma. This, in fact, was the approach to the solution, and the results seem to bear out the reasoning. The aberration and sine condition are well corrected in the final form of the lens, which is shown in Fig. 3.

It was necessary only to give to the stationary lens sufficient aperture to assure a full cone of light to the rotating member over its entire travel; and then, after the lens was constructed, to make some rather careful adjustments of the mounting. Looking after such details as to make all components in any particular case of the same piece of glass, and resorting to a special method of grinding the large meniscus, which obviously could cause trouble in centering, completes the story. Figs. 4 and 5 illustrate the revolving lens, and Fig. 6 a panoramic camera developed by Elms. Fig. 7 shows a clipping of a picture made under normal studio conditions, at a speed of 24 frames per second.

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DISCUSSION

MR. MITCHELL: In the illustration you showed, you had a curved line on the right-hand side.

MR. ALTMAN: That was the curved aperture.

MR. MITCHELL: What was the size of the lens used for photographing the motion picture frame we saw?

MR. ALTMAN: That was a 50-millimeter focal length lens.

MR. MITCHELL: What was its physical size?

MR. ALTMAN: The overall length of the symmetrical component was 25.42 mm. The elements of this part of the lens were 15.7 mm. in diameter. The stationary negative element was 12 mm. thick, and the outer and inner curves were 30.00 and 18.00 mm., respectively. The element was spaced 5.29 mm. from the rotatable member or 18.00 mm. from the center of the lens system. The stationary element was 43.00 mm. in diameter.

CHAIRMAN CRABTREE: What does the lens weigh, and how is it supported for rotating?

MR. ALTMAN: It was very light. The rotating part has very little mass. It was mounted upon a shaft so that the adjustments we spoke of could be made. Of course, the two systems had to be perfectly aligned so that the optical centers were not only together but on the axis of rotation in both cases; and there could not be any elevation difference, so that one picture would be high and the next low. To take care of that we had to have a jig made and examined on the lens bench with the microscope, to make sure that the four images came around right on the cross-wire and there was no shift laterally or vertically.

MR. MCGUIRE: Does Mr. Elms know where wide pictures are now being shown?

MR. ELMS: I think Mr. Spoor showed a few wide pictures at the World's Fair last year.

MR. MCGUIRE: Mr. Elms may be pleased to learn that yesterday I escorted a group of our members through the factory of the International Projector Corp. and showed wide pictures with one of the special Grandeur projectors. Six of them were specially made some years ago at a cost of more than $200,000, and have been lying in the warehouse, unused, until yesterday. The showing of Grandeur pictures in the Roxy Theater is a small section of motion picture history and it was a great disappointment to many of us when it was decided that the industry was not yet ready for wide pictures. I believe I am justified in stating that all our members who witnessed the showing of the old Grandeur pictures yesterday were greatly pleased, and realized that certain results could be attained with 70-mm. which could not be achieved with 35-mm. films. Of course, it is not for me to say that 70-mm., 65-mm., or some other width is best, but it is still my opinion that wide films have certain very definite advantages. The most practical illustration of the possibilities of wide pictures can be seen in viewing of a baseball game. The complete diamond can be shown and the images of the players are large enough to stand out very clearly.

For nearly fifteen years we have followed Mr. Elms' work, and our factory has taken an active part in developing equipment through the various stages that led to the manufacture of the Grandeur projectors to which I have referred, and I believe that the public finds an additional satisfaction in seeing pictures shown in this manner. There are a number of us who believe in the great possibilities of wide pictures. It is our hope that the motion picture industry will some time see its way clear to adopt wide pictures as it did sound pictures.

CHAIRMAN CRABTREE: I believe we all agree with Mr. McGuire, that for panoramic subjects, there is no doubt that the wide film gives a more realistic effect. The question is whether the additional realism given to the picture justifies the expense involved.

Can you tell us more about the method of suspending the lens? It would seem to be a rather delicate job to suspend it so that the successive images would not move laterally or vertically.

MR. ELMS: There is a shaft that runs to the center, top, and bottom, which is worked by gears. It runs very smoothly, with absolutely no vibration or noise of any kind. The lens that we have, I believe, weighs in the neighborhood of from four to six ounces, including the mounting.

MR. ELMS, JR.: Since the question of mounting the lens has been brought up I would like to say that the lens was originally mounted at the Hawk-Eye Plant by Mr. Altman and since then has never been touched.

There can be no lens shift since the elements are permanently locked and sealed in the mount, forming a complete unit and thus making it impossible for them to get out of alignment. The lens is encased in an inaccessible shell, since no adjustments are necessary after once being mounted and sealed.

RECENT DEVELOPMENTS IN THE ACOUSTICS OF MOTION PICTURE SOUND STAGES*

M. RETTINGER**

Summary.—*Methods of construction for achieving desirable reverberation characteristics in motion picture recording studios are dealt with. Ways and means are discussed which make possible a high degree of absorption of the low frequencies and a lesser degree of absorption for the high frequencies. Attention is called to the problem of monaural hearing; to the psychological effect of over-damped rooms; and to the question of feasible sound-insulation.*

Although several successful demonstrations have been given of the reproduction of sound with auditory perspective, the problem of recording and reproducing sound for motion pictures still remains essentially one of satisfying but one ear. Since in binaural hearing the attention can be concentrated upon sounds coming from a certain direction to the exclusion of sounds coming from other directions, the reverberation of the sounds and noises coming from different places can to a high degree be suppressed when listening with both ears. In monaural hearing, however, in which this faculty for listening to sounds coming from a single direction and ignoring sounds from all other directions is very much weakened, it is necessary that the room have a lower period of reverberation in addition to a lower level of noise than would be required for satisfactory hearing with two ears.

Hence it has become well-known practice in motion picture studio design to make the walls and ceiling of the stages as absorptive as possible. By doing so, the acoustical quality of the sound recording will be determined largely by the set materials and dimensions, thus permitting a greater freedom and simplicity in the acoustical design of the sets. It is the general practice to treat the inner walls of the sound stages with a 4-inch fill of mineral or rock wool between 2 × 4-inch wood studs covered with cloth or wire screen, and to treat the ceiling with a $1^1/_2$- to 2-inch rock or mineral wool blanket. With

* Received January 2, 1935.

** Pacific Insulation Co., Los Angeles, Calif.

such a treatment a stage of volume, say, 600,000 cubic feet, will have a reverberation period of about 1 second at 128 cycles per second and of about 0.8 second at 512 to 2048 cycles per second. This condition is shown graphically in Fig. 1.

Fig. 2 shows the absorption characteristic of granulated rock wool, 6 inches thick, 12 lb. per cubic foot, filled between 2 × 6-inch wood studs, 16 inch o.c., covered with cheesecloth, as determined by Knudsen.[1]

From Figs. 1 and 2 it is obvious that the established criteria for reverberation and absorption characteristics pertaining to ordinary speech and music rooms do not hold true for sound stages,[2] although

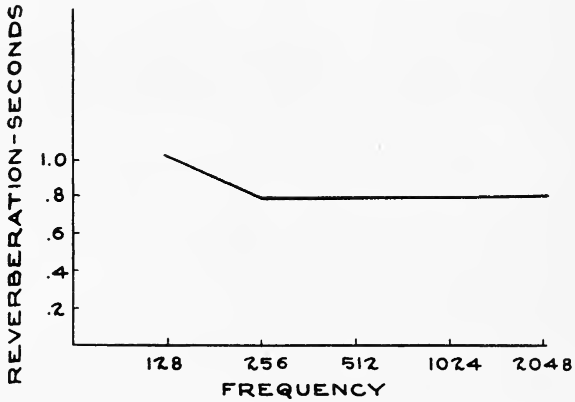

FIG. 1. Reverberation period of sets treated with 4-inch fill of mineral or rock wool between 2 × 4-inch wood studs covered with cloth or wire screen; ceiling with 1/2- to 2-inch rock or mineral wool.

reverberation controllers, (*i. e.*, variable absorbents in the shape of large panels covered on one side with a highly absorptive material and on the other side with a reflective one) are installed in many stages to allow some alteration of the reverberation time for different musical performances in accordance with the known principles of architectural acoustics.

As it would be beyond the scope of this paper to describe the actual conditions in the many sound stages that the author has investigated, only very general principles recently developed for absorption control in highly damped rooms can be mentioned. A notable contribution of this kind is due to G. von Békséy,[3] and deals with the elimination of the generally greater absorption at the high frequencies.[4] When sound is recorded in a room having excessive high-frequency absorption, the reproduced speech loses naturalness and the reproduced music brilliance. High frequencies display such decidedly limited directional qualities that, with the walls highly absorbent for them, the energy of these frequencies can not uniformly distribute itself throughout the room. Fig. 3 shows the directional characteristics of a tone having a frequency of 2000 cycles per second. The solid curve represents the intensity at points on a circle out in the open at the angles indicated on the abscissas. The dotted curve shows that when in an 1100-cubic-meter room the time of reverberation is 1.0 second for the 2000-cycle tone, there still exists, due to the direc-

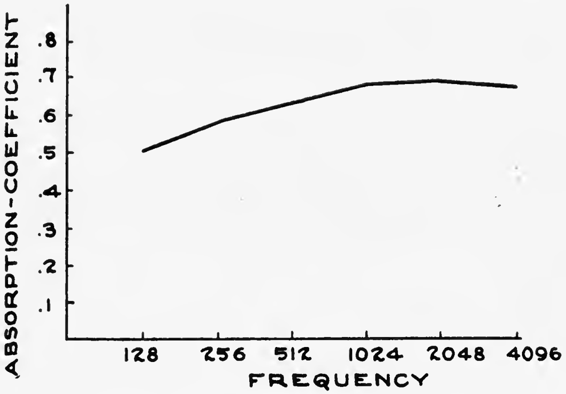

FIG. 2. Absorption characteristic of granulated rock wool, 6 inches thick, 12 lb. per cu. ft., between 2 × 6-inch wood studs covered with cheese cloth.

tional effect, a lack of intensity at the previously mentioned points. The curve made of dots and dashes, however, which shows the intensity at the same points in the same room when the time of reverberation is 1.6 seconds for the 2000-cycle tone, is flat enough to allow a uniform distribution of sound energy throughout the room, thus permitting good recording from almost any point in the sound stage.

Hence, acoustical materials having decreased absorption at the higher frequencies are frequently demanded. If it is further taken into consideration, however, that frequencies above 2000 cycles per second are to a great extent absorbed by the air,[5] it becomes a problem to find a really satisfactory absorbing material for sound stages, that is, a material with a sufficiently small absorption coefficient for the high frequencies. Realizing this, von Békésy searched for such a material, although he chose the alternative; that is, he desired a material having a high degree of absorption for the low frequencies. Fig. 4 shows the absorption curve for his material. It is made up of moderately tightly stretched canvas behind which is a 4-cm. layer of very loose cotton. The canvas must not be stretched too tightly, because it must be allowed to vibrate as a membrane.

Another way to increase the absorption at a certain frequency* consists in introducing an air-space between the absorptive material and the rigid wall of the studio. This air-space should be equal to about one-fourth the wavelength of the tone that it is desired to absorb to a very appreciable extent. Obviously, frequencies of slightly different wavelength will be absorbed highly, too, since sharp peaks

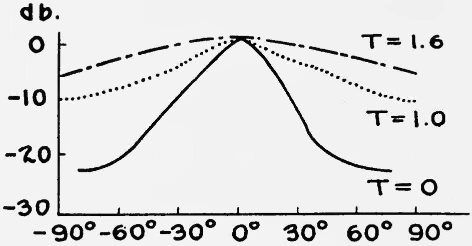

FIG. 3. Illustrating directional qualities of 2000-cycle tone.

in the absorption curve of any acoustical material or construction are rare. Hence a considerable range of frequencies may be absorbed. Thus, if a movable wall of absorptive material were constructed in a sound stage, the absorption could be controlled nicely for almost all small "bands" within the audible frequency range. While such construction has, so far as this author knows, not as yet been adopted, a recently built broadcasting studio at Hamburg has a wall that can be moved by an elaborate mechanism so as to increase or decrease the volume of the studio, thus permitting a change in the reverberation time for different performances.[6]

Yet another way to increase the absorption as well as the diffusion of sound in a studio consists in using absorbents of different characteristics, supported independently in the form of corrugations, or triangular or trapezoidal "flutes." The sides of these projecting

* Developed in the Physics Department of the University of Oslo, Norway.

forms should be comparable to the average wavelength of the sounds, the minimum depth being 18 inches. Such construction, besides providing additional area, also causes increased absorption by internal reflection within the air-space in the back of the material, provided, of course, that the frame is stiff enough to minimize any resonance phenomena and the normally resulting transmission of sound by the vibration of the structure as a whole. The plans for the Central Film Studios to be built at Wembley, England, specify that the walls of the stages have such triangular "flutes," with braces made of L-irons $2^1/_2 \times 2^1/_2 \times {}^1/_4$ inch.[7] Fig. 5 shows cross-sections of two such possible corrugate constructions.

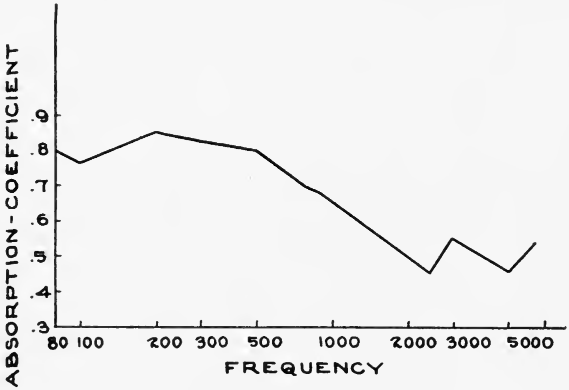

FIG. 4. Absorption curve of canvas stretched moderately tightly, backed by a 4-cm. layer of loose cotton.

In order to minimize the fire risk if an air space is interposed between the acoustical material and the wall, the acoustical material should be painted on the air-space side with a fire-resisting acoustical paint that will not fill up the pores, which are so necessary for the absorption by internal reflection. Fire-resisting screening in the form of perforated metal trays or tiles have for a considerable time been on the market, and the absorption coefficient of such materials is but slightly less than that of the uncovered material.

It should be pointed out here that the absorption in a studio must not be allowed to become too great. When open-air conditions are approached in a sound stage, the reproduced music or speech becomes unpleasantly "dead" or "flat"; and the musicians find it difficult in highly padded rooms to elicit from their instruments music of the proper intensity and tone. A musician, as is aptly remarked by Bagenal and Wood,[8] responds especially to the sense of "power" afforded by a good room. Music is not one absolute tone after another, but as equence of tone relationships modified at every point by

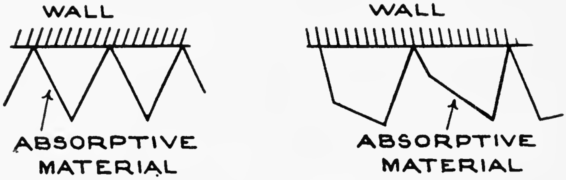

FIG. 5. Cross-sections of two possible corrugate constructions.

the player and the room together. Some musicians have strong preferences for certain rooms where they perform, due to the fact that the all-but-imperceptible tone adjustments that constitute musical "color," "depth," and "personality" are always influenced by room acoustics.

Nevertheless, highly absorptive materials are much in demand by

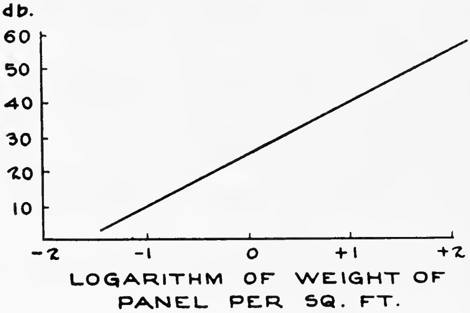

FIG. 6. Sound-insulation properties of homogeneous partitions.

the studios. In a paper[9] published by the author are set forth the conditions necessary for a material to absorb a given frequency completely. If the experiments to be conducted at the University of California at Los Angeles this year bear out the calculations, the quality of reproduced music and speech may be enhanced even more than it has been in the past months by the introduction of newly developed electrical apparatus.

A matter no less important than achieving the proper degree of absorption in a studio is to have sufficient sound-insulation to prevent the transmission of sound either from without or from within.

The work that has been done in that direction is enormous, and again only very general ideas recently worked out can be mentioned. It has been found that the insulation of homogeneous partitions is proportional to the logarithm of the mass per square foot, a condition illustrated by Fig. 6; while the insulation of porous-flexible materials is proportional to the thickness of the material. Thus, if the thickness of a porous-flexible material such as hair-felt is increased ten-fold, the sound-insulation will increase ten-fold; whereas if the thickness of a rigid non-porous material, such as brick, is increased that many fold, the sound-insulation will increase only two-fold. Note, however, that whereas a solid 9-inch brick wall has an insulation of 50 db., two separate $4^1/_2$-inch brick walls, separated by a small air space, have a combined insulation of 90 db. Although a 90-db. insulation represents a very high transmission loss, structures with even still higher transmission loss have been constructed successfully. Thus the NBC studios of Radio City have in part an insulation of 100 db.—a transmission loss so great that as yet no suitable apparatus is available to measure accurately such attenuation with sound levels normally attained in studios.[10]

The author wishes to express his sincere appreciation to Professor V. O. Knudsen, and Messrs. Townsend and Hansen of the Fox Film Corporation, for their assistance in the preparation of this paper.

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ON THE RELATION BETWEEN THE SHAPE OF THE PROJECTED PICTURE, THE AREAS OF VISION, AND CINEMATOGRAPHIC TECHNIC*

B. SCHLANGER**

Summary.—*A shape of projected picture is suggested differing from the present one in respect of its conforming more nearly to the contours of the central- and peripheral-vision areas of the eyes. In addition to the physiological advantages of such a shape, greater flexibility and effectiveness of artistic composition in cinematography and in projection would be achieved. The present shape limits the size of the photographic images and details of the picture, which would be considerably enhanced in the broader picture shape herein described. The possibility of cinematography of a type that would more nearly depict what the eye sees in real life is discussed.*

Motion pictures today are not displaying the full dramatic force of which they are capable. Making them audible was an important addition to the art, but there is yet much to be done to establish the motion picture as the dominant instrument for recreating real life in the theater. The work yet to be done deals principally with conditions under which the cinematographic and projection technic of the motion picture must be pursued. The cinematographer's "tools" consist of (*1*) a picture shape having a ratio of three equal parts in height to four equal parts in width; (*2*) a 35-mm. film width; (*3*) restricted camera angles. The projectionist's "tools" consist of (*1*) a 35-mm. film width; (*2*) a limited screen size; and (*3*) an auditorium poorly adapted to the purpose of effectively presenting the motion picture.

Wide-range sound reproduction and methods of acoustically correcting auditoriums were developed to give sound a more natural and realistic effect. Now new developments are needed just as much to make the motion *picture* seem more natural and realistic. The tools that the cinematographer and the projectionist have do not readily lend themselves to further development toward such an end. Better productions would be forthcoming as the result of an impetus derived from a more realistic method of motion picture portrayal.

* Presented at the Spring, 1934, Meeting at Atlantic City, N. J.

** New York, N. Y.

To make the motion picture seem more natural and real, an illusion must be created to cause the spectator to feel as though he were within the confines of the space within which action is being portrayed. Considerable research has been carried on in attempting to achieve a third-dimensional effect in the screen image, and thus attain greater realism. Such studies are still being carried on. Yet, a perhaps more vital consideration, that of "projecting" the viewer into the scene of action, a most necessary requisite to the feeling of realism, has received little attention. Notably, the shape of the motion

FIG. 1. Illustrating the accurate focusing of images in the peripheral-vision areas, in present-day pictures.

picture and the cinematographic arrangement therein are the important clues toward attaining this aspect of realism.

The name "motion picture" is somewhat misleading, and is not truly expressive of the science and art of cinematography. The word *motion* is self-explanatory, intimating action, but the word *picture* must be analyzed in its application to the cinema art. A picture may be a painting, a photograph, or a sketch—to be held in the hand, hung upon a wall, or to be bound into a book. It is a work of art, recording a past incident in life. As such it has its value. Its shape and pictorial composition are optional, subject perhaps only to the requisite of being artistic. The motion picture, on the other hand, should not be a physical document or record of a past event. The viewer of the motion picture should not be looking at a picture or through a picture frame; rather he would like to feel as though he existed at and when the action is supposed to be taking place, even though the "subject" may be past history. By a sheer stretch of the imagination, it may be possible to project oneself into time and space by looking at a still picture; the element of motion in the motion picture makes imagining in this sense easier for the spectator, but it is not yet easy enough. The appeal of the motion picture will strengthen as this ease-to-imagine increases.

The motion picture shape can not be thought of in the same sense as the shape of a vase, a tree, a building, or a work of art. A physical artistic form has a definitely committed shape, the outline of which should be pleasing to the eye by virtue of its beauty of line and proportion. As for the motion picture, it is important that it should assume a shape that makes the viewer least conscious of an obviously committed outline or shape. Therefore, the particular beauty of form and proportion of its shape are of no primary importance. As contrary as it may seem, it is the apparently "shapeless shape" that is most adaptable for the motion picture—a shape that would make the viewer least conscious of a limited boundary. There are, of course, special instances when the motion picture can be restricted to a definite and committed geometrical form, as when the viewer is supposed to be looking through an aperture formed by a window, door, or other opening. But instances utilizing such an aperture effect are few, and act only as an occasional accent in any one production.

To arrive at what would be a so-called "shapeless shape" for the motion picture, it is necessary to delve into the facts of physiological optics affecting this problem. In order to project the viewer into the scene of action of the story being unfolded, what he sees and how he sees it with his optical mechanism must be analyzed. Does he see in the motion picture unfolding before him what he would see actually existing at the scene of action? The motion picture should present as near a duplication as possible of what he would see by means of his optical mechanism in actual, real life. The same effect as is encompassed within the field of view by the human eyes should be visualized upon the screen. This field of view has an outline or shape, the characteristic of which should be used as a basis for the shape of the motion picture, but just how this shape may be advantageously employed can be better appreciated by analyzing the human optical mechanism as it affects the problem.

Helmholtz in his *Physiological Optics* states, "The eye is an optical contrivance of remarkably wide field of view, but it is only within a very limited part of this field that the images are clear-cut. The entire field is like a drawing which is carefully executed to delineate the most important central part of the picture while the surroundings are simply sketched in more and more lightly and less distinctly out toward the borders. He adds that, "In spite of the vagueness of the broad field of view, the eye is capable of taking in a rapid glance of the main features of the whole surroundings and of noting immediately the sudden appearance of new objects in the remoter parts of the field." From this observation, it can be seen that the visual appreciation of our external world is accomplished by direct and indirect vision. The direct vision is known as distinct or central vision, the indirect vision as indistinct or peripheral vision. The motion picture takes no cognizance of peripheral vision. It presents only a restricted area of direct central vision.

To duplicate the effect of natural vision, the motion picture must undergo two changes. First, its shape must conform more nearly to the shape of the natural field of vision, and, second, there must appear within this shape areas of both central and peripheral vision. Merely changing the shape of the motion picture alone, and not including within it areas of peripheral vision, will not suffice. Including peripheral vision will not only assist in "projecting" the viewer into the scene of action of the motion picture, but it will also greatly enhance the art of cinematographic expression. Peripheral vision in real life serves as a transition for blending the sharp contrasting details directly in front of the eyes into the complete obscurity that exists behind the head of the viewer. The motion picture should possess such an effect; but at the present time, viewing a motion picture can be compared to viewing our surroundings constantly as though we had horse-blinders attached to the sides of our heads. Such an effect would be annoying in real life, and there is good reason to believe that in the case of the motion picture it has an equally incomplete and restless effect.

The present motion picture shape completely precludes the possibility of including peripheral-vision effects at the extreme sides, because every bit of its limited width is needed for action portrayal. As will be noted in Fig. 1, this condition always demands sharply defined images and details, having the characteristics of direct vision, out to the very edges of the picture, where indistinct vision should exist. With a more broadly shaped screen more area could be allowed toward the extreme edges to introduce peripheral-vision effects. Yet, as stated before, a wider screen-shape improperly used would still be ineffective, as in the case of the "grandeur" screen which was recently given a trial use. Here the mistake was made of placing distinct central-vision images in sharp contrasting outlines out at the extreme sides. Not only did the images appear unreal, but they also caused the spectator the annoyance of having to shift his head from one extreme end to the other in order to follow the sharp, distinct images and details stretching across the entire screen. Had peripheral-vision areas been employed, the difficulty of the spectator in apprehending the entire screen at one time would have been reduced.

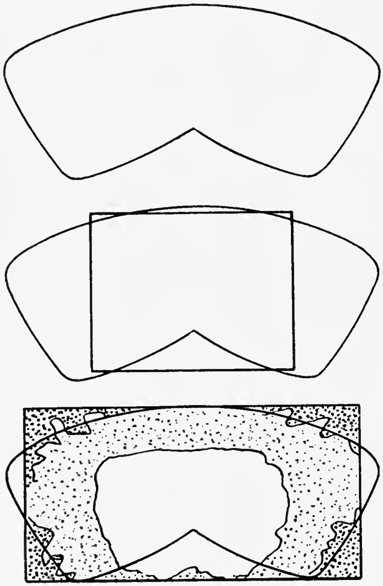

FIG. 2. (*Upper*) Contour of the field of vision of the eyes; (*center*) shape of present screen superimposed upon the field of vision; (*lower*) a suggested shape of picture conforming more nearly to the contour of the field of vision.

The shape of the field of vision has a decided horizontal emphasis, and has a proportion that makes the horizontal dimension slightly more than twice the vertical. Fig. 2 shows the outline of the field of vision. The irregular shape is caused by the bone structure of the head and by the characteristics of the retina.

The shape of the motion picture could not for practical reasons follow exactly the irregular outline of the field of vision as shown in Fig. 2. But its shape could be a rectangle, the relative horizontal and vertical dimensions of which could be suggested by the extreme dimensions of the field of vision. Fig. 2 shows at the top the outline of the natural field of vision, below which is shown the same field of vision with the present motion picture shape superimposed. Note the peripheral areas that do not come within the present motion picture. At the bottom of Fig. 2 is shown the field of vision with a suggested motion picture shape superimposed. This rectangle would include the complete field of vision within its shape. Note the shaded peripheral portion, and the still darker shaded portions suggested at the corners, where the picture composition would fade out to simulate the irregular outline of the field of vision. In order to be able to utilize correctly the entire width of the suggested shape, it would, of course, be necessary to investigate the possibility of successfully photographing the peripheral areas. This involves the problem of the lens and the rest of the camera mechanism. The camera must be able to record the peripheral-vision area as it should properly appear to the eyes.

The direct-vision area on the suggested wide screen does not and should not always be centered upon the screen as shown at the bottom of Fig. 2. The direct-vision area may appear to one side, leaving a large peripheral area on one side only, rather than a small peripheral area on both sides. The peripheral area may appear concentrated near the top or the bottom of the screen. Such a varied use and positioning of the direct and peripheral areas would open up a new vista for effective cinematography. Both interior and exterior shots would profit by the advantages offered. When the "grandeur" motion picture was tried, it was claimed that it was best adapted to panoramic exterior shots. As a matter of fact, the ultra-wide picture can be used effectively for a multiplicity of all kinds of exterior shots, including the panoramic type.

In the case of interior shots, peripheral areas are important with only a few exceptions. These exceptions include large close-ups, views intentionally taken through a door or window, or views showing the interior of a small room. When these exceptions are in order, any optional, sharply outlined geometric form may be photographed upon the film, leaving the remainder of the picture area at an even and fairly dark tone. This, in essence, becomes a changeable picture shape within a prescribed larger screen-form. As stated before, such instances are comparatively few, and are most effective when used judiciously to heighten a particular dramatic moment.

An example of the effect that could be created by the cinematographer's having at his disposal the peripheral-vision areas in the motion picture might occur, for example, in a scene wherein new action or a new image is introduced at one side of the picture. The viewer would at first receive a vague, and then gradually a more distinct, impression as the image passed from the peripheral- to the direct-vision areas. With the present motion picture shape, the continuity of the action portrayal of such a scene is interrupted and delayed due to the obvious limitations of size and shape.

Another advantage of including the peripheral areas would be to make the spectator feel more readily the position he holds in the scene of action, as well as the sense of space. For example, the extent of peripheral-vision area above, below, or to the side of the direct-vision area would vividly express whether the viewer is at a high point, low point, or to one side of the physical enclosure of the scene. The viewer would also be able to sense more readily the form and expanse of the surroundings of the scene of action. The director could at will "place" the spectator so as to create the best dramatic effect.

Yet another advantage to be derived from the newly shaped picture utilizing peripheral vision would be the possibility of including supplementary action within the field of vision, which might be entirely separated from the principal action in a particular scene. In such an instance, the supplementary action contributes to the principal action without being disconcerting, because such action would appear less distinct than the main action. This effect obviously can not be attained with the present motion picture.

Changing the shape of the motion picture directly affects the size of the screen. Of course, primarily, the size of the screen is subject to the viewing distances to be accommodated in the theater auditorium. The images and details upon the screen must not appear too small from the seats farthest from the screen. With the present average screen size, details are not sufficiently clear from the more remote seats; and if the more horizontal picture-shape were projected upon the average present screen (*i. e.*, maintaining the present width but reducing the height), the clarity of details and images would be still further reduced. Therefore, in order to change the shape of the motion picture, the screen would have to be increased in size. More specifically, the screen would have to be slightly greater in height and considerably greater in the horizontal dimension to offer sufficient area for both distinct-vision and peripheral-vision details of sufficient size. Enlarging the screen naturally involves increasing the width of the film to assure clear vision of the image from the seats nearest the screen.

Another factor that limits the realism of the motion picture lies in the relation of the screen to the auditorium. The screen always appears small against the adjacent walls of the auditorium. The walls or forepart of the auditorium compete strongly with the screen, especially because such strong contrast exists between the lighted screen surface and the darker surroundings of the screen. In place of the dead black masking now used to frame the screen, a supplementary border should be used, having a shape conforming to the natural vision contour, which could be lighted to an intensity that would blend with the lighting of the auditorium and the screen. This screen border lighting would then serve as a transitional blending between the walls of the auditorium and the illuminated screen surface.

MECHANICAL RECORDING ON FILM*

A. F. CHORINE**

Summary.—*A method is described of mechanically recording sound upon used film by means of a diamond cutting stylus. The same instrument can be used for reproducing the sound so recorded, merely by substituting a needle for the stylus, and making appropriate changes in the input and output of the amplifier. The quality of the recordings is surprisingly good, and is proving satisfactory for certain purposes.*

The Soviet sound motion picture industry is operating under conditions that often make it necessary to make repeated recordings and to accumulate much recorded material from which to select the best records for the composition of the picture. When field expeditions are made, it is more than ever necessary to make many and varied recordings.

There are two reasons for making a great number of recordings, both variants and repetitions: One is the abundance and originality of sound material, suitable for travelogues, in such regions as Siberia and Middle Asia, and the other is to assure successful reproductions, inasmuch as in such places there are no facilities for developing the films, reproducing them on the spot, and thereby ascertaining their quality.

Under such conditions the material has to be developed and tested after the return of the expedition, and therefore the use of ordinary films and optical methods of recording becomes exceedingly expensive. All this has suggested the idea of inventing an instrument for recording sounds mechanically on a *used* film. The principle of this contrivance is very simple. Figs. 1 and 2 show the general appearance of the apparatus. In it may be seen the mechanism for moving the film along the plate *1* together with a mechanical filter to assure a uniform motion of the film. Above the plate there is a recording arm *2*, in which a stylus made of hard stone or diamond is inserted.

* Received Aug. 20, 1934.

** Director, Central Laboratory, All-Union Electrical Trust, Leningrad, U. S. S. R.

With the aid of a special contrivance *3*, it is possible to adjust precisely the position of the sound record upon the film. Over the entire width of the film can be placed nearly 50 such records side by side. This mechanical recorder has a special dial indicating the ordinal number of the tracing and the micrometer for adjusting the stylus. For rapid transition from one groove to another during the sound reproduction there is a second dial by means of which the pick-up with inserted needle can be moved rapidly across the film. The same arm can be employed both for recording and for reproduc-

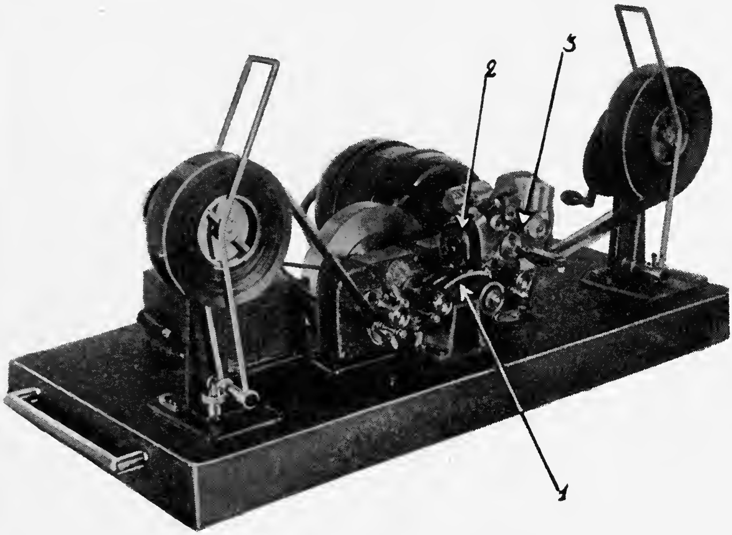

FIG. 1. Mechanical recorder and reproducer.

tion. In order to pass from recording to reproduction it is sufficient to replace the stylus by a needle and to interchange the input and the output connections of the amplifier, thereby making it immediately possible to hear the recorded material and judge its value. For the purpose of observing the sound record during the process of cutting there is a small magnifying attachment, with the aid of which it is easy to look after the adjustment of either the stylus or the needle during their performance. Experience has shown that a film is excellent material upon which to cut sound records, and is very durable in the sense of permitting a great number of reproductions. Since 50 tracings can be cut on the same film, it is possible to record many hours of material upon a reel containing only 300 meters of film. This is many times in excess of what could be recorded optically. In this connection, it is worth noting that already exposed films or films rejected for optical imperfections can be utilized for mechanical recording.

Under the conditions existing in the Soviet Union, the mechanical system of sound recording directly upon a film is of special interest not only in its application to recording instruments but also for its potentialities in the establishment of provincial and "kolkhoz" talking motion picture shows. In the U. S. S. R. there are, at present,

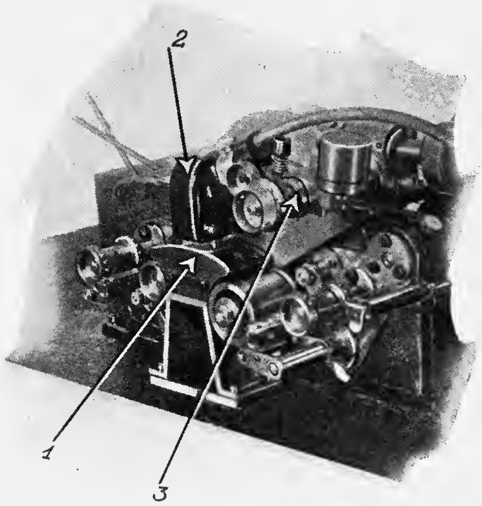

FIG. 2. Close-up view of mechanism.

nearly 40,000 travelling silent motion picture shows; in the near future their number will be greatly increased. The necessity for their adoption is urgent. Moreover, there exists a tremendous supply of silent films intended for rent in these travelling, motion picture shows. If the mechanical system of sound recording is utilized, the film with the sound records is run synchronously with the silent motion picture film, and the latter is immediately converted into a talking picture.

In small motion picture shows this mechanical system of sound reproduction offers a number of practical advantages over the photoelectric system because of its greater simplicity. Because of the greater efficiency of the pick-up by comparison with the photoelectric cell, the necessary amplification will be reduced, and the optical system, especially the light source, is excluded altogether. On account of the enormous area of the Soviet Union and because of the frequent lack of electric power supply, such a system of sound recording, even if used solely for the purpose of musical accompaniment, is already very promising. This is especially true as only a 6-volt battery is required, which can always be borrowed from a car or a tractor, both of which are nowadays easily found in any settled region.

The only drawback of the system is its equality. The present engineering tendency in talking moving pictures is to assure a transmission band up to 7000–8000 cycles, and it appears that the mechanical system is not a step forward in so far as quality is concerned, since the frequency band will actually be narrower. However, the quality of the system is surprisingly good, and is proving satisfactory in an emergency.

THE EDUCATIONAL MOTION PICTURE OF YESTERDAY, TODAY, AND TOMORROW*

H. A. GRAY**

Summary.—*The evolution of mechanical aids to learning is traced briefly, and the advantages of the motion picture in overcoming limitations to learning are discussed. Experiments for testing the efficiency of silent and sound pictures as media of instruction are cited.*

Reference is made to some of the problems that must be solved before educational motion pictures can be used more widely in formal public instruction. Suggestions are made for measuring objectively the effects of sound motion picture elements upon the observer by means of mechanical recordings and detailed study of the individual.

In this paper is presented, not the point of view of an engineer, but that of a research worker who is concerned with the development of the sound picture for instructional purposes. The evolution and present status of the educational motion picture will be described briefly, and the movement that its developments have created will be alluded to. Also, some of the problems involved in its utilization will be mentioned, and an area of research calculated to enhance its power to stimulate human beings will be outlined. The latter point is of particular significance because in the future the sound picture engineer and production specialist may be envisaged as devoting considerably more attention to the problem than has been the case in the past.

Since the beginnings of society the acquisition and dissemination of knowledge have been influenced by the facilities available for such activities. As a savage, man's learning was restricted to that obtained from signs, demonstrations, and experiences with the elements going to make up his environment. Then came sounds and language, which for a time were destined to become the chief means of propagating information. With the invention of writing, man was able to record his learnings for current and future reference; first on clay tablets, and later on the papyrus roll, and for hundreds of years,

* Presented at the Fall, 1934, Meeting at New York, N. Y.

** Erpi Picture Consultants, Inc., New York, N. Y.

spoken and written language, demonstrations, and experiences were the modal methods of acquiring knowledge. The invention of the printing press gave impetus to the widening of intellectual horizons, and for another long period the printed page dominated, to the exclusion of almost everything else, the quality and quantity of learning. As time went on, however, a need was felt for other devices to serve as learning aids. This need was gradually met by science as invention created a number of instruments of instruction. Laboratory apparatus, still pictures, models, exhibits, charts, graphs, maps, stereographs, slides, silent motion pictures, phonographs, radios, and sound motion pictures are among the more important ones, and all have contributed materially to the advancement of learning. Those whose use depended upon the sense organ of sight became known as visual aids, and the phonograph and radio have acquired the title of auditory aids. Recently the sound motion picture has been referred to as a visual-auditory aid.[1]

The term *visual education* may be taken literally to mean the sum total of all visual experiences, but for practical purposes it is usually limited to the educational use of materials specifically created to enhance the impression that an observer may acquire of a situation. The indications are that each device may occupy or carry on a particular function in the classroom, that it is possible to achieve results with one device that can not be as satisfactorily obtained with other devices. The question was first of all a matter of opinion. Then it became a matter for scientific experimentation to decide. The effectiveness of still pictures, models, exhibits, charts, maps, graphs, and stereopticon slides has been demonstrated by their widespread use in all forms of educational activities. Teachers have come to depend upon these devices for assisting them in developing concepts otherwise difficult to acquire. Early experimentation, however, such as that conducted by Weber,[2] has shown that the effectiveness of materials of visual instruction depends to a great extent upon the degree to which they are integrated with verbal concepts and printed supplementary materials.

About the beginning of the present century, the late Thomas A. Edison[3] predicted that the silent motion picture would in time occupy a prominent place in education. It was not until some years later, however, that educators all over the country became enthusiastic over the educational potentialities of the film. Its use led to considerable experimentation regarding its instructional effectiveness. Wood and Freeman[4] found in their controlled experiment with 11,000 school children, that the group instructed through the use of motion pictures achieved about 17 per cent more in mean gain in geography tests and about 11 per cent more mean gain in general science tests than the members of their control groups. Knowlton and Tilton[5] reported gains of 19 and 12 per cent, respectively, in favor of those experimental groups that had seen *The Chronicles of America* before taking tests in American history. These early experiments were substantiated by similar ones conducted in England, where Burt, Spearman, and Philpot[6] concluded from their investigation that the motion picture should be an integral part of the educative process. Some time later, Freeman[7] and his collaborators in America described the motion picture as having a distinct educational value in the subjects of nature study, geography, handwork, high-school science, home economics, English, health, and even handwriting, their conclusions being based upon the experiments that they conducted as a further check upon the film's efficacy.

With the advent of the sound motion picture, additional experimentation was undertaken. A testing project, supervised in part by the U. S. Office of Education, indicated that the sound film was about twice as rich in instructional values as its predecessor, the silent film.[8] About the same time an independent investigation, conducted at Columbia University with adult graduate students as subjects, showed a twenty-minute sound picture to be a significantly more effective stimulus than longer periods of time spent on discussions, writings, and lectures.[9] A third experiment, conducted in England under the auspices of the Middlesex School Committee, indicated not only substantial learning increments on the part of the pupils but definite interest and enthusiasm from the teachers participating.[10] The Arnspiger experiment[11] carried on in the five cities of Schenectady, New York, Elizabeth, Camden, and Baltimore, and involving sixty-four schools with some 2200 pupils, showed that the groups using the pictures achieved 25.9 per cent more in natural science and 26.9 per cent more in music. In addition, the sound picture groups retained more of the knowledge thus gained over a period of three months. Other testing projects conducted under the auspices of Columbia, Harvard, and New York Universities have substantiated for the most part the previous findings involving the use of the sound film.[12,13,14]

The recent investigation, financed by the Payne Foundation to study the effect of theatrical motion pictures upon children likewise indicated the effectiveness of the medium for shaping attitudes, stirring up emotions, molding morals, and generally influencing behavior.[15] The sound motion picture has been described as being one of the most influential forces in contemporary social life; a fact easily determined by study of the success of advertising, propaganda, and other types of films designed to mold public opinion.[3]

Many teachers colleges and normal schools are now requiring their students to develop skill in the use of visual aids, including motion pictures, as an essential part of their training. Other teacher-training institutions offer courses in such instruction as electives. At the present time, thirty-one colleges and universities list such instruction as separate courses, and twenty-one university extension divisions maintain visual instruction service chiefly with motion pictures.[16]

During the past few years a great number of books and articles in educational periodicals dealing with aspects of education by motion pictures have appeared. The magnitude of this activity is attested by a recently published bibliography listing fifty-one books, thirteen booklets, thirteen M.A. and Ph.D. theses, and hundreds of articles, selected from an even more extensive list.[17]

The movement has grown to the point where the state and national governments of practically all civilized countries are taking an active part in the production and distribution of educational motion pictures.[3] In America, the Federal government is probably the largest single sponsor of educational motion pictures. The Bureau of Mines, the Department of Agriculture, and other governmental departments have prepared an enormous amount of picture material for imparting information upon matters with which they are concerned. Without doubt, the government's activity in this field has been of great value to many industries and individuals throughout the world.

The preceding indicates that educators internationally have recognized the power of the celluloid film, particularly the sound picture, to overcome physical and human limitations to learning—physical with respect to the restrictions of time and space, and human with regard to the inability of the human senses to perceive objects and relations too abstract in nature or too finite in dimension for human conception.

The sound motion picture is one of the most powerful motivating devices in existence for stimulating such learning and its constituent attitudes and appreciations; and if created and utilized intelligently it can be made to serve the purposes of education as no other device available. With it entire new vistas are opened up to the learner's perception. The streaming of protoplasm through cell tissues, animated molecular action, the sight and sound of a human heartbeat, the striking colors and sounds of under-sea flora, slow motion pictures of bird's wings in flight, ultra-rapid pictures of growing plants, x-ray portrayals of mineral deposits, and many other natural phenomena may be seen and heard by means of the various sound-photographic technics that have been developed.

Then there are the more subtle elements of social and economic relations, which can be vividly portrayed in life situations with a challenging appeal to the learner's attention and interest. The social studies, particularly, have become beneficiaries with these materials.

Schools not possessing elaborate plant and equipment facilities for comprehensive study activities, need be no longer so handicapped. With a comparatively small capital outlay, the sound film can bring to the individual classroom unlimited study materials. The messages of world leaders, difficult and expensive laboratory experiments, exhibits of museum and art collections, travel experiences—in fact, almost every conceivable element of a world environment now may be made available for boys and girls with previously restricted educational opportunities.

So much, in brief, for the development and present status of the educational motion picture. Its advantages will now be objectified by presenting a film devoted to the explication of sound phenomena. Note how the medium is employed to portray the mechanism of hearing; how such intangibles as sound velocity, refraction, range, intensity, attenuation, low and high frequencies, reverberations, and focusing are treated by the marvels of animation and sound effects. Compare this method of presentation with the effectiveness of conventional methods in the physics classroom, and draw your own conclusions.

(*At this point Dr. Gray presented the sound picture "Fundamentals of Acoustics," courtesy of Erpi Picture Consultants, Inc.*)

We shall now refer to some of the major problems that must be solved before the sound film can render the optimal educational service of which it is potentially capable. Some of these problems are common both to the producers of educational pictures and to the manufacturers of sound projection equipment. Other problems are the chief concern of either the picture producer or of the equipment manufacturer. Still others rest squarely upon the educational authorities themselves.

Part of the failure of educators to use the silent picture more extensively was due to the frequent failure of the films offered to fit into any particular course of study. Also, such pictures often duplicated what the teacher could do quite as effectively with other devices. Many films lacked either logical or psychological continuity, or both. Few were arranged with definite teaching objectives in mind, and still fewer were accompanied by printed supplementary material for the teacher's edification, not only on the picture's projection, but on its integration with other study activities as well. This is primarily the producer's problem, and Erpi Picture Consultants have attempted to solve it by developing objective standards for the production of instructional sound films; surveying the various fields of educational effort to determine wherein the sound film could make contributions; analyzing courses of study for the selection of picture topics; preparing scenarios for the topics; meeting the standards and criteria set up; retaining production specialists for the preparation of pictures; testing the classroom effectiveness of the sound films produced; coöperating with school authorities in developing utilization programs; and arranging supplementary printed material to accompany each picture.

A second major problem concerns the manufacturers of sound equipment. Ultimately auditorium equipment should be in every school having such an assembly space. This will serve for the instruction of large groups of students and occasionally for entertainment purposes. However, the big future of the sound picture will be in the individual classroom, where the teacher may on a moment's notice project upon the screen a vitalized part of his lesson plans. The specifications for such equipment obviously call for low initial cost and upkeep, portability, simplicity of operation, rigidity of construction for reliable performance, and, of course, 16-mm. sound-on-film reproduction of good quality.

These two problems must be solved simultaneously, for, until adequate pictures and equipment are available, producers can not sell prints nor can the manufacturer find an outlet for his projectors, however good either may be.

A third problem concerns the responsibility of educational authorities to plan for the extension of instruction by sound pictures. This involves first of all the training of teachers in the use of projection equipment and the handling of sound film. Each teacher-training institution should include such instruction in a course to be called perhaps, "Special Methods with Mechanical Aids." Teachers already in service may likewise receive instruction in the utilization of such devices. State departments of education can well promote the organization of local departments of audio-visual instruction, and sponsor the initial purchase of equipment and films for communities unable to bear the financial burden entailed. An inference regarding the state's responsibility for a comprehensive visual education program is made by Dr. C. M. Koon, senior specialist in radio and motion pictures of the United States Office of Education, who recently remarked:

"... Probably one of the most important problems facing workers in visual education is to determine means whereby the state can be made aware of the vast responsibility resting upon it to make provision for the use of films in all schools within its domain. As soon as visual instruction is sponsored by the state, we can rest assured that we shall have a much better educated populace."[17]

Another problem common to all concerned with the production and use of the educational sound picture is that of research devoted to discovering how, when, and why elements of sight and sound affect the individual visibly or otherwise, enough to modify his thinking or behavior. The sound picture with is human, animal, elemental, and mechanical sound stimuli; trick, natural, and animated photography of form stimuli; and its black, white, and other color stimuli; effect in the individual glandular, muscular, and neural systems; changes known as interests, attitudes, learnings, emotions, and appreciations. Past attempts to measure these characteristics of mental development fall into three general classifications. The first is individual observation, in which the experimental examinee is subjected to direct interrogation, participates in interviews, engages in discussions, and has his conversation analyzed.

A second type of experimentation has utilized paper-and-pencil tests and procedures. The individual's reaction to word association checklists, reading choices, questionnaires, opportunity for self-analysis, subjective questions, personal preferences, "yes-no" multiple-choice problems, contrasting statements, superstitions, and speed tests have been reported in voluminous detail along with records of his factual and vocabulary knowledge.

The third classification describes the technics that have been utilized in mechanically recording the subject's respiratory and pulse rates, his blood pressure, muscular tension, vocal responses, psychogalvanic reflexes, facial expression, and resistance to interference while subjected to selected stimuli.

Because of the experimental limitations, these approaches have been foredoomed to partial if not complete failure in attempting to solve the problems with which they were concerned. Until such procedures are developed in combination, together with a detailed study of the individual and of the stimulus to which he reacts, the recording of such degrees of failure is likely to continue.

At the present time, numerous tests and methods of gaining information about the individual are available. Each of these has some merit, but when taken singly and without respect to the individual as a whole their value is lessened decidedly. However, some knowledge of a subject's reputation, imagination, attitudes, morality, interests, inhibitions, home life, general character, aggressiveness, sexual traits, confidences, emotions, appreciations, community life, esthetic reactions, speed of response, sociability, physiology, and suggestability, along with some measure or index of his mechanical, abstract, auditory, and social intelligence, will provide valuable clues and reasons for his behavior in the experimental situation. Nevertheless, most of such information would be highly subjective and difficult to correlate, and the author feels that some measure of the individual's abstract and auditory intelligence, his reaction speed, and his electrical resistance and capacity would suffice for beginning the experimentation proposed. This information should be obtained before the individual reacts to the stimuli of the sound picture.

It is further believed that the recording of the individual's reactions to the sound film in synchronization with its presentation, and consisting of his respiration and pulse rates, muscular tension, psychogalvanic reflexes, facial expression, and brain oscillations would provide a much more valid and reliable measure of his whole response than anything yet attempted. The meaning of the variations and correlations obtained by such recordings would be clarified by paper-and-pencil procedures, discussion, direct questioning of his thoughts and feelings as to elements in his visual-auditory experience, and the data that were obtained prior to the presentation of the picture.

Similarly, an analysis should be made of the sound picture stimuli before they act upon the subject. A detailed description of the color elements, their location, contrasts, and combinations, should be provided. An enumeration and description of the sound elements, including their kind and source, also would be necessary, together with a classification and description of the form elements, their appearance, location, and mode of presentation in each scene. A synchronized record of the volume of sounds and the intensity of the light reflected from the screen, would provide an accurate index of the strength of the composite sound and light stimuli involved, and would be of value in interpreting the many cause-and-effect relations that undoubtedly would be discovered when all the data were grouped into comparable units for detailed analysis.

(Dr. Gray terminated his presentation by projecting the picture "Sound Waves and Their Sources," courtesy of Erpi Picture Consultants, Inc.)

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THE THEATERGOER'S REACTION TO THE AUDIBLE PICTURE AS IT WAS AND NOW*

MORDAUNT HALL**

Summary.—*A brief description, in narrative fashion, of the improvements that have come to the motion picture since the day of the silent, with particular reference to dramatic tastes and preferences, from the point of view of the critic.*

Not only has the linking of sound with motion pictures been responsible for the employing of infinitely more intelligent players than one usually found in silent films, but it has taught audiences to a great extent to appreciate a higher order of screen entertainment. The talking picture is now a diversion that appeals to all manner of men and women. Yet, at the outset, only a few years back, when Warner Brothers released their first Vitaphone features, sound was thought by several of the more astute and moneyed motion picture producers to be but a passing fancy on the part of the public. Many a writer scoffed at the idea of coupling the microphone and the camera and even that celebrated dramatist, Pirandello, took a fling at the notion of having speech come from a flat surface. Others contended that it sounded the death knell of the cinematic art. They bemoaned the new invention, or relatively new because of its sudden popularity. Undoubtedly the first sound pictures offered much to be critized adversely, and as the screen critic of the *New York Times,* I was frequently asked whether these squawking affairs would continue. Some declared that they meant the end of the great industry. They called attention to the ludicrous lisping of the actors, and the theater managers did not help matters by insisting upon having the speech come forth in deafening tones. They boasted that every seat was a front-row seat, and saw to it that those in the rear of their houses were never in doubt as to what was being said by the characters.

Even though the voice was the thing later in Lawrence Tibbett's film *The Rogue Song,* this baritone's vocal efforts were reproduced

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** New York, N. Y.

with such fierce loudness that one felt that the theater management hoped to have the première of the feature heard not only outside the theater in Times Square, but across the Atlantic. This was somewhat distressing to writers like myself, who favored the audibility of the screen, but soon it was evident that as each new dialog film was presented a steady improvement was revealed. True, there were the shortcomings of the players, such as those pretty blondes who should have been seen and not heard, for their baby voices or their twangy uncultured intonation was not a little irritating. Many of these attractive feminine players eventually found themselves in the discard, their places being taken by experienced stage performers.

Then, too, there was in the beginning of the sound offerings the disconcertingly poor synchronization. Frequently the voices appeared to be coming from the feet of the players, and this gave the opponents of sound further chances to heap ridicule upon the talking pictures, as did also the frightening explosive outbursts that were emitted from the screen all too frequently. Most of the players in those times seemed to be declaiming, speaking their lines as rapidly as possible, either because they feared that they would not be able to get rid of their speeches in the given time, or because they were in terror of forgetting what they had to say. Directors who had been in the habit of shouting through a megaphone were forced to do everything by signals while the sound appliance was working, and many a dainty graduate from a manicure shop or a lunch-counter failed to grasp what the director wanted her to do, with the result that the director either ordered a retake, or tore his hair as silently as possible. During this state of affairs it was not astonishing that intelligent persons did more jeering at the dialog films than they had done at silent ones. There were those patrons of the films who had found silence a boon and a blessing. If the feature was poor entertainment they at least could take a nap. The noise of audible pictures kept these people awake.

Those Russians who had done so well with mute works were by no means enthusiastic over giving voices to the shadows, but as years passed the Soviet film makers discovered that a resourceful and an imaginative director could inculcate art into a sound film as well as he could in a silent subject. In fact, he had a double instrument with which to appeal to his audiences.

Now and again in the days of five or six years ago, features appeared with periodical outbursts of speech, followed by silent episodes.

These films were really awful. One or two producers later took a chance at a silent film, but except in the case of Chaplin's *City Lights*, silence was no longer golden. Even the artistic Chaplin, who caricatured dialog films in his last comedy, took full advantage of certain sound effects. Chaplin was wise enough to know that his wordless film would sell all over the world, and it is hardly likely that dialog in his subjects would be as successful as pantomime, especially Chaplin's own work. Few of his hosts of admirers would ever want him to speak in his comedies. His films, however, are the exception that proves the rule.

So far as other more recent silent productions are concerned, they seem, after one has become accustomed to hearing speech from the screen, to be, if anything, more absurd than any of the first vocalized films. In the old product title writers committed many sins. They were fond of repeating pet phrases. How often one would read in the text, "Came the dawn," "Just around the corner dwelt," "The chatelaine of the manor was," and "It's a far cry from"! Even that was all very well until the sound productions showed progress; but viewing a mute offering then often resulted in great disappointment, as one had by that time become accustomed to hearing the characters speak and, therefore, refrain from gesticulations that had become quite common in even the best of silent films. It has been my experience invariably to find that the old gems of the past were far inferior to the present-day worthy talking picture. In fact, it often happened that when one saw the silent features over again they seemed quite inferior. Many believe that, in order to achieve satisfactory cinematic values, it is better to have a minimum amount of dialog. This idea, in my opinion, applies only to isolated instances, for in the majority of cases the real vitality of a film is now the dialog.

A remarkable subject that offered one of the most impressive combinations of the microphone and the camera was *The Invisible Man*. As one now listens to the extraordinary natural quality of the sound one can not but marvel at it, especially when he harks back only a year or so and remembers the curious things that happened in the studios. Monta Bell, the director, told me that in experimenting with sound films he had made the amazing discovery that a lump of sugar dropped into a tea-cup came forth from the screen like the sound of a fifteen-inch gun.

Talking pictures rival politics as after-dinner chatter. It is strange that one has only to sit down a few minutes before he hears the conversation drift to talking pictures, and once there it usually endures.

When I read of somebody damning a picture because it is nothing but a photograph of a dramatic work, I feel that there is something to say for the fact that we are now able to get even a photograph of a play, for that is surely preferable to some of the films that find their way out of the studios. But the poor stuff that is produced is not always quite the fault of film makers, for unfortunately, even in this year of grace, there are still many patrons who dote upon happy endings and dislike intensely to have their screen favorites pass away at the end of the story. One also finds that apple blossoms and love still go together with amazing frequency, and because of the desire to please unthinking audiences there exists no suspense in film tales. These are some of the heritages of the past. And strangely enough, educated persons with alert minds have frequently revealed to me their poor taste in pictorial narratives. But, as I have already remarked, motion pictures have improved immensely and it is to be hoped that the silly effusions will become fewer and fewer.

When the sound in pictures became what it is, or has been for the last year or two, some of the producers revealed a penchant for planting episodes in wash-rooms, and on one occasion a distinctly vulgar use was made of the marvelous invention. This peculiar type of humor was undoubtedly inspired by something that happened in a play. Incidentally, so far as coarseness is concerned, one might say that the stage is way ahead of motion pictures. True, there are wearying instances of stuff made to appeal to the clodhopper, with vulgar outbursts that are both reprehensible and silly.

If the producers, instead of concentrating so often upon suspenseless twaddle, were to turn their attention to something worth while, it would be doing something comparable to the work done by the inventors. As the uppermost thought of most picture makers when selecting a story is to turn out something that will bring home the bacon, there ought to be a few philanthropists who might encourage the production of Shakespeare's works, and other classics. Also, many persons over here and still more in Britain, Australia, Canada, South Africa, and so forth, would delight in hearing and seeing some of the Gilbert and Sullivan works on the screen. Such features might not bring in returns equal to those of *Forty-Second Street* or *Chained*, but they might, if really well done, surprise their producers. As to Shakespeare, granting that the audiences might not be numerous enough to pay for showing films of the bard's plays in the big cinemas, such productions might easily be screened in schools and colleges.

I do not recall whether when I addressed this gathering several years ago, I commented upon the number of performances given in pictures; it is a marvelous contrast to the stage. When *Grumpy*, with the English player Cyril Maude, was put on at the Paramount here, Mr. Maude was very proud of having given 1300 performances of the play in various sections of the world. Had he acted continuously, which he did not, I believe that I am right in saying that the 1300 performances would have taken more than three years. Now, take the picture of the play suddenly bursting forth in various centers in huge theaters, often for five and six and seven shows a day. It has been computed that before Mr. Maude's shadow got through playing *Grumpy* it had given something like 150,000 performances.

There was a time when it was estimated that the weekly attendance in the United States at motion picture houses was 115,000,000. This figure has not been touched since the prosperous times.

Spectators have now reached a point when they expect perfection in sound recording, so much so that they would complain of the slightest technical deficiency. Although Eugene O'Neill's *Strange Interlude* was cut down to suit the commercial length of pictures, and therefore much of the brilliant play was left out of the film, it is interesting to note that the idea of "asides" being spoken was far better suited to the screen than to the stage. On the stage the players were called upon to speak these asides, and it was not entirely successful because their between-the-teeth utterances were not always clear. For the screen these asides were recorded before the players were photographed for the scene, and in the picture their lips were still. It was, I believe, in *Blackmail*, an English picture, that the first thoughts were heard from a character, and this brings to mind the fact that the producers of the film of Dreiser's *American Tragedy* would have added greatly to their picture had they made audible the thoughts of the young murderer while he was in the telephone booth talking to his victim and asking her to meet him.

Sound or audibility was employed in a new fashion in Jesse L. Lasky's *Power and the Glory*, the treatment of which was termed "narratage." The story began at the end; the incidents were not unfurled in the usual flash-back way, but told by living characters about a husband and wife who were both dead. The opening scenes revealed the funeral of the central character and also what certain people thought of him. After that the story came from several angles, showing what led to the suicide of the principal character and, prior to that, of the suicide of his wife.

Notwithstanding the superior taste of audiences in motion pictures since talking films were made, it is regrettable that narratives endowed with much subtlety are seldom successful and also that satirical ventures invariably fail to bring in much to the box-offices. Hokum is popular, but, I am glad to say, it is an improved type of hokum over what was usually offered in the silent effusions. Hence, even in this respect audibility has accomplished something.

Ernst Lubitsch, that masterful German director, was, if memory serves correctly, the first to blend the sound of machinery with music, which made a curiously effective rhythm. He placed Jeanette MacDonald in a train coach, and had her sing to the accompaniment of a combination of music and the sounds of the speeding train, which included the whistle warning, the roar of the coaches and the jogging sound of the wheels. And while this director produced some fine examples of silent pictures, there is no doubt but that sound gave him something more with which to conjure. As somewhat of a contrast to Lawrence Tibbett's *Rogue Song*, there was recently the opera singer, Grace Moore, in a picture called *One Night of Love*, which even at a time when the public and the press had become accustomed to very high quality of reproduction, aroused great praise for the fine recording, particularly of the singing. Little did audiences expect such excellent results when they beheld that first musical film, *Broadway Melody*, wherein there was the absurd idea of having theatrical troupers singing in a hotel room accompanied by Paul Whiteman's unseen orchestra. Think of that outstanding picture, *Cavalcade*, which never could have been equalled as a silent film, for the very lines, spoken so well by all the players, especially Diana Wynyard, Clive Brook, and young Frank Lawton, were something that could never have been handled in mere text. I saw a photograph of the play *Calvalcade*, as it was done on the Drury Lane stage, and Winfield Sheehan's masterful production was greatly superior to the flesh-and-blood performance, in cast and scenic effects. Thinking up the several reels of titles that would have been needed to give anything like an adequate idea of the conversation between the characters may cause persons to reflect upon the fact that with even the skeletonized text of silent films the titles took about one-fifth the length of the picture. Then, too, one might miss a few words, through somebody's passing his seat, and much of what went on for several scenes would be rather obscure. Nowadays even though one's view of the screen may be shut off temporarily, the voices are heard, and in any good film there is never the least doubt concerning what has happened.

The dubbing in foreign countries of American productions appears to have been more satisfactory than was expected. Then there are also those superimposed titles, which, to my mind are even more satisfactory than giving a player a voice that does not belong to him. Anent dubbing, there have been films dealing partly with thugs and crooks who were supposed to be British. Occasionally a dialect was attempted, but more often than not it seemed as though all the gentry involved were old Oxonians. However, if the dubbing is done with greater care, it does help to give the producers additional financial returns. Few such offerings are shown in this country, as the distributors of foreign productions here usually prefer the superimposed title to the dubbed voices.

The most successful British films put on over here have been, *The Dreyfuss Case*, *The Private Life of Henry VIII*, *Catherine the Great*, and *Rome Express*. The *Henry VIII* production captured popular fancy and was the inspiration of many a humorous picture in the periodicals. Although it was directed by the Hungarian, Alexander Korda, it was made in England and the title rôle was played by that brilliant British actor, Charles Laughton, who obviously could never have done so well by pantomime in a silent film.

It must be agreed, however, that notwithstanding certain uninspired uses of the screen's audibility, there have been many instances of really fine works. And it is to be hoped that the producers will do more to lead the public rather than give even as many instances of catering to the moronic fancy as they have in the past. A well-told story with imaginative ideas invariably appeals to all manner of men.

DISCUSSION

CHAIRMAN CRABTREE: Have you ever noticed that between the end of one reel and the beginning of another, a little black circle appears upon the screen? It often has a white circle around it. That is the signal for the projectionist to push the lever to change over to the next reel. Have you ever noticed those spots, and do you think the audience notices them?

MR. HALL: No, I don't think I have, really. I have noticed where there have been cuts and so forth, but I believe that even those things pass unobserved by the spectator as he becomes really absorbed in the story.

CHAIRMAN CRABTREE: You have viewed hundreds of pictures; have you felt any desire to see a larger picture than what you have seen?

MR. HALL: I don't believe so; because when they tried it with the Grandeur screen, the voices were very poor when several characters were on the screen The dialog seemed to be coming from the corners of the screen and not from the actors.

CHAIRMAN CRABTREE: We have seen recently some very excellent three-color pictures, *La Cucaracha*, for example. Color pictures up to within the past year have been produced largely by two-color processes, so that we could not reproduce yellow, purple, rose, and so on. The colors were not what we should call natural colors. But now with a three-color process available and perfected to quite a wonderful degree, what is your reaction, and what do you think the public's reaction is to these improved pictures?

MR. HALL: I have seen only the one. I do think the color improves the Walt Disney subjects a great deal; now the Silly Symphonies are far superior to the Mickey Mouse features. But *La Cucaracha* seemed to me to be very dark and somber in spots. In most of the color pictures I have seen, there seems to be too much of a desire to show color and flash it before you.

MR. ROGERS: Have you any criticism as to the way the light is applied in making motion pictures? My own criticism is that the details are too much enhanced. In some scenes even the darkest corners are shown with great detail. I should think that very often "atmosphere" could be created by lighting in a more natural manner—the Rembrandt effect, for example—leaving out the unimportant details and letting the light also have a dramatic effect upon the picture.

MR. HALL: Such extremely artistic pictures are all very well now and then, but whether they would have an appeal commercially, I do not know.

A GLOSSARY OF COLOR PHOTOGRAPHY*

*The following glossary which has been prepared by the Color Committee contains some two hundred terms used in connection with color photography. Although, for convenience, all the listed terms are arranged alphabetically, it is really made up of two groups of material. One group consists of technical terms useful in the art. This group is composed for the most part of terms for which satisfactory definitions are not easily found in the text-books and dictionaries of the fundamental sciences, or in the general glossary of the Society.*** *It is not, therefore, intended as a complete technical vocabulary of the subject. The other group (marked by italicized type) contains proprietary names of special processes and equipment. The Committee admits to some uncertainty in connection with this portion. Some processes that are here described may be of no lasting importance; possibly other processes which have been omitted should have been included. In the case of some of the proprietary processes, complete, accurate information is not available; in the case of others the nature of the marketed product is changing from time to time.*

Absorption Band (of a color filter)—A dark zone in a spectrum resulting from the failure of a color-filter to transmit light of wavelengths corresponding to the band.

Acid Dyes—Dyes in which the color resides in the negative ion (anion). Commonly, salts of colorless inorganic bases with colored or potentially colored organic acids.

Additive Mixture—See ADDITIVE SYNTHESIS.

Additive Process—A process for reproducing objects in natural colors by means of the principle of additive synthesis. Usually, black-and-white positives, printed from negatives taken through the primary color filters, are projected or viewed in register by means of light beams of the primary colors.

Additive Synthesis—The formation of a color by mixing light of two or more other colors. *Any* color may be formed by mixing light of three primary colors in the proper proportions. *Some* colors may be formed by mixing light of two other colors.

Agfacolor Process—A 16-mm. adaptation of the lenticulated film principle. (1932)

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Angström Unit—A unit of length generally used for specifying the wavelength of radiation, especially light and radiant energy of wavelengths shorter than light. Numerically equal to 0.0000001 mm. (10^{-7} mm.). The unit more frequently used in colorimetrics is the millimicron.

Aniline Dyes—A term broadly applied to synthetic dyes derived from aniline or other coal-tar products.

Artificial Daylight—Light (visible radiation) having the same (or nearly the same) spectral composition as direct solar radiation plus skylight—in practice produced by selectively absorbing some components of the light emitted by artificial sources.

Autochrome Process—A process for three-color additive photography, plates for which are made by Lumière. The plates carry an irregular mosaic screen of red, green, and blue-violet starch grains with a panchromatic emulsion over-coating. (1907)

Basic Dyes—Dyes in which the color resides in the positive ion (cation). Commonly, salts of colored organic bases with colorless acids.

Beam-Splitter—An optical system so arranged as to reflect or transmit two or more portions of a light-beam along different optical axes. Such a device is frequently used in the production of color-separation negatives.

Bichromated Gelatin—Gelatin sensitized to light by the incorporation of a soluble bichromate, usually ammonium or potassium bichromate.

Bipack—A unit consisting of two superposed films or plates sensitive to different portions of the spectrum, and intended to be exposed one through the other.

Biprism—A prism having a principal section which is a triangle with a very obtuse angle and two equal acute angles, sometimes used as a beam-splitter.

Black—Incapable of reflecting light.

Black Body—1. A body which when heated radiates ideally according to fundamental physical laws (*i. e.*, Wien radiation law) relating energy, frequency, and absolute temperature. The properties of incandescent tungsten or carbon approximate those of a black body. 2. A body which absorbs all light incident upon it.

Bleach—*v. t.* To remove the color by chemical means; in photography to remove, by chemical action (usually oxidation), the silver of an image. An image thus treated may be restored by suitable means generally leaving the gelatin film toned and/or tanned. *n.* A chemical reagent used for bleaching.

Bleach-Out Process—A process for making color-prints from a color-transparency, by use of a support coated with a mixture of dyes, each of which is capable of being decolorized by exposure to light in a different portion of the spectrum.

Bleeding of Color—The diffusing of dye away from a dye-image; most noticeable where dark areas adjoin light areas in a picture.

Brewster Process—A subtractive two-color process utilizing a double-coated negative film. A colored negative is printed on double-coated positive film, and the final silver images are bleached and dyed. (1914)

Brightness—The light (luminous power) per unit area, per unit solid angle, emitted from a surface in a given direction; the candle-power per unit area.

Brilliance—The characteristic of a color that expresses the intensity of the sensation.

Busch Process—An additive two-color process. The negative is produced by running 35-mm. film horizontally through the camera. Twin lenses form a pair of images upon a single frame area; image pairs are superposed when projected. (About 1928)

Carbon Printing—A process for making prints in one or more colors by exposure of a bichromated and pigmented gelatin tissue to produce local insolubility of the gelatin, followed by the development of a relief image through the solvent action of warm water.

Carbon Transfer Process—A process in which a relief image, produced in carbon printing, is transferred to another support from the one upon which it was developed.

Chemical Toning—The process of converting the silver of a photographic image into a colored substance, or replacing it by a colored substance through the use of chemical reagents which are not dyes.

Chromatic Aberration—A defect of a lens resulting in a difference in focal length for light of different colors.

Chromaticity—The quality of colors that embraces hue and saturation but excludes brilliance.

Chromoscope—1. A viewing-device for obtaining superposed images of color separation positives. 2. A type of colorimeter using colors produced by the rotary dispersion of quartz as standards.

Ciné Color Process—A subtractive three-color process. Negatives are made with a beam-splitter camera using a single film and a bipack. Double-coated film is used for the red (dye tone) and blue (iron tone) images. The third (yellow) image is added to the film from a matrix by imbibition.

Colloidal Dyes—Dyes the particles of which are submicroscopic in size, but larger than molecules or ions.

Color—1. The general name for all sensations (other than those related to spacial distribution) arising from the activity of the eye and its attached nervous system. Examples of color are the sensations red, yellow, blue, black, white, gray, *etc.* 2. More loosely, as above but excluding the black, white, and gray sensations.

Color Analyzer—1. A colorimeter. 2. An instrument used to determine the relative brightness of light of different wavelengths reflected or transmitted by a substance or emitted by a source.

Color Balance—The adjustment of the intensities of printing or viewing colors (of a color picture) so as to reproduce properly the scale of grays.

Color Blindness—An ocular defect resulting in failure of the eye to distinguish between chromatic colors. In total color blindness all colors appear as grays; the more usual partial color blindness (dichromatism) is marked by inability to distinguish between certain pairs, as, for instance, red and green.

Color Contrast—See CONTRAST, COLOR.

Colorcraft Process—A two-color subtractive process of cinematography. The negative is made by a beam-splitter or by a bipack method; the positive is on double-coated film. Print images are dye toned with the aid of an iodide mordant. (About 1929)

Color Developer—A substance or mixture of substances capable of reducing silver halides with the simultaneous production of an insoluble colored oxidation product in the regions of the silver deposit.

Color Filter—See FILTER.

Colorimeter—An instrument used for measuring color. The *monochromatic* colorimeter operates according to the principle that any color sensation may be matched by a pure spectral hue mixed with white, or by adding a pure spectral hue to the unknown color to produce white. The *trichromatic* colorimeter operates according to the principle that any color sensation may be matched by the addition in the proper proportion of three primary colors, *viz.*, red, green, and blue.

Colorimetric Purity (of a color)—The ratio of the luminosity of the dominant wavelength to the total luminosity of the color being measured.

Color Index—A publication of the Society of Dyers and Colorists (British), listing practically all dyestuffs in commercial use.

Color Match—The condition resulting when samples of light from two or more sources produce identical color sensations.

Color Mixture Curves—See COLOR SENSATION CURVES.

Color Negative—A negative record of the color values of the original object.

Color Photography—A process in which an attempt is made to reproduce objects in their natural colors by photographic means.

Color Positive—A positive photographic (print) record of color values.

Color Saturation—See SATURATION, COLOR.

Color Screen—1. A color filter. 2. A surface bearing a mosaic, either regular or irregular, of minute, juxtaposed, transparent elements of the primary colors; used in a screen-plate or screen-film process of color photography.

Color Sensation Curves (Excitation Curves)—Curves based upon the response of the normal human eye, showing the relative excitations of the three elementary sensations, according to the Young-Helmholtz theory of color vision.

Color Sensitivity, Photographic—The sensitivity of a photographic material to light of various portions of the spectrum.

Color Separation—The obtaining of separate photographic records of the relative intensities of the primary colors in a subject in such a manner that a photograph in natural colors can be produced therefrom.

Color Specification—A description of a color made in such a way that the color sensation may be duplicated. This may be done either with the aid of a color analyzer or by the use of certain visual color matching devices, such as colorimeters or color comparators.

Color Temperature (of a source)—The temperature (expressed on the absolute scale) at which a black body radiator will visually match the color of the source.

Color Transparency—A color photograph upon a glass or film support to be viewed or projected by transmitted light, as distinguished from a color photograph on paper or other opaque white support to be viewed by reflected light.

Color Tree—A graphical method for specifying color sensation. Brilliance, hue, and saturation are presented in three dimensions.

Color Triangle—A graphical method of specifying hue and saturation. The three primary colors are represented at the apexes of a triangle and white at its center.

Complementary After-Image—A sensation caused by ocular fatigue characterized by the persistence of an image of the color complementary to that of the original stimulus.

Complementary Colors—Two colors of light, which, when added together in proper proportions, produce the sensation of white or gray. Also, two colors of dye or pigment, which, when superposed in proper concentrations, produce a gray.

Cones—One of the two chief light-sensitive elements of the retina, frequently regarded as the seat of color vision. See RODS.

Continuous Spectrum—A spectrum, or section of a spectrum, in which radiations of all wavelengths are present; opposed to line spectra, or band spectra.

Contrast, Color—The ratio of the intensities of the sensations caused by two colors. Sometimes the logarithm of this ratio.

Daylight—Total radiation from the sky and sun. For standardization of spectral quality, measurements are made at noon. The quality of daylight matches approximately that of a black body at 6500 degrees Kelvin.

Density—The logarithm to the base 10 of opacity (for transparent materials). The logarithm of the reciprocal of the reflecting power (for reflecting materials).

Desensitization—Treatment of a photographic material, as with a solution of a suitable dye, to reduce its sensitivity to subsequent light exposure without destroying the developability of a previous exposure.

Developed Color Images—Colored photographic images produced by direct development.

Dichroic—Pertaining to the property of certain crystals of showing different colors when viewed in different directions by transmitted light; or pertaining to the property of some solutions of varying color with layer thickness or concentration.

Dichromatism—See COLOR BLINDNESS.

Differential Hardening (of gelatin)—The production of an image in gelatin in a manner such that the hardness is proportional to the original silver density of the image; or, in other cases, to the amount of light which has fallen upon a specially treated gelatin coating.

Dominant Wavelength—In a system of monochromatic colorimetry the wavelength, the hue of which matches the hue of the color being measured.

Double-Coated Film—Film having a sensitive emulsion on both sides of the base, the emulsions or the base often being impregnated with a dye which prevents the penetration of actinic light to the opposite emulsion when exposing either one of them.

Double-Image Prism—A prism so designed that with a lens it will form two images of an object; a beam-splitter.

Dufaycolor Process—A regular mosaic screen-plate process for three-color additive cinematography. (1931)

Dufay Process—A regular mosaic screen-plate process using four constituent colors. (1908)

Dupack Process—A process using a combination of a green-sensitive and panchromatic film sold by du Pont for making two-color motion picture negatives. The green-sensitive film bears a red filter layer upon its emulsion surface. The two films are run through the camera with their emulsion sides in contact. Exposure is made through the base of the green-sensitive film. (About 1931)

Duplex Color-Plates—Similar to the Paget screen-plate. The regular mosaic screen and the sensitive emulsion are on separate plates. (About 1927)

Dye Density—1. The logarithm to the base 10 of the visual opacity of an area in a finished dye image. 2. The density of a single component of a two- or three-color print as measured by light of the complementary color.

Dye Mordanting—Broadly, the process of fixing a dye to a substance for which it has no affinity by means of a second substance which has an affinity both for the dye and for the first substance. More especially, in color photography, the treatment of a silver image so as to replace it in whole or in part with a substance having an affinity for dyes.

Dye Toning—The process of affixing a dye to a silver image or of replacing a silver image by a dye image through the action of mordants.

Effective Wavelength—See DOMINANT WAVELENGTH.

Elementary Colors—See PRIMARY COLORS.

Elements (of a screen-plate or lenticular color-film)—The individual filter particles of a color-screen, or the minute lenses of a lenticular film.

Embossing—*v. t.* The process of impressing minute lens elements upon a film base to produce a lenticular color-film. *n.* The lens elements collectively.

Equality of Brightness (of colors)—The state in which two colors have equal visual luminosity.

Etch—To dissolve portions of a surface not protected by a resist, as in making a halftone plate on copper or zinc; also to remove differentially hardened gelatin from an image.

Excitation Curves—See COLOR SENSATION CURVES.

Farbstoff-Tabellen (Lehmann and Schultz)—A listing of commercial dyestuffs similar to that of the Color Index.

Filter—A light-transmitting material (or liquid solution in a cell) characterized by its selective absorption of light of certain wavelengths. A so-called "neutral gray" filter absorbs light of all wavelengths to which the eye is sensitive to approximately the same extent and so appears without hue.

Filter Cut—The wavelength or spectral region at which the absorption of the filter varies rapidly with changing wavelength.

Filter Factor (Filter Ratio)—The ratio of the exposure required to produce a given photographic effect when a filter is used to that required without the filter. Many considerations, such as color-sensitivity of the emulsion, quality of radiation, and time of development influence the filter factor.

Filter Overlap—The spectral region in which two or more filters transmit light effectively.

Filter Ratio—See FILTER FACTOR.

Finlaychrome—See *Finlay Process.*

Finlay Process—A regular mosaic screen-plate process of color photography utilizing either a screen separate from a panchromatic plate (1929) or coated upon the same plate. The latter type is known under the trade-marked name, "Finlaychrome." (1931)

Flicker Photometer—An instrument in which two colors are presented alternately to the eye. Above a certain minimum frequency, equally brilliant colors show no flicker such as is shown by colors of different brilliance.

Fraunhofer Lines—Definitely located absorbed lines in the solar spectrum. Certain of the lines are named by letter, their positions being used as references of position in the spectrum.

Fringe—A defect in a color picture resulting from lack of registration of the component images. A fringe may be caused by parallax, error in printing registration, or by movement in the object which has taken place between the exposure of color-separation negatives.

Fundamental Colors—See PRIMARY COLORS.

Gaspar Process—A three-color subtractive motion picture process. Prints are made on film coated with three emulsion layers sensitized to three different spectral regions. In each emulsion is incorporated a dye which is destroyed in a bleach bath to a degree controlled by the silver image density. (1934)

Gaumont Tri-Color Additive Process—An additive method of three-color cinematography using a triple lens system both in the camera and in the projector. The frames are of standard (silent) width and three-fourths the standard height. (1912)

Gelatin Filter—A filter in which gelatin is used as the vehicle for the absorbing material.

Gray Filter—See FILTER.

Gray Key Image—An image of neutral color occasionally printed in register with the images in tri-color inks or dyes. In the imbibition process, the gray key image is sometimes developed on the printing material by the ordinary photographic method.

Half Silvered Mirror—See MIRROR, SEMI-TRANSPARENT.

Handschiegel Process—A process of applying color to local areas of black-and-white prints by imbibition, using one or more dyed matrices.

Harriscolor Process—A two-color subtractive process of cinematography. Prints from color-separation negatives are made on single-coated film printed first through the back, processed, and blue-toned with iron. The residual emulsion on the front is subsequently printed, processed, and red-toned. (1929)

Herault Trichrome Process—An additive three-color process for cinematography. The three-color print, consisting of successive red, green, and blue dye-tinted frames, is projected 24 frames per second in a non-intermittent projector. (About 1929)

Heterochromatic Photometry—The comparison of the intensity of light of different colors.

Horst Process—An additive three-color process in which the three images are exposed and later printed within one standard frame. (About 1929)

Hue—That attribute of certain colors in respect of which they differ characteristically from the gray of the same brilliance, and which permits them to be classed as reddish, yellowish, greenish, or bluish.

Hue Sensibility—The sensibility of the eye to differences of hue.

Hypersensitization—The treatment of an unexposed photographic material by immersion in a solution, such as ammonia, to increase its sensitivity, principally to longer wavelengths.

Imbibition—A process for producing a dye-image by mechanical printing. A dyed relief or differentially tanned matrix of some substance such as gelatin is brought into intimate contact with a moist absorbing layer such as gelatin, the dye diffusing from the matrix to the absorbing layer.

Imbibition Matrix—A coating of gelatin or other colloid upon a support having an image capable of being dyed with water-soluble dye. See IMBIBITION.

Interference Colors—Colors resulting from the destruction of the light of certain wavelengths, and the augmentation of the light of others in a composite beam by interference. Colors of thin films and polarization colors of doubly refracting crystals in the polariscope are examples of interference colors.

Isopaque Curve—A line connecting a series of points of equal opacity. Such curves when applied to spectrograms may be used to demonstrate the color-sensitivity of photographic materials.

Joly Color Screen—A regular mosaic screen-plate consisting of ruled lines. (1894–5)

Keller-Dorian-Berthon Process—See *Keller-Dorian Process.*

Keller-Dorian Process—A three-color additive motion picture process. A banded tricolor filter is associated with the camera lens. The film support which faces the lens is embossed with small lens elements. Each lenticular element images the filter bands upon the emulsion surface. A filter of similar form is associated with the projection lens. (Pat. 1908–9; introduced 1925)

Kinemacolor Process—A two-color additive process involving the use of a rotary shutter of color-filters before the lenses of both camera and projector. (1906)

Kodachrome Process—A two-color subtractive process for still photography and 35-mm. motion pictures, devised by the Eastman Kodak Company. Prints are made upon double-coated film; the positive is bleached with a tanning bleach and dyed with dyes which penetrate soft gelatin preferentially. (1915)

Kodacolor Process—A 16-mm. adaptation of the Keller-Dorian process. (1928)

Kromogram—Three transparent stereoscopic pairs of images which appear as a single color picture when viewed in a special viewing device called the "Kromskop." (1894)

Kromskop—A special form of the chromoscope invented by F. E. Ives, utilizing two semi-transparent mirrors and suitable color-filters for exposing three images with one lens. Positives (Kromograms) printed from the images are viewed with a similar device. (1894)

Lake—A pigment formed by the combination of an organic dye with a metallic compound or another dye with which it forms an insoluble precipitate.

Lenticulation—Minute optical elements having the form of cylindrical or spherical lenses embossed into the support side of photographic film. They serve in the process of analysis and synthesis of images in an additive color process. See *Keller-Dorian Process.*

Leuco-Base—A white or slightly colored substance which, upon oxidation, sometimes accompanied by reaction with an acid or base, yields a more highly colored dye.

Light—Radiant energy evaluated according to its capacity to produce visual sensation.

Light Restraining Dye—A dye used for impregnating a light-sensitive emulsion to prevent the deep penetration of light during exposure.

Light-Splitter—See BEAM-SPLITTER.

Lignose Process—An irregular mosaic three-color process applied to roll film and film pack. (1927)

Line-Screen Process—A color-screen process in which the screen is formed by a regular pattern of ruled lines.

Lippmann Process—A process of direct color photography based upon the interference of light. An exceedingly fine-grained panchromatic emulsion is exposed in intimate contact with a metallic (mercury) mirror. A standing-wave pattern is produced throughout the depth of the emulsion layer, the silver being reduced in the anti-nodal planes, thus forming a system of reflecting laminae. The plates are viewed by reflected light. (1891)

Magnachrome Process—A two-color additive process of color cinematography. Half the normal picture height is used for each of the pairs of pictures.

Magnacolor Process—A two-color subtractive process for cinematography. Bipack negative and double-coated positive films are used. (1930)

Maxwell Experiment—The first demonstration of the principle of additive synthesis with color-separation negatives. Clerk Maxwell and Thomas Sutton in 1861 produced a set of four plates and projected them in register before an audience.

Maxwell Primaries—The colors red, green, and blue-violet used by Maxwell to demonstrate the application of the Young-Helmholtz theory to color photography.

Micron—A unit of length equal to 0.001 mm. (10^{-3} mm.). Used frequently to designate the wavelength of radiant energy in the infra-red region.

Millimicron—A unit of length equal to 0.000001 mm. (10^{-6} mm.). This is the unit usually used in colorimetrics in expressing the wavelength of radiant energy.

Minus Color—The color which is complementary to the color that is named; for example, *minus red* is a color complementary to red.

Mirror, Semi-Transparent—A mirror uniformly coated with reflecting material in such a manner that part of the light incident upon it is reflected, the other part passing through the surface. A type of beam-splitter.

Moiré Effect—A "watered" pattern produced when two or more screens bearing a system of fine regular lines or similar pattern are superposed nearly but not exactly in register.

Monochrome—A picture executed in a single color.

Mordanting—See DYE MORDANTING.

Morgana Process—A two-color additive process of color cinematography (for 16-mm. reversal pictures). In the projector, the film is moved two frames forward, one backward, and so on. Effective camera and projection speed is 24 frames per second, although the special projector movement produces 72 alternations per second. (1932)

Mosaic Screen Plate—A color screen plate.

Motion Fringe—A fringe of color occurring at the edge of images when the color-separation negatives are taken at different instants.

Multicolor Process—A two-color subtractive 35-mm. cinematographic process. The negative is made with a bipack. The colored print is made on double-coated film. (1929)

Neutral Color—Gray; achromatic; possessing no hue.

Neutral Filter—See FILTER.

Neutral Wedge—A wedge composed of a neutral (gray) absorbent material.

Orthochromatic—1. Characterizing the equivalence between the photographic effect of various colors upon a photographic material and the physiological effect upon the eye. 2. By usage, characterizing a photographic material sensitive to all colors except red.

Paget Color Screen Plate—A regular mosaic color screen plate (1912), available commercially since 1929 as the Finlay plate.

Panchromatic—Characterizing a photographic material sensitive to all colors of the visible spectrum.

Parallax—The apparent displacement of an object as seen from two different points.

Pathéchrome Process—A cinematographic process in which color is applied to a black-and-white print through a celluloid film stencil. (1928)

Photochromoscope—See CHROMOSCOPE, *Kromskop*.

Photocolor Process—A two-color subtractive process using a twin lens camera and dye-toned prints on double-coated film. (About 1930)

Pigment—An insoluble colored material in finely divided form.

Pilney Process—A two-color subtractive cinematographic process. (1930)

Pinachrome Process—A printing process based upon the use of leuco-bases which oxidize upon exposure to light, yielding color images which are assembled by superposition.

Pinatype Process—A subtractive three-color process for still pictures based upon the differential staining action of certain dyes for hard and soft gelatin. (1906)

Primary Colors—Three colors, which, when mixed in the proper proportions, can be used to produce all other colors. The three colors most commonly used are red, green, and blue-violet.

Prismatic Spectrum—A spectrum formed by a prism.

Purkinje Effect—A shifting of the visibility curve to shorter wave-lengths at decreased intensities, *e. g.*, as intensity is decreased object colors may change from reddish to bluish.

Quality (color)—CHROMATICITY.

Quality of Radiation—An expression which refers to the spectral composition of the radiation. In both photography and in the viewing of colored pictures the quality of the radiation used is important.

Ratio Diaphragm Cap—A mask placed over a banded tricolor filter shaped to permit a predetermined ratio of the different colors of light to pass through a filter for lenticulated film color photography.

Ratiometer—Any device used to test the actinic equality of differently colored lights transmitted to the photographic material in making color separation negatives.

Raycol Process—A two-color additive process of cinematography. The image pairs are exposed ($^1/_4$ standard size) on each frame and disposed in diagonal corners of the frame. The image pairs from contact positives are superposed by a suitable optical system. (1930)

Register—*v. t.* To cause to correspond exactly; to adjust two or more images to correspond with each other. Such correspondence may be required either in printing or in projection. *n.* A state of correspondence.

Relief Process—Any color process in which relief images are produced, for the purpose of matrix printing.

Resist—A coating used to protect certain portions of a surface upon which an image or design is to be produced by etching, dyeing, or other chemical or physical treatment.

Rods—One of the two chief light-sensitive elements of the retina. See CONES.

Saturation, Color—The degree of freedom of a color from admixture with white.

Saturation Sensibility—The sensibility of the eye to saturation.

Screens, Color—See COLOR SCREEN.

Screen-Plate Process—See COLOR SCREEN.

Sennettcolor Process—A subtractive cinematographic process using a bipack negative and a double-coated film for the print. (1930)

Sensation Curves—See COLOR SENSATION CURVES.

Sensitizers—Materials, usually dyes, used to increase the sensitivity of photographic emulsions to light of various wavelengths.

Separation, Color—See COLOR SEPARATION.

Sirius Process—A two-color subtractive cinematographic process in which alternate frames of the negative are exposed with the aid of a beam-splitter, and the positive print is made upon double-coated film. (1929)

Soft Gelatin Process—A process in which there is preferential dyeing of soft gelatin portions of the image. See *Pinatype*.

Spectral Composition (of radiation)—The specification of the relative energy at different wavelengths of radiation emitted by a source, or reflected or transmitted by a material; usually shown graphically as a spectral distribution curve.

Spectral Distribution Curve—See SPECTRAL COMPOSITION.

Spectral Energy Curve—See SPECTRAL DISTRIBUTION CURVE.

Spectral Sensitivity—The sensitivity of a light-sensitive material (or instrument, such as a photoelectric cell) to radiation of various wavelengths.

Spectral Transmission (of a filter)—The extent to which a filter will transmit radiation of different wavelengths. Shown graphically as transmission, opacity, or density plotted against wavelength.

Spectrogram—A photograph of a spectrum. See WEDGE SPECTROGRAM.

Spectrophotometer—A spectroscope with a photometric attachment used to determine the relative intensity of two spectra or spectral regions.

Spectroscope—An instrument for forming a spectrum and measuring wavelengths in various regions throughout the spectrum.

Spectrum—An image of a source formed by light or other radiant energy through the medium of an optical device which refracts or diffracts the radiation of different wavelengths to different degrees. Throughout the visible spectrum of a continuous light source the spectrum appears as a number of juxtaposed areas of color varying from red to violet; *e. g.*, the rainbow.

Spicer-Dufay Process—See *Dufaycolor Process.*

Splendicolor Process—A three-color subtractive process in which the three-color separation records are printed as follows: blue record upon one side by iron toning, and the yellow and red as successive color layers upon the opposite side by dyed bichromate methods. (1928)

Subtractive Primaries—The three printing colors used in a three-color subtractive process; usually named magenta (minus green), blue-green (minus red), and yellow (minus blue).

Subtractive Process—A process of reproducing objects in natural colors using a restricted number of primary component colors in which the composite image is produced by passing a single beam of white light successively through two or more layers of colored images, each of which absorbs one region of the spectrum which is passed by the other layers.

Tanning Developers—Solutions which cause hardening, or which render insoluble, the gelatin of an emulsion in proportion to the amount of latent image converted into silver.

Technicolor Process—A trade-name applied to various types of subtractive cinematographic color processes. (About 1915) At one time marketed as a two-color relief process; more recently as a three-color imbibition process.

Three-Color Process—Any process, either additive or subtractive, for producing photographs using three primary colors.

Tinctorial Power (of a dye)—The reciprocal of the concentration necessary to produce a given amount of absorption in a layer of given thickness.

Tintometer—An instrument for estimating or specifying color by comparison with a graded series of standard colors.

Toning—See CHEMICAL TONING, DYE TONING.

Transfer Process—A process in which an image, usually dyed or pigmented, is transferred from one surface to another.

Trichromatic Process—See THREE-COLOR PROCESS.

Tricolor Filter—1. A composite filter containing areas of three primary colors; 2. A single filter of one of three primaries.

Tripack Process—A process of exposing three films (or plates) simultaneously, in which the films are arranged as a pack so that the outer films (or interposed filters) transmit certain portions of the light to expose the following layers. (*cf.* BI-PACK).

Two-Color Process—Any process, either additive or subtractive, for producing photographs using two colors.

Utocolor Process—A three-color subtractive transfer process using the bleach-out method for making a color print by printing from a color transparency. It depends upon the bleaching property of certain wavelengths for certain dyes. (1895)

Visibility (of radiation)—The ratio of the luminous flux (lumens) to the corresponding energy flux (watts).

Visibility Curve—A graphical representation of the relation between visibility (expressed relatively) and wavelength. This curve has a maximum in the green at 555 $m\mu$.

Vitacolor Process—An additive two-color cinematographic process similar to Kinemacolor. (1930)

Warner-Powrie Process—A three-color regular line-screen process. (1905)

Wedge—An optical device composed of absorbing material in which the transmission varies progressively from point to point. Such a device may cause a variation in either hue or intensity, or both.

Wedge Filter—See WEDGE.

Wedge Spectrogram—A spectrogram produced by photographing a spectrum through a neutral wedge (sometimes an optical wedge), placed usually over the slit of the spectrograph. Such a spectrogram shows graphically the effective photographic sensitivity *vs.* wavelength for the photographic material and light source used.

White Light—Radiant energy which has a wavelength-intensity distribution such that it evokes a neutral gray (hueless) sensation in the average normal eye.

White Object—An object of a color such that it reflects all wavelengths of the visible spectrum equally; an object which if illuminated by white light will appear without hue to the average normal eye.

Wratten Filters—A widely used commercial brand of color-filters.

Young-Helmholtz Theory (of color vision)—An explanation of phenomena of color vision assuming three separate elements in the normal eye, each stimulated by a different section of the visible spectrum.

Zoechrome Process—A three-color subtractive process of color cinematography with a black-and-white key. In the camera every alternate frame is normally exposed; on each remaining frame, three images are exposed through primary filters. The standard size image is printed first, and each of the color-images in succession is enlarged and superposed upon the first. Between successive printings, the film is varnished and recoated with emulsion. Each image layer is dye-toned before the next layer is added. (1929)

Zoetrope Process—Probably the first color photography process using the rapid substitution of primary images before the eyes. (1869)

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NEW MOTION PICTURE APPARATUS*

A MOTOR-GENERATOR FOR THE NON-ROTATING HIGH-INTENSITY ARC**

The following descriptions of equipment were included among the presentations in the Apparatus Symposium at the New York Convention of the Society, Oct. 29–Nov. 1, 1934.

The recent introduction of the d-c. high-intensity "Suprex" carbons has necessitated a new design of projection lamp, and has likewise presented an opportunity for developing a motor-generator for converting the alternating current of commercial power mains into direct current of the proper voltage and regulation for most efficiently utilizing the advantages of the new lamps and carbons.

Until eight or ten years ago the motor-generator that was most widely used was the two-unit series type. Despite its shortcomings, it possessed the advantage that no ballast resistance was required. However, due to the increasing demand for more intense screen illumination, the reflector type of lamp and improved models of the original high-intensity lamps came to be quite generally adopted. At the same time, the new arcs demanded a more stable source of current than the series machine, and the two-unit multiple motor-generator became the accepted standard.

The two-unit multiple machine possesses the requisite flexibility and stability for operating lamps having voltages of 55 or more at the arc. But the advantages of flexibility and stability were achieved rather expensively, for the ballast resistance required to achieve them accounted for a loss of as much as 30 or 40 per cent of the purchased power. In other words, somewhat less than half the purchased power is used, not for furnishing illumination for projection, but in uselessly and wastefully heating the ballast resistors.

The three-unit "Stabilarc-Unitwin" motor-generator was designed to combine most of the advantages of the series and multiple types with as few as possible of their disadvantages. As shown in Fig. 1, the machine consists of two d-c. generators, one for each arc, on either side of and direct-connected to an a-c. motor. Terminal leads for each of the three units are brought out separately into their respective conduit boxes, and all openings are guarded with removable perforated or louvre covers. The shaft revolves in four ball-bearings and ball-bearing flexible couplings connect the a-c. motor with the d-c. generator unit on either side.

The d-c. control panel is shown in Fig. 2. It includes two small field rheostats, one for each generator unit, a voltmeter, and a double-throw toggle switch for connecting the voltmeter in circuit with either generator unit. Fig. 3 shows the

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* Presented at the Fall, 1934, Meeting at New York, N. Y.

** Automatic Devices Co., Allentown, Pa.

comparative simplicity of the connections between the motor-generator, panel, and arcs. Each generator feeds directly into its own arc. Only the field and voltage circuits are connected to the control panel, so that the connecting wires may be of the minimum size allowable under local insurance regulations, thus effecting a substantial saving in wiring costs.

Operating without load, the voltage of each generator is about 55 to 60, depending upon the setting of the field rheostat. When the carbons are brought to-

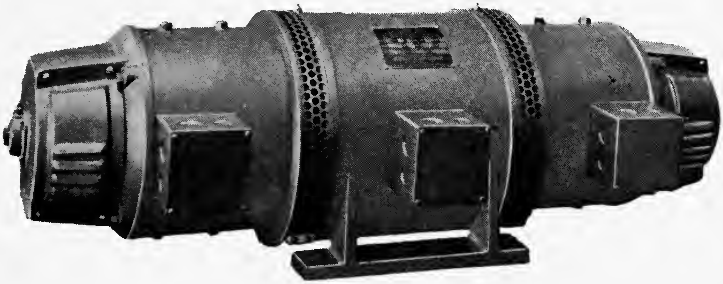

FIG. 1. Stabilarc-Unitwin motor-generator for d-c. Suprex carbon arcs.

gether, so as to strike the arc, the voltage of the corresponding generator unit immediately and automatically drops to approximately 15 volts. The carbons are held together for a moment or two and then slowly separated, without the explosive and sputtering action that is unavoidable when striking an arc fed from a multiple generator, due to the heavy short-circuit current that occurs before the arc is formed. This explosive action tends to destroy the crater and blow out the core of the carbon, apparently having the effect of hurling particles of incandescent carbon and copper against the mirror, and is responsible for excessive reflector repairs and replacements. By means of this "controlled strike," pitting of the lamp mirror is greatly reduced if not entirely eliminated, thus materially extending the useful life of the reflector.

FIG. 2. The d-c. control panel.

Referring again to Fig. 1, it will be noted that the three-unit combination is long and narrow, the proportions being similar to those of 3600 rpm. high-speed machines. However, as the synchronous speed of the Unitwin is only 1800 rpm., the peripheral speed is reduced accordingly, thereby very materially decreasing brush, wind, and other noises of rotation. Extremely quiet operation is the result, a very desirable feature when the motor-generator must be placed in or near the projection room.

In the multiple type of motor-generator, the single-generator unit is depended upon to supply one or more arcs in operation while another arc is being started. During the change-over period, the large short-circuit current caused by striking the additional arc, added to the load already carried by the generator, usually amounts to two to three times the normal rating of the machine, causing a consequent strain upon the commutator, brushes, and other load-carrying elements. In contrast, a Unitwin generator unit never supplies power to more than one arc, and is therefore never overloaded. During change-over, or at any other time when the entire machine supplies two arcs, the burden of the double load is placed where it properly belongs—on the rugged squirrel-cage motor without any current-carrying moving parts.

For the same reason, since each generator unit supplies only one arc, striking

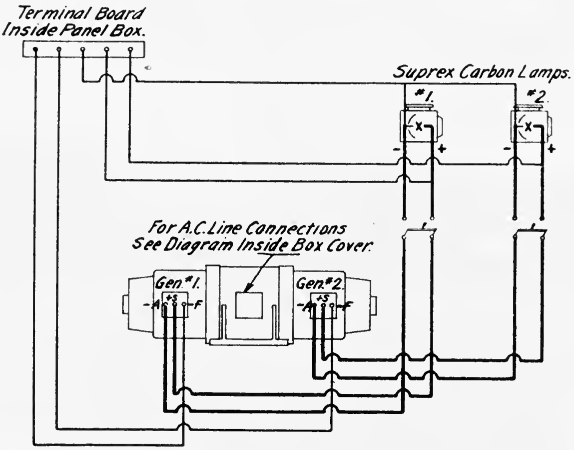

FIG. 3. Wiring connections between motor-generator, panel, and arcs.

the second arc has no effect upon the first arc, and the illumination of the screen is uniform throughout the entire operation.

The characteristics of the Unitwin are admirably suited to the requirements of the Suprex arc. Whether the same three-unit combination can be economically adapted to other types of arcs is a question that can not yet be definitely answered.

THE DAVIDGE DEVELOPING APPARATUS*

The effects of agitation of the developer in relation to the film during the operation of developing motion picture film are fairly well known. The chief effects are (*1*) an increase in the rate of development, and (*2*) a partial offsetting of the effects of the reaction products of development as typified by the "Mackie Line."

With any particular developing equipment, therefore, the developer should be sufficiently agitated, and the agitation should be non-directional so that the current impulses strike the emulsion surface at constantly changing angles, supplying

* Roy Davidge Co., Hollywood, Calif.

new developer and displacing the by-products of development in such a manner as to avoid distortion in density where a heavily exposed area lies adjacent to one of less exposure.

The Davidge developing apparatus (Figs. 4 and 5) consists of a wheel or rotor which acts as a carrier for the film and the spacing apron, the latter comprising a molded celluloid strip having buttons placed alternately at either side which contact the two surfaces of the interwound film at the perforation area. The buttons or protuberances are so elongated as to be incapable of entering the per-

FIG. 4. Davidge developing apparatus: 1200-ft. unit.

foration, and also to act as baffles to disperse the current of developer from the space on the opposite side.

The exposed film with the separator is wound upon the rotor in lengths up to 1200 feet, and clipped at the outside. A spacing of approximately $^3/_{16}$ inch is attained between each successive turn on the rotor, and the combined film and separator are in no way attached to the rotor, being free to move and change relationship to the impulse fins at every revolution.

The rotor is made of non-corrosive tubular metal, and has a small fin which extends outward from each spoke, 22 on each side for the 1000-ft. rotor. When wound, the unit is placed into the developing solution and revolved at approximately 20 revolutions a minute. The developing tank also has a baffling device which creates a side-to-side motion of the solution through the wheel. This motion, in turn, is deflected at constantly changing angles by the fins on the rotor. The rotation is mechanically reversed at intervals of one minute during development.

Films developed by the system show readings that are identical on butted sensitometric strips placed throughout the wind.

FIG. 5. Davidge 16-mm. developing unit.

FIG. 6. Moviola film viewing machine, model *C*.

MOVIOLA FILM VIEWING MACHINES*

The Moviola film viewing machine, model *C*, Fig. 6, is now, like model *D*, regularly equipped with a hand rheostat and hand switch for controlling the motor, in addition to the foot controller always furnished with this machine. The hand rheostat and foot controller are in series, and the hand switch short-circuits the foot controller. Therefore, when the hand switch is closed, the hand rheostat controls the speed of the motor; and when the hand switch is open, the hand rheostat controls the maximum speed of the motor attainable by the foot controller.

Fig. 7 shows a Moviola film viewing and sound reproducing machine, model *UDC*, for use with composite film only, and specially equipped with a footage and frame counter. This machine is particularly suitable for checking prints in the exchanges, as each frame on a reel of film can be easily identified.

FIG. 7. Film viewing and sound reproducing machine, model *UDC*.

* Moviola Company, Hollywood, Calif.

Fig. 8 shows the front view of a Moviola film viewing and sound reproducing machine, model *UDSL*. This machine is made to be used with a standard 35-mm. picture film and two separate sound films, one for standard 35-mm. film or $17^1/_2$-mm. "split" sound film, and the other for 16-mm. sound film. It includes a

FIG. 8. Film viewing and sound reproducing machine, model *UDSL;* for standard 35-mm. picture film with separate sound-track (full width or split) and an additional sound-head for 16-mm. sound-film.

standard Moviola film viewing machine, model *D*, which contains a reversible, variable-speed motor, a standard Moviola sound-head, model *SD*, belt-driven by a reversible $^1/_4$-hp. constant-speed induction motor, and a Moviola sound-head, model *SL*, for 16-mm. film. Foot control is provided for each of the two motors, and a three-wire attachment cord (including a ground connection) is furnished.

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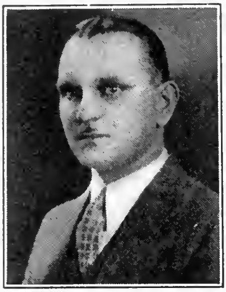

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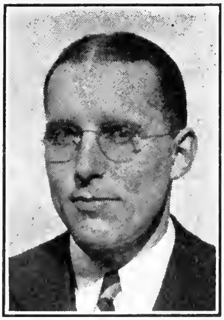

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(Corrected to April 20, 1935; additional appointments may be made at any time during the year as necessity or expediency demands.)

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SOCIETY ANNOUNCEMENTS

CORRECTION TO PUBLISHED STANDARDS

At the bottom of Chart *31*, in *Standards Adopted by the Society of Motion Picture Engineers*, published in the November, 1934, issue of the JOURNAL, p. 283, an error appeared which should be corrected immediately. The sentence reading "Viewed from the light source, the sound-track is to the left" should be corrected to read "Viewed from the *objective*, the sound-track is to the left."

This correction should be made also in all reprints of the standards that have been distributed. Copies of these reprints are available at the General Office of the Society at a cost of twenty-five cents each.

ATLANTIC COAST SECTION

At the regular monthly meeting of the Section, held on March 20th in the new re-recording building at the Vitaphone Studios of Warner Bros. Pictures, Inc., New York, papers were presented by Messrs. P. H. Evans and C. K. Wilson entitled, respectively, "Present Day Re-Recording Practices" and "Facilities for Present Day Re-Recording."

The meeting was attended by approximately 250 members and guests, and opportunity was provided for thoroughly inspecting the new building and installations. Preceding the meeting an informal dinner was held which was attended by approximately seventy members.

MID-WEST SECTION

The regular monthly meeting of the Section was held on April 4th at the Electrical Association, Chicago, Ill. Mr. O. J. Holmes, of the Holmes Projector Corp., presented a paper on "New Developments in Portable Sound-Film Projectors," illustrating his paper with demonstrations of the equipment. The meeting was well attended, and plans were laid for the next meeting of the Section, to be held on May 2.

STANDARDS COMMITTEE

Among the projects considered by the Standards Committee at its last meeting, held on March 28th, were those of possible standardization of sound, printer, and camera sprockets. Steps were taken to gather data on the subjects and to present these data at the next meeting. The question as to the approved method of guiding film in cameras (*i. e.*, edge-guiding, sprocket-guiding, or a combination of both) was answered by the fact that the Society had already approved edge-guiding by establishing all the dimensions of the film lay-outs in the various charts of the S. M. P. E. Standards from a designated guided edge. The adoption or recommendation of methods of determining screen brightness was tabled pending anticipated reports of the Projection Screens Committee and the Projection Practice Committee.

The problem facing the Society, and, in fact, the entire American 16-mm. sound-film industry, was thoroughly discussed by the Committee, and it was felt that steps should be taken to establish the S. M. P. E. 16-mm. sound-film standards as American national standards by having the newly formed Sectional Committee on Motion Pictures (A. S. A.) consider them for submission to the American Standards Association.

Accordingly, the following resolution was adopted:

"Resolved that the standards of the Society of Motion Picture Engineers published in the November, 1934, issue of the S. M. P. E. JOURNAL, approved by the Committee and subsequently by the Board of Governors of the Society, be submitted to the Sectional Committee on Motion Pictures, A. S. A., for subsequent action by the American Standards Association, with the following correction:

"That the wording at the bottom of Chart 31 be changed from 'Viewed from the light source, the sound-track is to the left' to 'Viewed from the objective, the sound-track is to the left.'"

Other subjects considered by the Committee, but held in abeyance for further action, were as follows: 8-mm. sound-film; British Standard Specification for photoelectric cells used in sound-film apparatus; a possible 16-mm. standard test-film, similar to the present 35-mm. test-film; and the possible standardization of recorder slit width and reel dimensions.

SECTIONAL COMMITTEE ON MOTION PICTURES UNDER THE A. S. A.

At the first meeting of the Sectional Committee, held on March 29, the resolution given above, under the heading "Standards Committee," was received and considered. In view of the fact that several additions are expected to be made to the membership of the Sectional Committee, from organizations that are particularly interested in 35-mm. standardization, it was decided to take action only upon that part of the project relating to 16-mm. standardization—especially in view of the fact that the present discussion between American and European interests hinged only upon the 16-mm. standards. The Committee accordingly voted unanimously to approve the 16-mm. standards, and letter-ballots were subsequently mailed to all members of the Sectional Committee whether they were present at the meeting or not. Passage of the standards will be determined by the letter-ballots. Action upon the 35-mm. standards was withheld until the next meeting of the Sectional Committee.

Plans were laid for designating delegates to discuss the 16-mm. project at the International Film Congress at Berlin, April 25th, and at the International Congress for Photography at Paris, in July.

SPRING, 1935, CONVENTION

SOCIETY OF MOTION PICTURE ENGINEERS

HOTEL ROOSEVELT, HOLLYWOOD, CALIF.

MAY 20–24, INCL.

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Headquarters

The headquarters of the Convention will be the Hotel Roosevelt, where excellent accommodations and Convention facilities are assured. Registration will begin at 9 a.m. Monday, May 20th. A special suite will be provided for the ladies attending the convention. Rates for S. M. P. E. delegates, European plan, will be as follows:

Single: $2.50 per day; one person, single bed.
Double: $3.50 per day; two persons, double bed.
Double: $4.50 per day; two persons, twin beds.
Suites: $6.00 and $8.00 per day.

Technical Sessions

An attractive program of technical papers and presentations follows. Several sessions will be held in the evening, to permit those to attend who would be otherwise engaged in the daytime. All sessions will be held at the Hotel.

Studio and Equipment Exhibit

The exhibit at this Convention will feature apparatus and equipment developed in the studios, in addition to the usual commercial equipment. All studios are urged to participate by exhibiting any particular equipment or devices they may have constructed or devised to suit their individual problems, conform to their particular operating conditions, or to achieve economies in production, facilitate their work, or improve their products.

Those desiring to participate should communicate with the General Office of the Society, Hotel Pennsylvania, New York, N. Y. No charge will be made for space. Each exhibitor should display a card carrying the name of the particular studio or manufacturer, and each piece of equipment should be plainly labelled. In addition, an expert should be in attendance who is capable of explaining the technical features of the exhibit to the Convention delegates. Expenses incidental to installing and removing equipment, and the cost of any power consumed, will be borne by the exhibitors.

Semi-Annual Banquet

The semi-annual banquet of the Society will be held at the Hotel on Wednesday, May 22nd. Addresses will be delivered by prominent members of the industry, followed by dancing and entertainment. Tables reserved for 8, 10, or 12 persons; tickets obtainable at the registration desk.

Studio Visits

S. M. P. E. delegates to the Convention have been courteously granted the privilege of visiting and inspecting the Warner Bros. First National Studio (courtesy of the Electrical Dept.), the Fox Hill Studio of Fox Film Corp., and the Walt Disney Studio: admission by registration card only. A visit has also been arranged to the California Institute of Technology. All bus charges on studio and other trips will be assumed by the individual delegates.

Motion Pictures

Passes will be available during the Convention to those registering, to Grauman's Chinese and Egyptian Theaters, Pantages' Hollywood Theater, Warner Bros.' Hollywood Theater, and Gore Bros.' Iris Theater.

Ladies' Program

An especially attractive program for the ladies attending the Convention is being arranged by Mrs. E. Huse, *hostess*, and her Ladies' Committee. A suite will be provided in the Hotel where the ladies will register and meet for the various events upon their program.

Further details of the Convention will be published in the next issue of the JOURNAL.

Points of Interest

En route: the gigantic Boulder Dam project, Las Vegas, Nevada; Union Pacific Railroad.

Hollywood and vicinity: Beautiful Catalina Island; Zeiss Planetarium (Open May 1st); Mt. Wilson Observatory; Lookout Point, on Lookout Mountain; Huntington Library and Art Gallery (by appointment only); Palm Springs, Calif.; beaches at Ocean Park and Venice, Calif.; famous old Spanish missions; Los Angeles Museum (housing the S. M. P. E. motion picture exhibit); Mexican village and street, Los Angeles; the California Pacific International Exposition at San Diego, Calif. (open May 29th); Agua Calienta, Mexico; Tia Juana, Mexico.

Golf

Members attending the Convention have been extended the privileges, at the usual course rates, of the following courses:

Hollywood Country Club, North Hollywood
Oakmont Country Club, Glendale
Westwood Country Club, Westwood
Rancho Golf Club, Westwood

TENTATIVE PROGRAM

OF THE

SPRING CONVENTION

HOTEL ROOSEVELT, HOLLYWOOD, CALIF.
MAY 20–24, 1935

MONDAY, MAY 20TH

9:00 a.m. Registration.

10:00 a.m. General Session.

Address of Welcome.

Presidential Response; H. G. Tasker.

Society Business.

Report of Membership Committee; E. R. Geib, *Chairman.*

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

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

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

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

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

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

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

For members and guests of the Society; speakers to be announced later.

2:00 p.m. General Session.

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

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

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

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

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

"Production Problems of the Actor Related to the Technician"; D. C. Jennings, Hollywood, Calif.

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

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

8:00 p.m. Studio Visit.

Visit to Walt Disney Studio, under the direction of Mr. W. Garity, *Studio Manager;* admission by registration card only; buses leave the Hotel promptly at 7:30 p.m.

TUESDAY, MAY 21ST

9:30 a.m. Studio Session.

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

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

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

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

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

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

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

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

"Make-Up for Motion Pictures"; M. Firestine, Max Factor, Inc., Hollywood, Calif.

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

Luncheon on the lot, and inspection of Warner Bros. First National Studio; courtesy of the Electrical Department, under the direction of Mr. F. Murphy, *Chief Studio Engineer.* Admission by registration card only; buses leave the Hotel promptly at 1:00 p.m.

8:00 p.m. Meeting of the Technicians Branch of the Academy of Motion Picture Arts and Sciences; Mr. K. MacGowan, presiding. Members and guests of the S. M. P. E. are cordially invited.

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

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

"Some Problems in Directing Color Motion Pictures"; R. Mamoulian, Hollywood, Calif.

Feature Motion Picture in Color: *Becky Sharp.*

WEDNESDAY, MAY 22ND

9:30 a.m. Laboratory Session.

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

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

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

"Optical Printing"; L. Dunn, RKO Studios, Hollywood, Calif.

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

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

"New Agfa Motion Picture Film Types"; W. Leahy, Agfa Ansco Corporation, Hollywood, Calif.

"Some Sensitometric Studies of Hollywood Laboratory Conditions"; H. Meyer, Agfa Ansco Corporation, Hollywood, Calif.

2:30 p.m. Studio Visit.

A Visit to the Fox Hill Studio, under the direction of Mr. W. J. Quinlan, *Chief Studio Engineer*. Admission by registration card only; buses leave the Hotel promptly at 2:00 p.m.

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

The semi-annual banquet and dance of the Society will be held in the New Supper Room of the Hotel. Addresses by eminent members of the motion picture industry. Tables reserved at the registration desk, for 8, 10, and 12 persons.

THURSDAY, MAY 23RD

9:30 a.m. Projection and Studio Lighting Session.

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

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

"The Relation between Projector Illumination and Screen Size"; D. Lyman, Eastman Kodak Company, Rochester, N. Y.

"The Optical Efficiency of Mirror Guards"; W. B. Rayton, Bausch & Lomb Optical Company, Rochester, N. Y.

"The Photoelectric Cell and Its Use in Sound Motion Pictures"; M. F. Jameson, Bell Telephone Laboratories, Inc., New York, N. Y.

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

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

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

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

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

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

2:00 p.m. Sound and Standardization Session.

Interim Reports of Academy Committees on the Release Print and Screen Brightness; G. S. Mitchell, *Manager*, Research Council, Academy of Motion Picture Arts and Sciences.

"The Technical Aspects of Recording Music for Motion Pictures"; R. H. Townsend, Fox Film Corporation, Hollywood, Calif.
"A Device for Automatically Controlling the Balance between Recorded Sounds"; W. A. Mueller, Warner Bros. First National, Burbank, Calif.
"Improvements in Play-Back Disk Recording"; G. M. Best, Warner Bros. First National, Burbank, Calif.
"The Projection Background Process"; F. Jackman, Warner Bros. First National, Burbank, Calif.

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

A visit to the Institute, under the direction of Dean F. W. Hinrichs, Jr.; inspection of the astronomical, aeronautic, and high-voltage laboratories. Admission by registration card only; buses leave the Hotel for Pasadena promptly at 1:30 p.m.—a beautiful scenic trip.

8:00 p.m. Studio Session.

Report of the Sound Committee; P. H. Evans, *Chairman*.
"Newsreel Standardization"; J. A. Battle, Electrical Research Products, Inc. New York, N. Y.
"Non-Directional Moving-Coil Microphone"; F. F. Romanow and R. N. Marshall, Bell Telephone Laboratories, Inc., New York, N. Y.
"Wide-Range Reproduction in Theaters"; J. P. Maxfield and C. Flannagan, Electrical Research Products, Inc., New York, N. Y.
"Optical Printing of 35-Mm. Sound Records"; G. L. Dimmick, RCA Manufacturing Company, Camden, N. J.

FRIDAY, MAY 24TH

9:30 a.m. Sound and Acoustics Session.

"Sixteen-Mm. Negative-Positive and Grain"; D. Norwood, Lt., U. S. Army Air Corps, Chanute Field, Rantoul, Ill.
"Modern Instruments for Acoustical Studies"; E. C. Wente, Bell Telephone Laboratories, Inc., New York, N. Y.
"Principles of Measurement of Room Acoustics"; E. C. Wente, Bell Telephone Laboratories, Inc., New York, N. Y.
"Recent Developments in Architectural Acoustics"; V. O. Knudsen, University of California, Los Angeles, Calif.
"Studio Acoustics"; M. Rettinger, Pacific Insulation Company, Los Angeles, Calif.
"Technical Considerations of the High-Fidelity Reproducer"; E. D. Cook, RCA Manufacturing Company, Camden, N. J.
"Development and Design of the High-Fidelity Reproducer"; F. J. Loomis and E. W. Reynolds, RCA Manufacturing Company, Camden, N. J.

2:00 p.m. General Session.

"Technical Aspects of the Motion Picture"; A. N. Goldsmith, New York, N. Y.
"The Contribution of Dr. Lee deForest to the Electronic and Motion Picture Arts"; G. A. Chambers, Eastman Kodak Company, Hollywood, Calif.
"The History of the Talking Picture"; W. E. Theisen, Hollywood, Calif.

Apparatus Symposium

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

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

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

"Arc Supply Generator for Use with Suprex Carbons"; O. S. Imes, Century Electric Company, St. Louis, Mo.

"The Akers 35-Mm. Hand Camera"; W. Blunel, Akers Camera Company, Hollywood, Calif.

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

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

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

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

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

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

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

8:00 p.m. Sound Session.

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

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

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

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

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

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

"Application of Vertical-Cut Recording to Sound Pictures"; K. F. Morgan, Electrical Research Products, Inc., Hollywood, Calif.

This is a tentative program and, as such, is subject to change. The Society is not responsible for statements made by the authors.

The expenses incident to trips to studios and other points of interest in connection with this program are to be borne by the individual members.

JOURNAL

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MOTION PICTURE ENGINEERS

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SYLVAN HARRIS, EDITOR

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NEW DEVELOPMENTS IN MICRO MOTION PICTURE TECHNIC*

H. ROGER**

Summary.—*After a brief description of the various factors involved in designing and operating equipment for making micro motion pictures, apparatus developed by the author is described. This apparatus is the result of years of experience in such work in the biological laboratory, particularly in collaboration with Dr. Alexis Carrel during the past eleven years. The details of the apparatus are discussed under the headings: Optical Bench, Camera and Driving Mechanism, Motors, and Control Panel. A table is given showing the manner of presetting the equipment for any purpose of research. The paper concludes with a brief reference to the use of 16-mm. equipment in micro- and macrocinematography.*

Those who have studied the history of the motion picture know that it originated in the physiological laboratory. The study of the movements of men and animals by such men as Muybridge in America and Marey in France gave rise to the now existing enormous motion picture industry. The fact that through its invention we have become masters of the elements of time was realized at an early stage of development. Unfortunately, for a long time scientists turned away from the motion picture, leaving it entirely to entertainment, not realizing its possibilities as an aid to research. Comparatively recently motion pictures have found their way back again into the research laboratory.

Microscopic research, especially, has profited to a great extent, as many new facts about the structure and physical behavior of microörganisms (for example, blood and tissue cells of men and animals) have been revealed with the aid of the motion picture. Many outstanding research laboratories are today using the motion picture camera in one way or another for automatically recording microscopic or macroscopic phenomena. It should be mentioned here that a definite boundary line exists between research on the one side and education or teaching on the other in the use of the motion

* Presented at the Fall, 1934, Meeting at New York, N. Y.

** Rolab Photo-Science Laboratories, Sandy Hook, Conn.

picture. Many film records obtained for research have never passed through a projector, their only use being the study, frame by frame, of minute changes in the specimen under observation.

To the uninitiated an equipment for taking micro motion pictures appears to be practically identical to a photomicrographic outfit, the difference lying only in the camera. However, one appreciates the difference at once when the specimen to be photographed is taken into consideration. Generally speaking, the objects for photomicrography are either dead material, specially prepared for the purpose, stained to bring out details; or, if living, are used only for a brief instant, so as not to be affected by the light or heat. Mounting the specimen upon the ordinary glass slide, protected by a cover glass, is almost ideal from the optical view-point, because all lenses, eyepieces, and condensers are corrected for a certain standard of slide mounting.

Two opposing factors must be taken into consideration when motion pictures of living specimens are to be taken over a period of time. Biological conditions must be fulfilled in the first place; that is, the specimen must be prepared and maintained in such a way as to render living conditions as natural as practically possible. The specimen is very often extremely delicate and sensitive to light, heat, atmospheric, chemical, bacteriological, and other influences, and has to be protected. These facts make it difficult to fulfill the optical and photographic requirements, and the outcome is in the best case a compromise under which the biological factor requires first consideration.

To illustrate some of the problems just mentioned the author's experiences with living cells of tissue and blood may be reported. The study of tissue cultures, as now conducted in the laboratories of well known institutions, here and abroad, is of the greatest importance to the future welfare of humanity. It offers, in fact, a possibility of solving many medical problems, the most outstanding of which is that of cancer. Experiments with normal and malignant tissues, irradiated with x-rays, gamma rays, *etc.*, have been and are being carried on and may lead to a final control of the disease.

One of the outstanding pioneers of research who succeeded in cultivating tissue cells outside the body, and winner of the Nobel prize in medicine of 1912, is Dr. Alexis Carrel, with whom the author had the privilege of collaborating for the past eleven years. His now almost 23-year-old strain of living tissue, originating from a fragment of chick embryo heart which was extirpated on January 17, 1912, is still as active as at any time, indicating that tissue is immortal if kept in an environment normal to the cells.

The author's problem was to study by means of motion pictures the structure and the physical behavior of cell groups and single cells, normal and malignant, their influence upon each other, and the

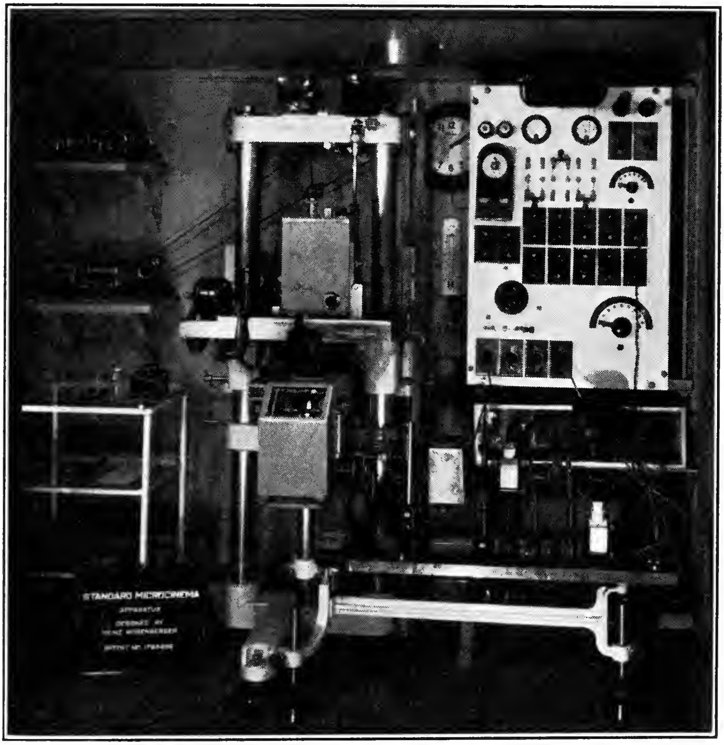


FIG. 1. Apparatus for taking micro motion pictures, developed by the author.

changes that take place under the influence of various substances or radiations, *etc.*

In order better to understand the optical problems and the microscopic technic, and the arrangement of the entire experimental set-up, it is necessary to describe briefly the cultivation of living tissue and blood. The small fragments of tissue taken either from the animal or from another culture are placed into a culture flask about 5 cm. in diameter and 8 mm. high having an oblique neck 8 mm. inside diameter through which all manipulations are made with long instruments, such as platinum rods and long pipettes. Needless to say, the strictest sterile methods are adhered to, as the slightest deviation from them will cause certain infection or poisoning of the specimen. Great numbers of these flasks are kept in incubators and opened at regular intervals in order to supply the cells with a nutrient medium and to wash off the waste produced by the cells. The flasks, which ordinarily are hermetically closed, can be placed under a microscope and examined at low power. For high-power microscopic observation the ideal way would be to place the specimen upon an ordinary slide with cover glass. However, the manipulation as well as the lack of oxygen necessary for the maintenance of life would impair the conditions and cause deterioration. Special flasks are therefore now used which are blown with extremely thin walls so that high-power oil immersions can be employed. The image so obtained permits the study of minute details of the cell structure, although not all the optical requirements are fulfilled. In high-power microscopy the so-called critical illumination of the object is just as important as the formation of the image through the system of magnifying lenses. With the use of these micro flasks, an air space about the culture is biologically necessary, but is not desirable from the optical point of view. Although a special substage condenser with a long working distance brought about certain improvements, the ideal arrangement could not be employed, which would prevail if an ordinary slide were used with no air between the front lens of the objective and the upper surface of the condenser. Experiments with a special culture chamber, made of optical glass, were carried on some time ago, but the danger of infection was increased and its use for routine work, so important with tissue research, was greatly limited.

When viewed under the microscope the cultures seem to be motionless, and it would be extremely tiresome, if not impossible, to detect any changes in position by observing the specimen for any length of time. Here the motion picture camera, in combination with the microscope and a timing instrument (or stop-motion device), has found its place in the research laboratory. With it, it is possible to make automatic observations over any length of time, of the development and the growth of tissue cells as takes place during the healing of wounds, the division of cells, or in phagocytosis; and at higher magnification, of structural details such as of the nucleus, nucleolus, granules, mitochondria, vesicles, *etc.*

It might be mentioned here that with increasing magnification the angle of vision, and hence the apparent speed of the object, is magnified proportionately. This naturally calls for an increasing frequency of exposure and hence an increase of light intensity. Considering the damaging effect of strong light upon living cells the number of problems also increases with higher magnifications.

Equipment for taking micro motion pictures, at low as well as at high magnifications, must be so arranged as to permit a great

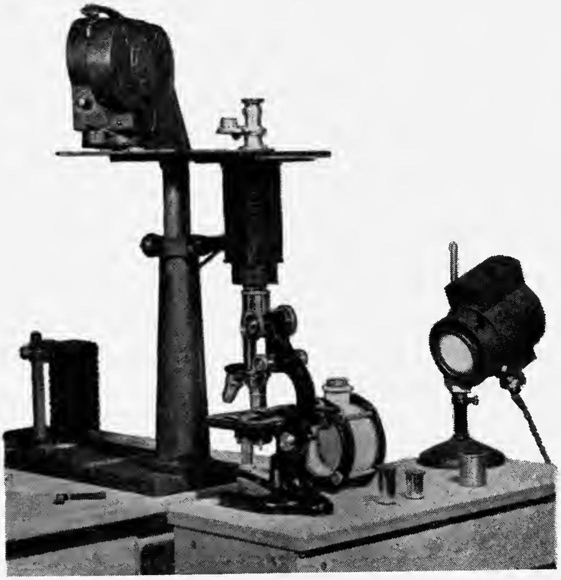


FIG. 2. Micro motion picture equipment for 16-mm. cameras; upper part turned 180 degrees; microscope on separate table.

variation in taking speed. Table I indicates the most useful settings for any purpose of research. The table is self-explanatory.

MICROCINEMATOGRAPHIC APPARATUS

Great indeed is the number of authors in recent years who have described in scientific journals equipment for taking micro motion pictures. It can be said of most of them, however, that their set-ups are incomplete, serving only one particular purpose. On the other hand, apparatus developed and sold by a few manufacturers, although the product of clever designing engineers, are practically useless for scientific research because their design is not the result of laboratory experience. All this seems to indicate that biologists are inexpert technicians and technicians are inept biologists.

It is true that occasionally good work has been accomplished by skilled workers with equipment that is comparatively crude, but for continuous work and results consistently of a certain standard of quality, an apparatus must be available that can be operated by any one in the laboratory and the set-up of which can be altered to suit any purpose. The number of adjustments must be limited to a minimum and the operator's attention must mainly be focused upon the specimen under investigation.

The Standard Microcinema Apparatus that will now be described is the result of a slow process of development, reaching back over some twenty years of laboratory experience. It was designed with the view in mind of making its operation as simple as possible without sacrificing quality of results, so important in research procedure.

In its original form, the apparatus was designed for the purposes of the most exacting research, where magnification, resolution of detail, and exact timing are concerned, so important for drawing conclusions of value to the scientist. Every part of the instrument and its function was carefully conceived and incorporated in its logical place. The number of manipulations is reduced to a minimum, making it possible for the experimenter to focus his attention upon the subject rather than upon its photography.

In viewing the apparatus, a layman might perhaps wonder why is it necessary to employ such heavy equipment, weighing about 500 pounds, to photograph images the size of which is only 18 by 24 mm. Considering, however, that, if an object is enlarged several hundred times its diameter, any motion of the object is also magnified at the same rate, it will then easily be understood that even the slightest vibration, not detectable by ordinary means, would exert a damaging effect upon the details and sharpness of the image. It is here a decided advantage to make the apparatus as heavy as possible. A saving in cast-iron, of which the apparatus is mainly constructed, would be negligible. The absorption of vibrations will be discussed later.

The apparatus (Fig. 1) consists of four units, which are separate from each other and have no mechanical connections between them other than the floor upon which they stand, and some flexible material, such as a leather bellows and an endless belt. The four units are as follows:

(*A*) *Optical Bench.*—This consists of a cast-iron stand which carries the microscope, the light source, condensers, cooling cells, color screens, and neutral screens, all mounted upon adjustable riders with the exception of the microscope, which stands upon an adjustable table. The three legs are so arranged that their height can be altered according to the experimenter's convenience. Levelling screws under each leg rest upon vibration absorbers, which are intended to eliminate the transmission of all vibrations of the building to the microscope. The microscope table itself can be adjusted within certain limits in all directions in order to bring it into optical alignment with the camera and the central beam of light.

(*B*) *Camera and Driving Mechanism.*—A heavy cast-iron base and two vertical columns support a cross-member bearing an electric relay, a platform for the camera, focusing device, driving mechanism and clutch, and motor, equipped with limit switches for raising and lowering the platform.

(*C*) *Motors.*—The direct motor is equipped with a governor for controlling the speed; the indirect motor with reduction gears and an electromagnetic brake.

(*D*) *Control Panel.*—Receptacles are provided having capacities up to 30 amperes, voltmeters and ammeters, two dials for setting the time intervals, per hour or per minute (see Table I), and a time clock for presetting the start and stop up to 12 hours in advance.

To increase the temperature, as is always necessary when working with tissue cultures and in bacteriological studies, the microscope is surrounded by an incubator which is so arranged that it can be removed and replaced in a few seconds without touching the microscope. The coarse and fine adjustment screws of the microscope have extensions to the outside of the incubator. Doors permit easy handling of the specimen and the stage of the microscope. All manipulations can be observed through a glass window in the upper part of the incubator. It is, in fact, as easy to use the microscope with the incubator in place as when used in the ordinary way upon a table.

To exclude external light there must be a connection between the microscope and the camera, which, by the way, is used without a camera objective. On the Standard Microcinematographic Apparatus there are three attachments which can be used alternatively: namely,

TABLE I

Time Required for Photographing, in Terms of Length of Film, Number of Images, and Rate of Exposure

Rate of Exposure	Single Pictures Taken Every: Min.	Sec.	Acceleration at Projection Speeds of: 16 p. s.	24 p. s.	Feet of Film 10 / Number of Images 160: Hr.	Min.	Sec.	20 / 320: Hr.	Min.	Sec.	40 / 640: Hr.	Min.	Sec.	50 / 800: Hr.	Min.	Sec.
Per Hour																
1	60		57600	86400	160			320			640			800		
2	30		28800	43200	80			160	40		320			400		
3	20		19200	28800	53	20		106	40		213	20		266	40	
4	15		14400	21600	40			80			160			200		
6	10		9600	14400	26	40		53	20		106	40		133	20	
8	7½		7200	10800	20			40			80			100		
12	5		4800	7200	13	20		26	40		53	20		66	40	
24	2½		2400	3600	6	40		13	20		26	40		33	20	
Per Min.																
1		60	960	1440	2	40		5	20		10	40		13	20	
2		30	480	720	1	20		2	40		5	20		6	40	
3		20	320	480		53	20	1	46	40	3	33	20	4	26	40
4		15	240	360		40		1	20		2	40		3	20	
6		10	160	240		26	60		53	20	1	46	40	2	13	20
8		7½	120	180		20			40		1	20		1	40	
12		5	80	120		13	20		26	40		53	20	1	6	50
24		2½	40	60		6	40		13	20		26	40		33	25
30		2	32	48		5	20		10	40		21	20		26	40
60		1	16	24		2	40		5	20		10	40		13	20
Per Sec.																
2		½	8	12		1	20		2	40		5	20		6	40
4		¼	4	6			40		1	20		2	40		3	20
6		⅙	2.66	4			27⅔			53⅓		1	36⅔		2	13⅓
8		⅛	2	3			20			40		1	20		1	40
10		1/10	1.6	2.4			16			32		1	4		1	20
16		1/16	Normal Speed	1.5			10			20			40			50
24		1/24	Slowed down (0.66)	Normal Speed			6⅔			13⅓			26⅔			33⅓
32		1/32	Slowed down (0.50)	Slowed down (0.75)			5			10			20			25

Rate of Exposure	Feet of Film 62½ / Number of Images 1000: Hr.	Min.	Sec.	100 / 1600: Hr.	Min.	Sec.	200 / 3200: Hr.	Min.	Sec.	300 / 4800: Hr.	Min.	Sec.	400 / 6400: Hr.	Min.	Sec.
Per Hour															
1	1000			1600			3200			4800			6400		
2	500			800			1600			2400			3200		
3	333	20		533	20		1066	40		1600			2133	20	
4	250			400			800			1200			1600		
6	166	40		266	40		533	20		800			1066	40	
8	125			200			400			600			800		
12	83	20		133	20		266	40		400			533	20	
24	41	40		66	40		133	20		200			266	40	
Per Min.															
1	16	40		26	40		53	20		80			106	40	
2	8	20		13	20		26	40		40			53	20	
3	5	33	20	8	53	20	17	46	40	26	40		35	33	20
4	4	10		6	40		13	20		20			26	40	
6	2	46	40	4	26	40	8	53	20	13	20		17	46	40
8	2	5		3	20		6	40		10			13	20	
12	1	23	20	2	13	40	4	27	20	6	40		8	54	40
24		41	40	1	6	50	2	13	40	3	20		2	27	20
30		33	20		53	20	1	46	40	2	40		3	33	20
60		16	40		26	40		53	20	1	20		1	46	40
Per Sec.															
2		8	20		13	20		26	40		40			53	20
4		4	10		6	40		13	20		20			26	40
6		2	46⅔		4	26⅔		8	53⅓		13	20		17	46⅔
8		2	5		3	20		6	40		10			13	20
10		1	40		2	40		5	20		8			10	40
16		1	2½		1	40		3	20		5			6	40
24			41⅔		1	6⅔		2	13⅓		3	20		4	26⅔
32			31¼			50		1	40		2	30		3	20

a flexible bellows, a telescope sleeve, and an observation eyepiece (beam-splitter). For macroscopic work, a small camera attachment can be used instead of the microscope, permitting the photography of small objects such as insects and other gross specimens. These can be placed conveniently upon the microscope table.

The focusing device previously mentioned is mounted, together with the camera, upon the camera support, in such a way as to permit either the camera or the focusing device to be brought into alignment

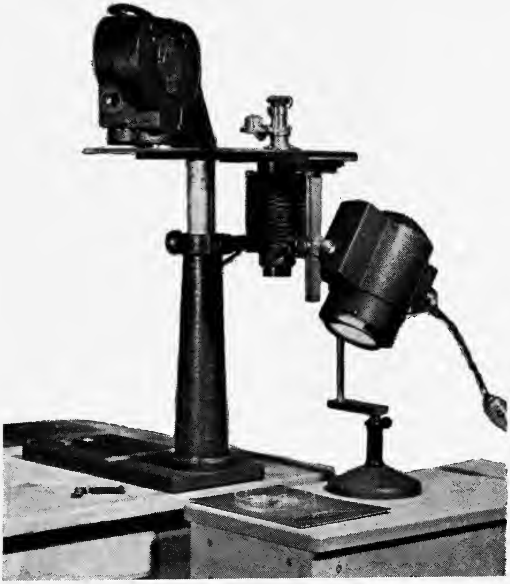


FIG. 3. Micro motion picture equipment used for macrophotography.

with the optical axis of the microscope. This arrangement has proved through many years of practice to be very valuable in obtaining critical sharpness of the images in the plane of the photographic emulsion at the highest magnifications.

With regard to the observation eyepiece (beam-splitter) it should be said here that all instruments of this kind, placed upon the market by a number of manufacturers and described frequently in the scientific literature, have only a limited use. The intensity of the light-source must be varied to a great extent, depending upon the magnification and the rate of exposure. Consequently, it would also be necessary to have a beam-splitter with a variable rate of reflection in order to compensate for the great changes of intensity, and so make it possible for the observer to see an image of approximately the same brightness in all cases. On the other hand, with all work requiring time-lapse photography there is generally enough time between exposures for checking the movement and the focus with the focusing device mentioned above, so that a beam-splitting device becomes

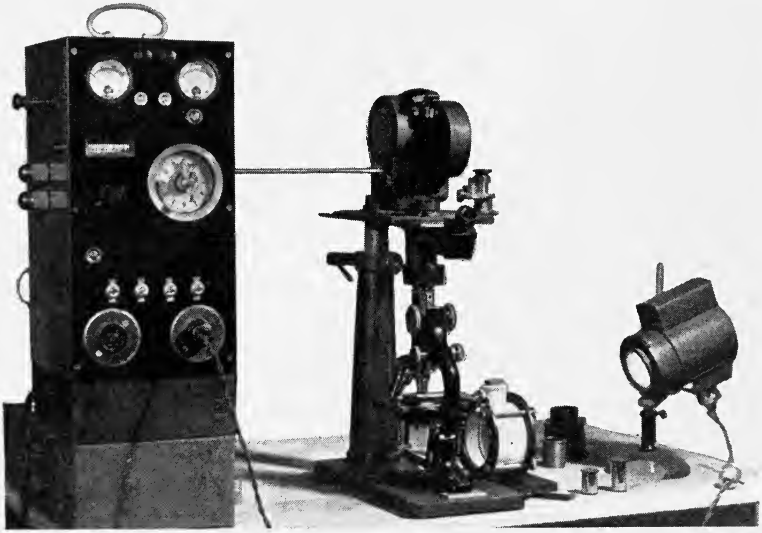


FIG. 4. Stand and 16-mm. camera in combination with portable timing device for time-lapse work.

unnecessary. Most of the research upon living cells requires time-lapse photography.

An outstanding feature of the Standard Microcinematographic Apparatus is the possibility of quickly changing the speed (or the frequency at which the pictures are taken). In microcinematography the variety of problems, and thec hanges from lower to higher magnification and *vice versa*, necessitate changes in the rate of exposure and hence also in the light intensity, which often requires replacing one kind of light source for another. In work with apparatus of the old type such changes always involved a great deal of experimentation consisting mainly of changing gears or pulleys in complicated devices, checking the rate of exposure with a stop-watch, readjusting the substage condenser, altering the light source, making a number of test exposures, developing and fixing, *etc.* The waste of time and often the deterioration of the specimen during the time adjustments were made, caused micro motion pictures to be considered a difficult art calling for men of knowledge and experience. Although it is practically impossible to build a machine that can be as simply adjusted as a radio receiver, much has been accomplished in reducing the difficulties of manipulation. The new apparatus described here is constructed in such a way as to make it easy to switch from one speed to another. It can be run either continually at various speeds or intermittently, which in itself offers a number of advantages.

The direct and the indirect motors (the one with speed reducer) are mounted at equal distances from the main driving pulley, making it easy to switch the driving belt from the one to the other. For time-lapse photography, the apparatus is set for intermittent operation; that is, the mechanism does not run during intervals between pictures. The number of pictures to be taken per minute or per hour is controlled by two dials upon the control panel, each of which is connected to a synchronous motor which closes and opens an electric circuit at the predetermined time interval. A relay included in the circuit starts and stops the motor that drives the mechanism and at the same time turns the light source on and off synchronously with the camera. Thus, only one revolution is made and one picture taken. The advantages of such an arrangement are obvious, considering that the change from one speed to another is accomplished merely by setting the dial on the panel. The correct exposure, once found, always remains the same whether the dial is set for one, two, three, or eight exposures per minute or per hour.

The procedure of making a film record of a specimen is as follows:

The specimen is placed upon the stage of the microscope in the usual manner, after which it is focused through the eyepiece of the focusing device. The distribution of light can be checked by switching over a small ground-glass disk and adjusting the mirror of the microscope, if necessary. By lifting a handle at the front of the apparatus and shifting it to the right, the camera is brought into the taking position. A clutch connecting the driving mechanism with the camera operates automatically at the same time. By turning the main switch the apparatus is set into operation.

For making test exposures or for loading new film, the camera does not need to be removed from the stand but can be tipped over and opened in the usual manner.

[As a demonstration of the work done with the apparatus here described, a film was projected showing some of the results of research carried on at the Rockefeller Institute, New York, N. Y., and at the Rolab Photo-Science Laboratories, Sandy Hook, Conn. The subjects were: living cells of tissue and blood, cell division, phagocytosis, details of cell structure, undulating membrane of white blood corpuscles (discovered with the aid of motion pictures), blood circulation, the growth of a culture of bacteria, Brownian movement of ultramicroscopic particles, *and other physico-chemical subjects.—Ed.*]

PORTABLE EQUIPMENT FOR 16-MM. CAMERAS

A camera stand and focusing device for 16-mm. cameras, having some of the features of the standard apparatus, has been described previously.[1] This stand with the additional features to be mentioned below, is especially designed for scientists and laboratories having limited resources but who may possess 16-mm. motion picture cameras, of any make. It is possible to do a great variety of work with the stand alone, the attachments and additional equipment being purchased later when required. The following combinations have been used successfully for a number of years in various laboratories where these 16-mm. outfits are in operation:

(*A*) Stand alone, with microscope and light source for slow-motion, normal speed, and stop-motion photography at low and high magnification.

(*B*) Stand with upper part turned 180 degrees permitting the microscope to be placed upon a separate table (Fig. 2).

(*C*) Stand with bellows attachment and objective for macrophotography (no microscope necessary); position normal, or upper part turned 180 degrees, permitting a greater distance between object and lens (Fig. 3).

(*D*) Stand and camera in combination with portable timing device for time-lapse work (Fig. 4).

REFERENCE

[1] ROSENBERGER, H.: "Progress in Micro Cinematography," *J. Soc. Mot. Pict. Eng.*, **XV** (Oct., 1930), No. 4, p. 439.

RECENT DEVELOPMENTS IN THE USE OF MAZDA LAMPS FOR COLOR MOTION PICTURE PHOTOGRAPHY*

R. E. FARNHAM**

Summary.—*This paper supplements a previous one in which the advantages of operating tungsten filament lamps at very high efficiencies were explained. The paper discusses the development of a glass filter, which when used with 33-lumen-per-watt lamps gives practically perfect white light, suitable for color photography.*

In a previous paper[1] attention was called to the need of substantially the same quantity of blue radiation from light sources as of green and red, made necessary by the inclusion of the third primary color, blue, in the newly available three-color processes of motion picture photography. The paper then discussed a method of approximately fulfilling this requirement with incandescent lamps operating at extremely high efficiencies.

Fig. 1 shows graphically the effect of higher efficiency operation. The horizontal scale indicates the wavelength or color of the radiation and the vertical scale the relative energy. The lower curve shows the character of the radiation from a standard 1000- or 1500-watt *PS* 52 bulb lamp now quite generally used for black-and-white photography. It will be observed that the radiation in the red region is about $4^1/_2$ times that in the blue-violet part of the spectrum.

By increasing the efficiency of the lamp to 33 lumens per watt the over-abundance of red to blue-violet has decreased only 2.3 times. Or, another way of expressing it, the blue-violet has increased 200 per cent, while the red has increased only 60 per cent. The curves are for lamps of equal wattage.

The actual effect is that the light of the high-efficiency lamp is very definitely whiter, and there is the added advantage of more total light for the same wattage since the lumen-per-watt output is greater.

For the general lighting equipment a lamp of 2000-watt and 67,000-

* Presented at the Fall, 1934, Meeting at New York, N.Y.

** General Electric Company, Cleveland, Ohio.

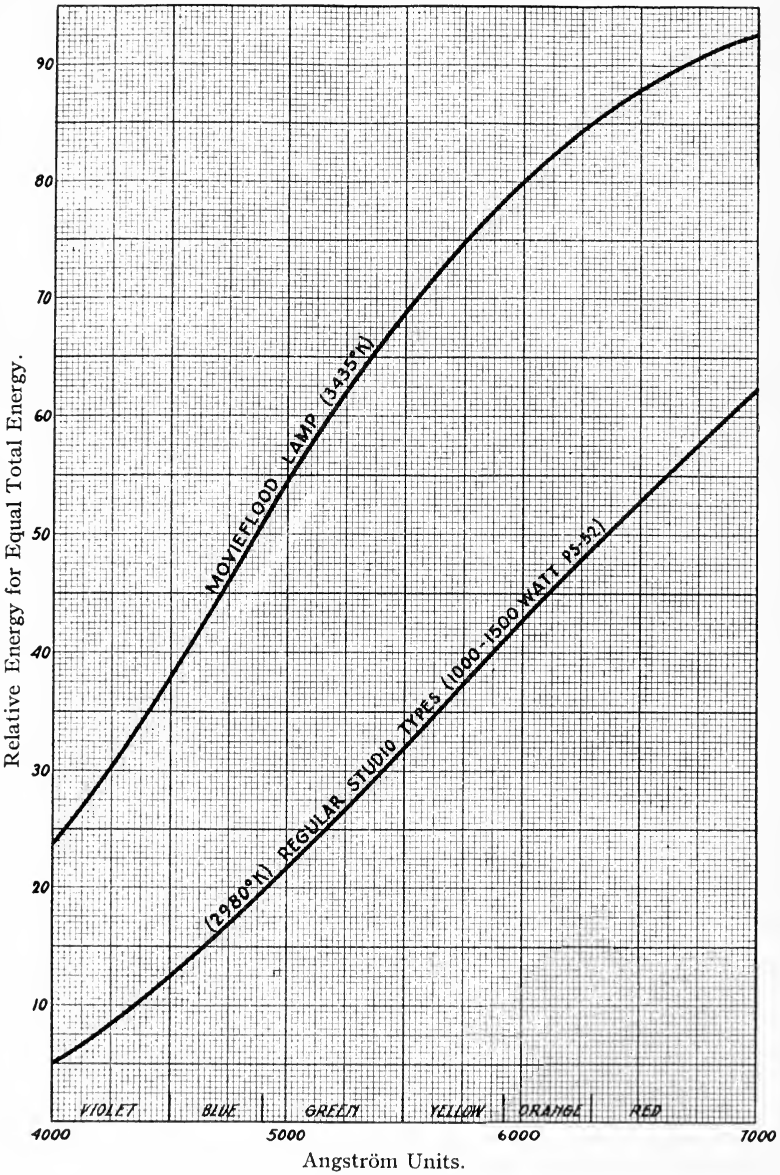


FIG. 1. Spectral energy distribution of Movieflood lamp in comparison with that of the more usual types.

lumen rating in the *PS* 52 bulb was developed and has since been called the *Movieflood.* For the modelling lighting requirement it was found that by operating a 5000-watt lamp of 105-volt rating on the usual 118- to 120-volt circuits of the motion picture studios, its efficiency rose to 33 lumens per watt, the same as the Movieflood lamp. This is possible because the efficiency of the 5-kw. lamp now used for studio work is 29.0 lumens per watt.

The requirements of one of the color processes was satisfactorily met by lamps of this efficiency. This was not sufficient, however, for another color process which requires an illuminant possessing more nearly equal quantities of the three primaries. Since further correction of the light quality by increasing the efficiency was hardly practicable from the standpoint of shortened lamp-life, the use of some form of correcting filter was necessary.

This filter can be either at the camera lens or incorporated in the lighting equipment. Further study of this problem during the past summer brought out the further requirement that it is frequently desirable to employ on a particular set more than one type of illuminant, such as the white-flame arc and Mazda lamps, or incandescent lamps and daylight. The color of the light must therefore be corrected at the source.

This requirement imposes a somewhat closer tolerance on the filter than if Mazda lamps were used alone, because some adjustment must be made for variations in the exposing light in printing the color positive film. No correction is possible, however, when the actors move from light of one color into that of another. An analysis of the filter characteristics showed that it must be one with a high transmission in the extreme blue-violet region and a decreasing transmission toward the red end of the spectrum.

In the actual solution of the problem a number of shades of gelatins were chosen whose transmissions approximated that of the required filter. Then a group of persons in variously colored costumes and settings were photographed first by the light of the white-flame arc and then by the high efficiency Mazda lamp with each of the gelatin filters, changing back to the control source each time before a new filter was put in place. Examination of the finished pictures indicated very definitely the proper filter, which proved to be the Brigham shade No. 26.

The transmission characteristics, as well as a sample of the gelatin, were turned over to the Corning Glass Works, who endeavored to

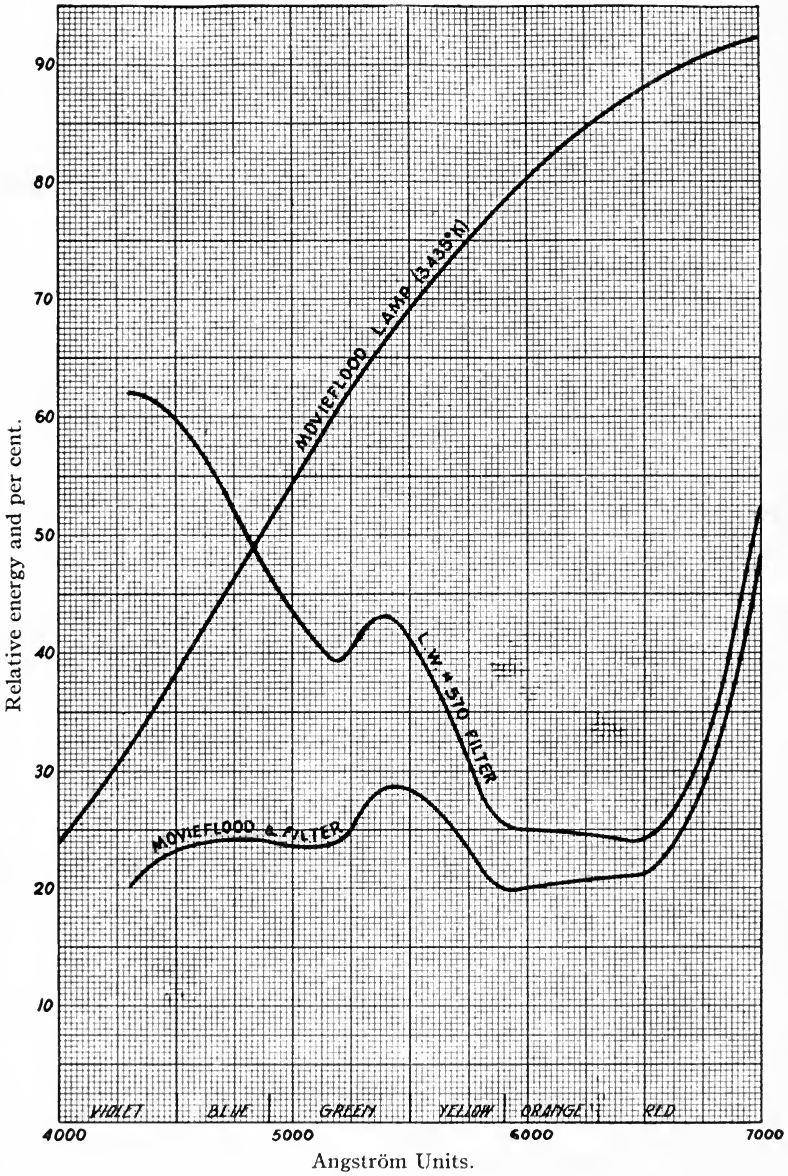


FIG. 2. Effect of Corning's Lunar White No. *570* filter upon the color quality of the light of the Movieflood lamp.

duplicate this in glass as well as to introduce some heat-reducing characteristics as well. A sample of the resultant filter was then tried out in the same manner as previously described.

Fortunately, this first attempt resulted in a filter that was slightly better than the gelatin, there being no observable difference between pictures photographed with the arc source, and the 33-lumen-per-watt lamps and the filter. This filter is known as Corning's *Lunar White No. 570.* Actual density measurements from sensitometric data taken at the time the color photographs were made show the light from this combination of lamp and filter to have 100 units of red, 102 units of green, and 99 units of blue, an almost perfect white.

Fig. 2 shows again the spectral energy distribution of the high-efficiency lamp, the transmission characteristics of the filter, and finally, the two in combination.

REFERENCE

[1] FARNHAM, R. E.: "The Use of Mazda Lamps for Color Photography," *J. Soc. Mot. Pict. Eng.*, **XXI** (Aug., 1933), No. 2, p. 166.

DISCUSSION

PRESIDENT GOLDSMITH: Does the filter have any heat-absorbing characteristics?

MR. FARNHAM: Some, but not as much as I should like it to have.

MR. POPOVICI: What is the color temperature?

MR. FARNHAM: About 3450 degrees. Tungsten melts at 3655, so we are not a great deal below the melting point of tungsten.

MR. POPOVICI: If the voltage drops, the color temperature will also drop, to a certain extent. What is the relation of the color temperature to the filter?

MR. FARNHAM: Apparently the blue end of the spectrum of an incandescent lamp drops off rather rapidly as we reduce the voltage, so it is essential that the lamp be operated up to true voltage.

MR. POPOVICI: What is the limit of allowable voltage drop?

MR. FARNHAM: I should say 5 per cent, plus or minus; 110 to 120 volts, averaging 115, is about a fair operating figure. A slightly closer voltage operation is called for than is usually the practice in black-and-white photography.

MR. MILI: Tests recently made in our laboratory indicate that a 5 per cent drop in voltage will lower the color temperature of the illuminant by about 75°. In other words, if the color temperature of a photoflood lamp at 115 volts is 3500°K., a drop to 110 volts will lower the temperature to about 3425°K., and a rise to 120 volts will raise the temperature to 3575°K. While such a change would not be very important in color photography, it would be better to have the voltage across the lamp terminals closely regulated. For this reason it would be worth while to use lamps in series with a very small rheostat and adjust for constant voltage, in order that the blue to red ratio in the luminous spectrum may not change during the course of a sitting or the shooting of a scene.

MR. PALMER: It is evident that color photography must be done much more carefully than black-and-white. When photographing in color, the density of the negatives must be kept quite uniform throughout. Consequently, the lighting of a given person must be the same in different sets. Since we have to be so careful about measuring the light, there should be no particular difficulty about being a little more careful about the voltages.

MR. POPOVICI: In measuring color, we have to correct the meter according to its sensitivity to the kind of light that is used, because the photometer reading may remain constant even though the voltage should drop a little without being noticed.

PRESIDENT GOLDSMITH: Until recently the color motion picture companies fought shy of using or taking out-door scenes to any extent, for later theater presentation. They seemed to restrict themselves to studio material taken under very closely regulated conditions. Of course, that is a severe restriction, and sooner or later there must be plenty of out-door scenes upon the screen. If the light changes in an out-door scene as it does every time a cloud drifts across the sky, the natural effect will be to have it show upon the screen. I am not so sure that the artificially perfectly maintained color in a studio production of color motion pictures is either a desirable or a faithful presentation. If we walk around this lecture room, our apparent color changes as we get nearer the green-gray reflecting walls or the orange-yellow lamps. If a color photograph were to be made of us in this room, it should show such effects.

MR. FARNHAM: When color first began to be used, the colors were usually quite brilliant, and you usually found yourself looking at a color picture, and the story was secondary. Now the color pictures seem to have the pastel shades and are very much lighter and actually more realistic, so you find yourself first looking at a story; then you feel that there is something more natural about it.

PRESIDENT GOLDSMITH: Quite right. The fact is that in real life bright colors, saturated colors, and primary colors are very much the exception. We deal entirely with degraded, secondary, and tertiary colors. I don't believe that a single pure color could be found in this room.

A NEW METHOD OF IMPROVING THE FREQUENCY CHARACTERISTIC OF A SINGLE-RIBBON LIGHT MODULATOR*

A. F. CHORINE**

Summary.—*After discussing briefly some of the difficulties involved in equalizing in the conventional manner the frequency characteristic of the light modulator previously described by the author, a process is described of equalizing by means of a small drop of oil placed at a chosen point upon the vibrating ribbon. By varying the size of the drop and its location upon the ribbon, a whole series of characteristic curves is afforded from which any desired one may be chosen. The advantages of such a system, as regards the frequency response, factor of safety for the ribbon, and amplification, are described.*

In sound recording it is very necessary that the amplitude be adequate and the frequency characteristic of the light modulator satisfactory. It is the purpose here to describe the development and improvements in the author's light modulator described in detail in previous issues of the Journal.[1]

With respect to the amplitude characteristic, it is difficult to produce anything essentially new because the modulator represents the commonly known sensitive string type of galvanometer which satisfies the most particular requirements. Fig. 1 shows the amplitude curve obtained with this instrument under the most strenuous conditions. Fig. 2 shows the schematic arrangement of the modulator. The current carried by the ribbon was so great as to cause a pronounced lengthening of the ribbon and to introduce other distortional factors. The proportionality between the current and the amplitude of the ribbon changes slightly; so, for that reason, in the construction of the instrument efforts were directed toward decreasing the loading of the ribbon by (*a*) working with great magnification; (*b*) applying doubling; (*c*) increasing the magnetic field density. In the latest construction these three modifications have made it

* Received March 7, 1935.

** Director, Central Laboratory, All-Union Electrical Trust, Leningrad, U. S. S. R.

possible to use a very small deflection of the ribbon (maximum amplitude not greater than 0.03 mm.), and the general amplitude characteristic was exceptionally good.

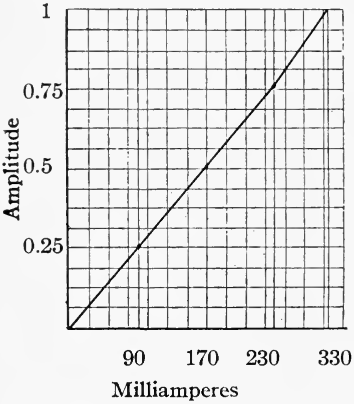


FIG. 1. Amplitude characteristic of the modulator.

The frequency characteristic in air is shown in Fig. 3. It is possible to work with such a characteristic only in combination with a filter designed to attenuate at the frequency of resonance. If the resonance frequency is within the recording band, or is fairly low, a filter that would attenuate the entire band, including the resonance peak, is used. Such systems are not convenient because they require extraordinary care in recording and very accurate tuning of the ribbon to a given natural frequency. Besides, in the case of small optical magnification, great current density resulted which caused the ribbon to burn out when overmodulated.

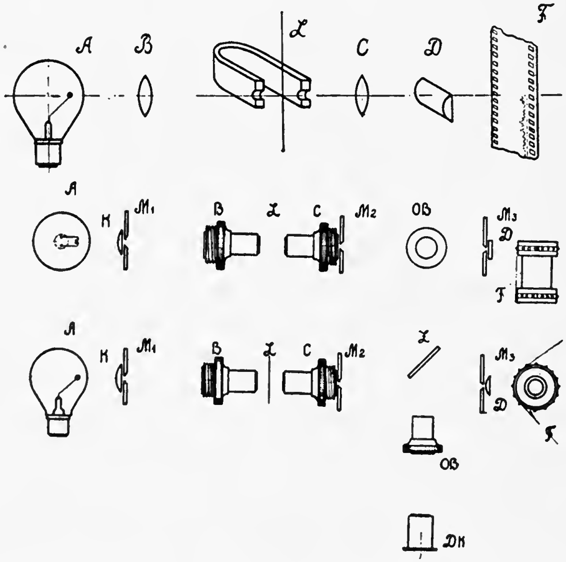


FIG. 2. (*Upper*) Schematic arrangement of first light modulator developed in the author's laboratory. (*Lower*) Details of modulator illustrated above.

Such systems had to be discarded for practical reasons. It was found to be more practicable to use damping fluids as a means of improving the frequency characteristic of the modulator. Best

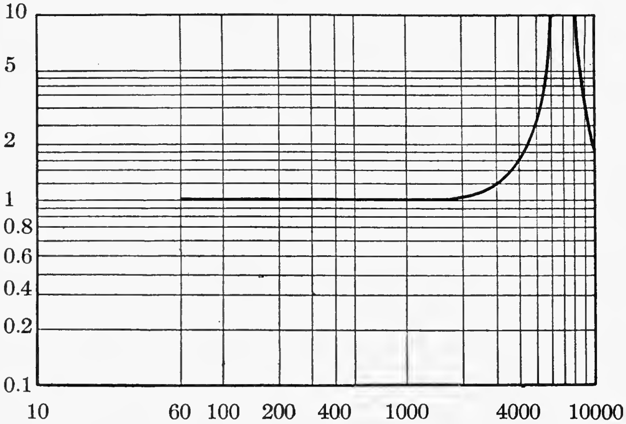


FIG. 3. Frequency characteristic in air after taking steps to decrease the loading of the ribbon.

results have been attained by using vaseline as the damping medium. For a duralumin ribbon 18 mm. long, having a cross-section 0.175 by 0.008 mm., characteristics have been normally attained like the

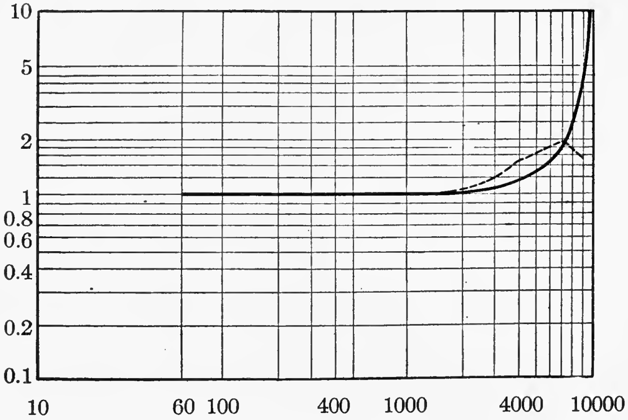


FIG. 4. Normal frequency characteristic of a duralumin ribbon 18 mm. long and 0.175 by 0.008 mm. in cross-section.

one shown in Fig. 4. The heavy curve represents the frequency characteristic obtained in air, and the dotted curve with the ribbon completely immersed in oil.

Analyzing the curve, we find that to satisfy the present technical requirements, it is necessary to improve the curve by lengthening as much as possible its linear portion. Extensive experimental work showed that a very good characteristic could be achieved by the comparatively simple method of depositing small drops of vaseline

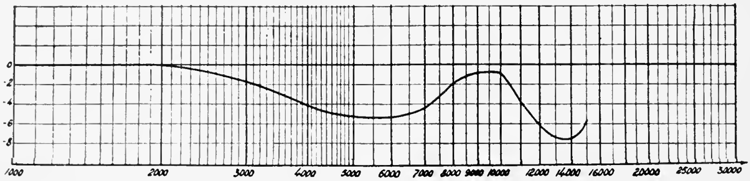


FIG. 5. Characteristic of the ribbon with a drop of oil placed one-third the distance from the end of the ribbon; natural frequency, 4000 cycles.

oil upon the half, third, or quarter length of the ribbon. The curves thus obtained are shown in Figs. 5, 6, and 7.

Fig. 5 is the curve of the same duralumin ribbon, 18 mm. long and 0.175 by 0.008 mm. in cross-section, with a drop of vaseline oil (about 2.5 mm. in diameter) placed one-third the distance from the end of the ribbon, the natural frequency of which was 4000 cycles. This curve shows a considerably wider frequency band as compared with

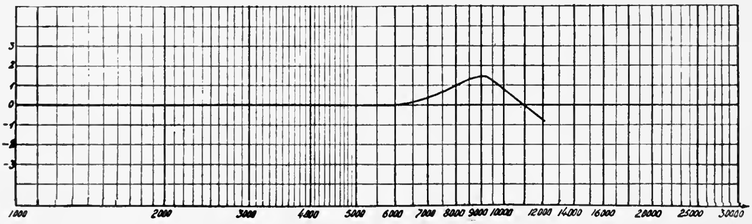


FIG. 6. Characteristic of the ribbon with oil drop $^7/_{16}$ths of the distance from the end of the ribbon; natural frequency, 6000 cycles.

the characteristic obtained with the ribbon completely immersed (Fig. 4).

Fig. 6 is the characteristic of the same ribbon, but with a higher natural frequency in air, namely, 6000 cycles, with the drop of vaseline oil of the same size placed at a distance of $^7/_{16}$ths of the length of the ribbon from its end. This characteristic shows an ideal frequency response within ± 1 db. up to 12,000 cycles. Fig. 7 represents the same ribbon with a natural frequency at 9000 cycles in air.

Physically, the process can be explained as follows: The current passing through the ribbon causes, by interaction with the magnetic field, forced vibrations of the ribbon. Since the oil drop divides the

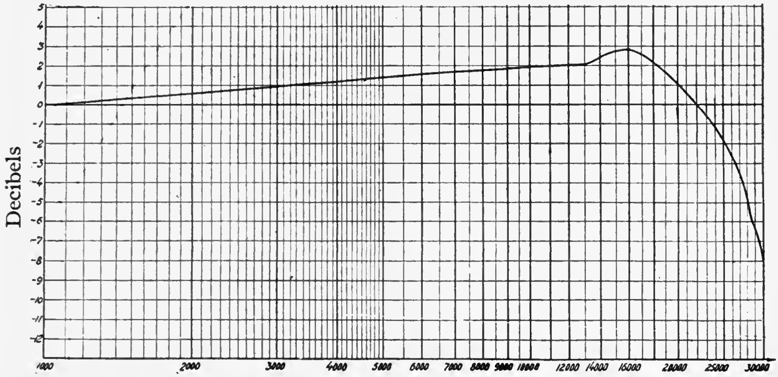


FIG. 7. Same as Fig. 6, but for a natural frequency of 9000 cycles in air.

ribbon into two parts, a vibrating system results consisting of three component parts, *viz.*, (*1*) the entire ribbon, (*2*) the one portion of the ribbon, and (*3*) the other portion of the ribbon. Experimentation showed that the geometrical size of the oil drop and its position upon the ribbon play important parts, and afford a whole series of families of characteristic curves, from which, in the majority of cases, it is possible to choose deliberately any required frequency characteristic.

Analysis of the three frequency response curves shown above indicates the influence of the natural period of the ribbon, a gradual increase of which causes a general widening of the straight-line portion of the characteristic. Such a system provides great advantages in recording sound for talking pictures:

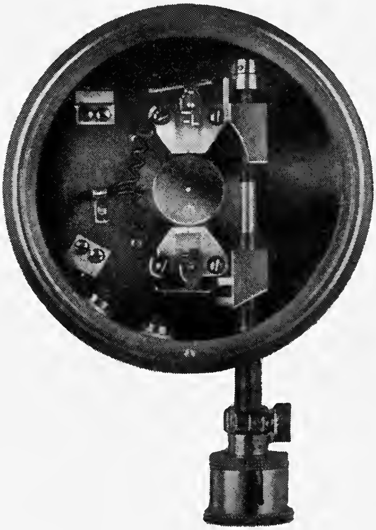


FIG. 8. Showing the construction of the modulator.

(*1*) It constitutes a simple method of achieving a frequency response band up to 12–13,000.

(*2*) A great saving of energy is effected, since, for a frequency band up to 12–13,000 cycles, the resonance frequency required in air is only about 4500 cycles. Hence, the saving in amplifier gain is about nine-fold.

FIG. 9. One of the pole-pieces, showing the metal plate shellacked to it.

(*3*) Only a very small current is required to produce the necessary deflection of the ribbon, resulting in a greater factor of safety and ribbon economy. Under practical conditions in vacuum tube circuits it is now impossible for the ribbon to burn out.

(*4*) The great factor of safety attained in respect to the current density makes it possible to decrease the cross-section of the ribbon, thus decreasing further the energy consumption and hence the power output of the amplifier. This is accounted for by the increased resistance of the ribbon, since generally the resistance of the ribbon was commensurable with the resistance of the connecting leads.

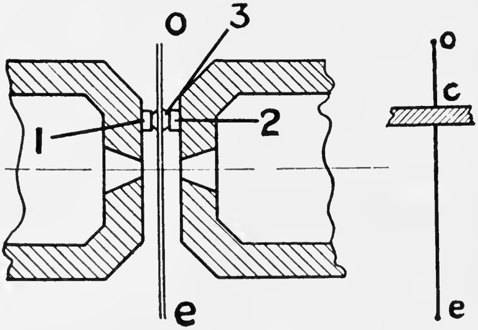


FIG. 10. Cross-section showing pole-pieces, ribbon, and oil drop.

In conclusion, it may be stated that for practical application to talking pictures, this improved light modulator provides great conveniences not only from the technical standpoint but also from the standpoint of practical application, since the adjustments, servicing, and operation are very simple. The actual construction of the modulator is not difficult. To both sides of the pole-piece (Figs. 8 and 9) small metal plates are attached by means of shellac One of the plates is lightly touched with a drop of oil. By putting both halves together a cross-section results as shown in Fig. 10, in which *oe* is the ribbon, *1* and *2* are the metal plates, and *3* is the introduced layer of oil. If the gap between the metal plates is within 0.10 to 0.15 mm., the oil drop holds very firmly. Practical tests in sound studios and laboratories have shown that the system is very stable.

At present, work is being done to derive the laws of vibration of the ribbon with the oil analytically. Experimental investigations are also being made with various damping fluids, various sizes of oil drops, with two drops at opposite ends of the ribbon, *etc.* Of especial interest would appear to be the investigation of the phase relations between the current and the position of the ribbon, at frequencies higher than the natural frequency of the ribbon.

REFERENCE

[1] CHORINE, A. F.: "Equipment for Recording and Reproducing Sound with Photo-Film," *J. Soc. Mot. Pict. Eng.*, **XXII** (March, 1934), No. 3, p. 157; concluded, *Ibid.*, **XXII** (April, 1934), No. 4, p. 215.

SOME FACTORS IN PHOTOGRAPHIC SENSITIVITY*

S. E. SHEPPARD**

Summary.—*Discussion is limited to gelatino-silver halide emulsions for development. Sensitivity is broadly defined as the reciprocal of the minimum incident light-energy per unit area giving a definable effect upon development. This definition is illustrated from the characteristic curve. The factors discussed are (a) intrinsic properties of silver halide layer; and (b) extrinsic factors, or exposure conditions. Under (a) are discussed grain size, nucleation, optical sensitizing, inhibition, layer thickness, etc.; under (b), intensity level of illumination, temperature, and humidity. Sensitivity is also envisaged broadly as a differential between progressive and regressive phases of latent-image formation.*

By photographic sensitivity will be understood the light-sensitivity of gelatino-silver halide emulsions for development, so that print-out and other processes are not considered. Quantitatively we shall understand by photographic sensitivity the reciprocal value of the minimum amount of light-energy incident upon a unit area which can give a specific, definable effect upon development under specified conditions. Actually, various measures of sensitivity may be, and are used, corresponding to various stadia of the characteristic curve (Fig. 1).

They will not be necessarily equivalent in rating different products, but for the broad purposes of this paper that is not very important. Finally, the sensitivity so far defined is that pertaining to a macroscopically sensible portion of a layer. We shall be actually considering much more in what follows the so-called "grain sensitivity," which is definable again as the reciprocal light-energy per unit area capable of making a grain developable. But with certain important exceptions—in dealing particularly with effect of grain-size and nucleation—deductions as to grain sensitivity have been made mostly from a study of the macroscopic sensitivity, which is derived from the individual grain sensitivities by an integration.

* Presented at the Fall, 1934, Meeting at New York, N. Y. Communication No. 546 from the Kodak Research Laboratories.

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

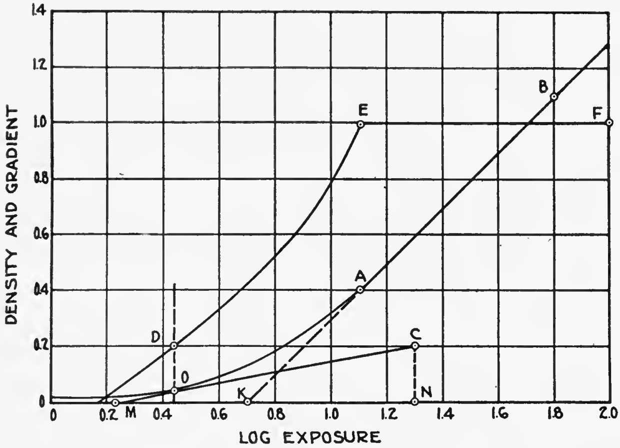


FIG. 1. *OAB* is the H&D curve for $\gamma = 1$; *DEF* is the first derivative of the characteristic, *i. e.*, the plot of $\frac{dD}{d \log E}$ *vs.* log *E*

(*i*) point *K* gives the value of log *i* (inertia) from which *H&D speed* is obtained as X/i, where *X* is a constant, *e. g.*, 10.

(*ii*) *D* on the first derivative corresponds to *O* on the characteristic, at which the (standard) minimum gradient of 0.2 is reached. The intercept log *x* on the abscissa gives a speed X/x.

(*iii*) The point where *ED* intercepts the abscissa corresponds approximately to the "threshold" value of exposure, formerly used as a "speed" number.

(*iv*) The exposure at which density = 1.0 has been used for astronomical purposes.

In the following I propose to discuss only certain selected factors conditioning sensitivity, divided as follows:

Intrinsic factors of silver halide layer	(*1*) Grain-size and mass composition.
	(*2*) Nucleation and micro-composition.
	(*3*) Inhibition.
	(*4*) Optical sensitizing.
	(*5*) Layer thickness, *etc.*
Extrinsic factors or exposure conditions	(*1*) Intensity-level of light and color.
	(*2*) Temperature.
	(*3*) Humidity.

INTRINSIC FACTORS

Before dealing in any detail with these factors, it is well to consider the fundamental process of latent image formation itself. It may be regarded as reasonably certain that this consists in the following events:[1]

$$
\begin{array}{lll}
(1) & Br^{-} + h\nu \longrightarrow Br + \theta \text{ (electron)} \\
(2) & Ag^{+} + \theta \longrightarrow Ag_{met} \\
(3) & Br + Br \longrightarrow Br_2 \\
 & Br \sim {}^{1}/_{2}\, Br_2 + Gel \longrightarrow Gel.\, Br \\
 & Br_2 + H_2O \longrightarrow HO\,Br + HBr \\
 & HO\,Br + Gel \longrightarrow Gel^{*}\ Br + H_2O
\end{array}
$$

The silver halide crystal is a regularly arranged lattice of silver and bromide ions, held together principally by electrostatic attraction. The absorption of light by the silver halide is a quantized event, in which one quantum of radiation (in the absorption spectrum of the silver halide) sets free an electron from a bromide ion, producing also a neutral bromine atom. The quantum event is completed by the acceptance of the electron by a silver ion, producing *one silver atom* per light quantum absorbed.

This will remain the photochemical yield of the absorption, provided no recombination of bromine and silver is allowed to take place. In the production of visible, print-out images, the prevention of this recombination is a very important phase of the process, and *chemical* sensitizing by halogen acceptors (*e. g.*, silver nitrate, sodium nitrite, *etc.*) is almost essential. In latent-image formation, where only some hundreds, in many cases very much fewer, atoms per grain are concerned, it is still quite a question whether halogen acceptance plays a major or only a minor role in the process, of which more will be said later.

Returning to the coupled event, (*1*) and (*2*), there are several important aspects to notice. The first is that the primary photochemical acceptor is not the silver ion but the halide ion. The removal of an electron from this requires a certain amount of work or energy (equal to the electron affinity of the halogen). On the other hand, the acceptance of an electron by a silver ion sets free a certain work or energy, which is subtracted from the total required. Since the electron affinity of the halogens decreases in the order:

$$E_{Cl} > E_{Br} > E_{I}$$

we should expect, and do find to be the case, that the spectral absorption and photochemical sensitiveness of the silver halides should extend into longer wavelengths in this order also. It is important to note therefore that (silver) bromide in an $AgCl/AgBr$ mixture, (silver) iodide in an $AgBr/AgI$ mixture (or mixed crystal) is an *optical sensitizer* for the grain. It extends the absorption and reaction to longer wavelengths, and adds its own absorption bands to the sensitivity spectrum of the silver halide. This is the simplest example of *optical sensitizing*, which will be discussed more fully later.

The second aspect to be noted is the disjunction of the quantized event, and the possibility of an interval between the release of the electron and its acceptance by a silver ion. The existence of such an interval is manifested by the phenomena of photoconductance, and still more perhaps, by the primary photovoltaic effect. These demonstrate a definite wandering or movement of electrons through a silver halide crystal, or at any rate, an equivalent electric displacement. One corollary from this is that the silver ion which accepts an electron need not be an immediately adjacent one—at an interval of about 3 Å.—but almost any one in the same lattice unit. In the formation of the latent image, and in regard to the minimum energy required to make a grain developable, it is of primary importance *which* silver ion does actually accept the free electron. In other words, for latent-image formation, it is not merely the *mass* of silver formed which is important but, much more, its *distribution*. This leads to *nucleation* as a very essential factor in photographic sensitivity to light. The combination of electron displacement and nucleus action makes the whole projective area of a grain approximate (within certain limitations to be discussed) the actual receptive area, so that this area a is *per se* one factor in determining sensitivity.

The existence and importance of nucleation are demonstrated by the following facts, *inter alia*. Out of a set of grains from the same emulsion, and of nearly equal size (projective area), there will be some of greater, some of lesser sensitivity. It appears that something is unequally distributed among the grains. Further, the existing sensitivity can be greatly reduced by treating the grains with oxidizing solutions, such as chromic acid, persulfate, or permanganate.

The fact that emulsions of precisely the same grain-size frequency could be finished with different gelatins to give widely different speeds pointed to the fact that the nucleation was largely controlled by the gelatin.

There was much speculation and experiment as to the nature and function of the nuclear material. Sheppard pointed out that for the same silver halide composition the spectral distribution of sensitivity was unaffected by desensitizing with oxidizing agents, and was determined by the silver halide itself. Hence, the nuclei could have nothing to do with the primary photochemical process, but merely served to make a smaller amount of primary product induce developability. To correlate these and other facts, the "concentration speck" theory of grain sensitivity was developed. According to this, the nucleus or sensitivity speck serves only to concentrate the atoms of silver photochemically produced from the silver halide, and ensure the formation of nuclei large enough to induce developability of the grain. The "development centers" of Svedberg and others represented "nuclei" or sensitivity specks brought to this level by accretion of photo-silver atoms. While many workers considered that these nuclei (or protonuclei, to use a term proposed to distinguish them from development centers) consisted of metallic silver, it was shown by the author and his co-workers that they consisted in whole or in part of *silver sulfide*. The difference in regard to sensitizing power between different gelatins was shown to depend largely upon their content of labile sulfur containing organic bodies. The inorganic ionizing sulfides, such as sodium sulfide, were not found to function readily as sensitizers, but generally produced fog. Sheppard[2] considered that a primary condition for a sulfiding sensitizer was that it should combine with silver halide to form a complex, which under given conditions could decompose *in situ* to form protonuclei of silver sulfide. Recent studies by Carroll and Hubbard[3] lend support to this view. The conception advanced by Sheppard that latent-image (development speck) formation involves an autocatalyzed oriented reaction at the boundary speck: silver halide is applied by Carroll to formation of these protonuclei themselves. It is probable that silver protonuclei do also function in sensitizing, because microänalysis shows the presence of small amounts of silver as well as of silver sulfide in the grains of ripened emulsions. These quantities are of quite small magnitude, as shown by the following table:

TABLE I

	Mass per 1 Gram *AgBr* in Grams	Molecules per Molecules *AgBr*
Photo-silver	10^{-10} to 10^{-7}	$1:10^{10}$ to 10^{7}
Sensitivity specks	10^{-6} to 10^{-4}	$1:10^{5}$ to 2×10^{4}

On the other hand, the mass of the sensitivity material ($^{Ag}_{Ag_2S}$ and/or Ag) appears relatively large compared with the masses of photo-silver, *i. e.*, of silver actually formed by light according to an equivalence of one *Ag* atom for one quantum absorbed.

TABLE II

Author	Material	2 *Ag* per 1 g. *AgBr* at Threshold	Atoms *Ag* per $1\,\mu^2 \times 0.1\,\mu$ at Threshold
Sheppard and Wightman	Leimbach:		
	Mittel-Rapid	3.6×10^{-9}	24
	Ultra-Rapid	2×10^{-9}	3
Eggert and Arens	Agfa Special	3×10^{-9}	21
Meidinger			1 to 1000
Hilsch and Pohl	Ultra-Rapid	1.6×10^{-9}	11
Jones and Schoen		1.5×10^{-9}	11–12

From this the author has concluded that the former hypothesis, that developability resulted when a nucleus reached a certain *size*, is inadequate.[4] It is suggested that the essential thing is rather the orientation and activation of relatively few atoms of photo-silver. Recently, Reinders and Hamburger,[5] arguing from quite a different direction, have also suggested that the effective photo-silver need not be more than, but can not be less than, 3 atoms per grain.

The conception of autocatalyzed growth of the protonuclei (by decomposition of complexes, *e. g.*, thiocarbamide-silver halide, or of sodium silver sulfite) advanced by Carroll appear to be of considerable importance in regard to *competition* between "specks." On the "concentration speck" theory, any increase in number of separated specks upon a grain surface above a certain minimum number, *e. g.*, one or two, should lead to diminished sensitivity, because of the competition of the specks (like crystal nuclei in a supersaturated solution) for the limited available silver atoms formed by light. In fact, experiments show that (*1*) an increase in the amount of a sensitizer beyond a certain optimum leads to diminished sensitivity; and (*2*) an increase in the time of digestion also leads to a maximum, with subsequent diminution of sensitiveness.

The existence of these optima rather definitely supports the conception of competition between "specks." The autocatalytic character of the sensitizing process would tend to reduce the number.

Function of Protonuclei (Specks) in Sensitizing.—The theory advanced explains the sensitizing action of silver sulfide and/or silver specks by orientation and concentration of the photolysis. There have been advanced other hypotheses, in partial or complete disagreement. The most important of these is the halogen acceptor

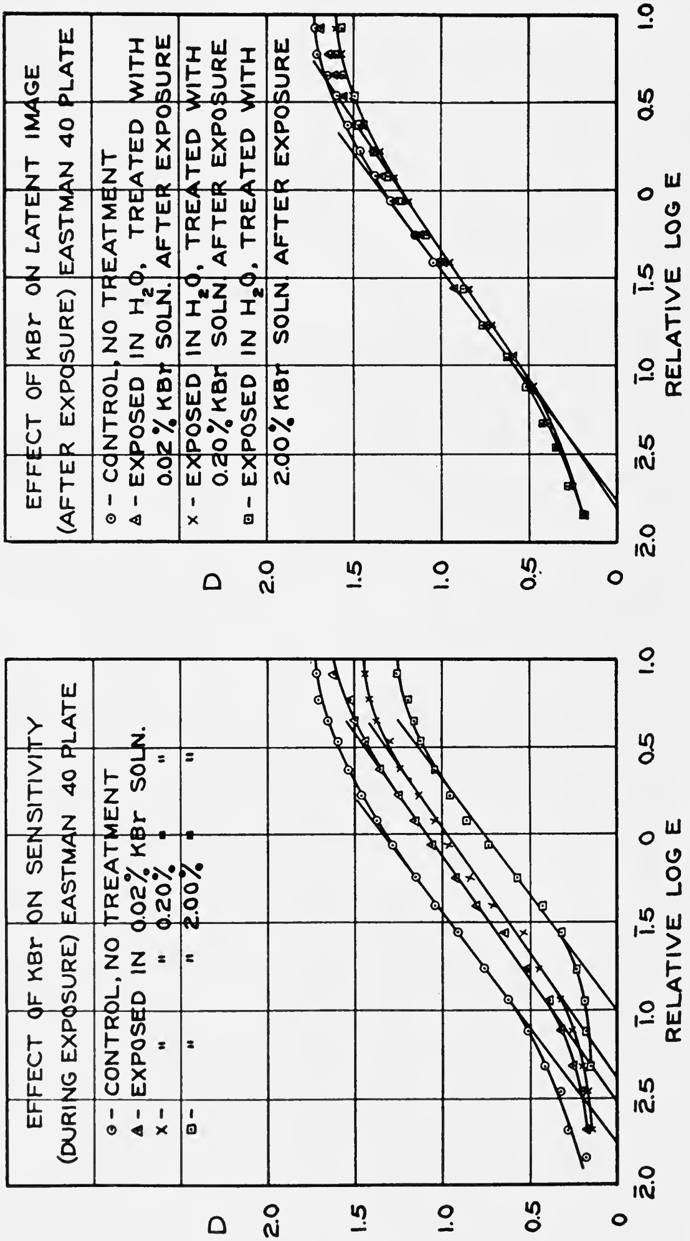


FIG. 2. The depressing effect of free bromide on photographic speed.

hypothesis. According to one form of this, silver sulfide acts as a halogen acceptor for the released bromine, thus stabilizing the photo-silver. What seems a fatal objection to this is the fact that specks or complexes of other equally readily halogen-accepting

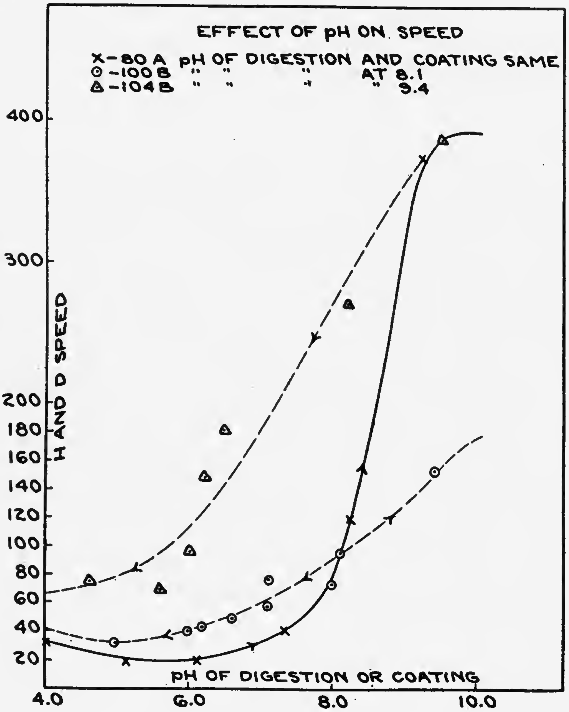


FIG. 3. The solid curve shows the increase of speed of an experimental emulsion with increase of *p*H of digestion, *p*H unchanged on coating. The lower broken curve shows, *left*, fall of speed by lowering *p*H at coating; *right*, increase of speed by raising *p*H at coating. Upper broken curve shows fall of speed by lowering *p*H at coating.

materials, as silver thioacetanilide, have no sensitizing effect. Nor does it explain very happily the sensitizing effects of silver and gold. A more specialized form was advanced by Hickman,[6] which supposed that the bromine reacted with silver sulfide to produce more silver from it. But apart from the fact that this reaction has not been established, it fails equally to deal with silver- and gold-speck sensitizing.

Inhibition and Stabilizing.—Silver halide emulsions for development usually have a small excess of free halide in the layer. This reduces the tendency to increase fog on keeping, but at the same time lowers the sensitivity. The curves of Fig. 2 illustrate the depressing effect of free bromide on photographic speed. This effect must not be confused with the restraining effect of bromide upon development. It is an effect produced during exposure to light, and *only* during exposure, as proved by careful control experiments.[7]

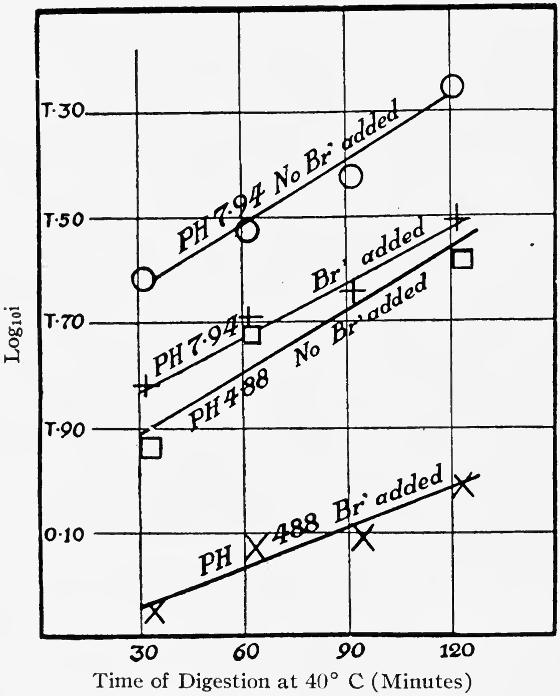


FIG. 4. Bromide ion effect and reversible *p*H effect.

Closely connected with this reversible bromide ion effect is the reversible *p*H effect upon sensitivity, discovered by Rawling.[8] This effect is illustrated in Fig. 3.

The reversible *p*H effect must be distinguished from the irreversible one, which is an acceleration of (permanent) nucleation by higher alkalinity. The reversible effect is shown in the fact that adjustment of *p*H of an emulsion just prior to coating affects the speed—raising it, *i. e.*, increasing *OH*-ions, increasing speed, and *vice versa*.

There appears to be an antagonism between the previously noted bromide ion effect and the reversible *p*H effect (Fig. 4) such that the bromide effect is lower, the higher the *p*H.

There have been various theories to explain these effects. An electrostatic adsorption and shielding theory was proposed by Sheppard and Wightman.[7] According to this, excess bromide ions complete an outer layer of bromide ions around the silver halide crystal. This increases the chance that the released photo-electron is deviated from useful action. Increase of *p*H provides *OH*-ions, which displace bromide ions, hence raise the sensitivity. On the

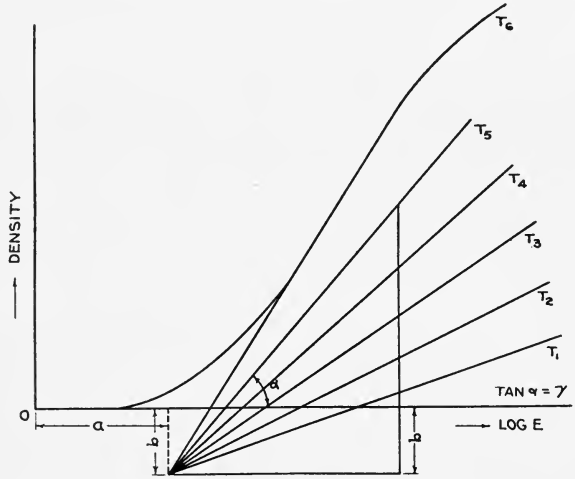


FIG. 5. Effect of bromide ion in development.

other hand, Slater Price[9] has proposed a chemical theory. According to this, increase of bromide ions and higher acidity (lower *p*H) hinders the absorption of free bromine by gelatin, hence favors regression of the latent image; whereas higher alkalinity (higher *p*H) favors formation of hypobromite which then attacks the gelatin. But whatever the explanation, these factors are of very considerable importance in determining the actual sensitivity.

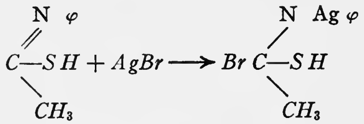
There is a further effect of bromide ion that must be noted, *viz.*, its effect in development. The general character of this effect is shown in Fig. 5. It will be seen that for the same gamma (contrast) the speed is lowered with free bromide. This effect, however, depends greatly upon the developer. It is large with developers of low reduction potential (and low Watkins factor) and small with developers of high reduction potential (high Watkins factor). Hence the considerable variation of apparent speed (sensitivity) of commercial emulsions with different developers.

The inhibitory and stabilizing effects of free halide (chloride, bromide) ions are, as we have seen, of a more or less transient, at any rate readily reversible, nature. This is because the inhibitor is not firmly incorporated in the grain substance. The inhibitory and stabilizing effect of small amounts of iodide in silver bromide grains is, therefore, of a less reversible character. The use of iodide in small amounts is nearly as old as gelatino-silver halide emulsions. It must be remembered, however, that since the work required to remove an electron from an iodide ion is less than from a bromide ion

$$\bar{I} + h\nu_1 \longrightarrow I + \theta$$
$$\bar{Br} + h\nu_2 \longrightarrow Br + \theta$$

i. e., $h\nu_1 < h\nu_2$; therefore iodide acts as an optical sensitizer, the absorption and sensitivity being displaced toward longer wavelengths.

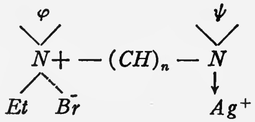
There are a number of other inhibitory agents, organic instead of inorganic, of which thioacetanilide is representative, and perhaps the first to be described in the literature.[10] The formation of a complex, according to the reaction



probably represents the chemistry sufficiently nearly. Gelatin itself, and, in particular, certain special ingredients, probably owes much of its unique colloid protective powers with silver salts to its capacity to combine with them. From this discussion of inhibitory factors it is apparent that we must regard actual attainable (grain) sensitivity as a differential between inhibitory and sensitizing moments. Silver bromide precipitated in the absence of gelatin (or other protective agent) is immediately reducible by ordinary developers without exposure to light. The presence of quite small amounts of gelatin suffices to retard greatly the rate of reduction. It is evident, then, that in general the sensitizing and inhibitory, or restraining factors of the gelatin are working as it were, in opposition.

Optical Sensitizing.—By optical sensitizing is usually understood the color-sensitizing of silver halides by certain dyes. It will facilitate the understanding of this, however, if we consider first the simpler case, already instanced, of optical sensitizing of silver bromide by iodide. It was pointed out that the work of removing an electron from an iodide ion is less than from a bromide ion. Hence the absorption of silver iodide extends further into the long wavelengths, even including a subordinate band in the blue not present with *AgBr*. Passing on to dyes, we may say that the primary event consists in the direct adsorption of dye molecules to the surface of the silver halide grains, forming unimolecular patches over the same. For such adsorbed dyes we may consider two principal cases, so-called acid dyes, *e. g.*, erythrosin, and basic dyes, like pinacyanol. With acid dyes the dye is chiefly present, at sufficiently high *p*H, as a dye anion, which is electrostatically adsorbed to the *silver* cations of the lattice

The absorption of the dye is modified by the attraction of the silver ion, so that the sensitizing spectrum is not identical to that of the dye in ordinary solution but shifted to the longer waves. The adsorption, and in some degree sensitizing, may be facilitated by pretreatment with silver ions. The behavior of the basic dyes is more complex. Taking the modern polymethine dyes, we have a fundamental polymethine skeleton



Quaternary N Tertiary N

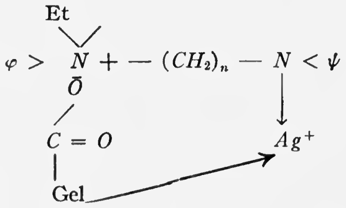
in which a quaternary nitrogen of one heterocyclic nucleus φ is connected with a tertiary nitrogen atom of another heterocyclic nucleus ψ by a chain of methines(—CH_2=). The quaternary *N* will tend to be attracted by the bromide ion of the lattice (qua cation) while the tertiary *N* atom, as in amines, will coördinate with a silver ion. (In general, we may say that other similar defectively coördinated atoms can tend to do the same.) Thus, there is formed a complex which, on absorption of light in the band of the dye (modified by the adsorption to silver halide), allows transfer of an electron from the dye molecule to a silver ion, and its reduction to metallic silver.

In principle then, in regard to the primary photochemical reaction, the dye molecule is simply replacing the bromide or iodide ion of the silver halide as the photochemical actor. Hence, for the photographic grain sensitivity (in the optically sensitized spectral region), the general sensitizing (for development) by "concentration specks" of silver sulfide and/or silver is of just the same importance as when bromide or iodide ions are the photochemical atoms in their absorption regions. This is an important aspect of optical sensitizing, first pointed out by Sheppard and recently confirmed by Carroll. Certain corollaries may be deduced:

(*1*) Although these (basic) dyes will be definitely adsorbed to silver halide grains covered with excess halide ions (halide bodies) yet excess halide may be expected to interfere with sensitizing, because the silver ions will be less available for coördination with other centers of the dye molecules. This is found in the practice of dye sensitizing (von Hübl, *et al.*)

(*2*) Factors decreasing $B\bar{r}$ ion sorption will favor sensitizing.

(*3*) While increase of *p*H is such a factor, its influence is complex. With some of these dyes (*e. g.*, orthochrome-*T*, and most isocyanines) the chromophore constitution depends upon *p*H, increasing therewith. Moreover, general sensitizing increases with *p*H. But also, with increased *p*H, the coördinative affinity of the *gelatin* for silver ions increases as well as the attraction of basic dye cation $>N^+$ ∧ for the negative gelatin. Possibly under these conditions there is one complex formed, gelatin, silver ion, and dye



(*4*) Although the blue-violet sensitizing of silver halide through the halide ion and the long-wave sensitivity through the dye are similar, and both function photographically through the "concentration speck" mechanism, there can arise a certain antagonism between them. Obviously, if the dye cover the whole grain, and the photochemical functioning of halide ions be reduced or eliminated, the blue-violet sensitivity will be depressed at the expense of the color-sensitivity. Also dyes are likely to be adsorbed preferentially at the interface, between silver halide and sulfide specks, as has been shown probable for fog inhibitors and dye desensitizers, so that they are capable thereby of interfering with the blue-violet (halide ion) photographic efficiency, although improving their own.

Fig. 6 illustrates a very schematic idea of the mosaic-like surface of a sensitized silver halide grain. For a given color-sensitizing ratio, the grain surface may be regarded as composed of two areas, the general silver halide, and the (diagrammatically, not actually) circular patches of dye molecules. In many cases these will surround sensitivity or concentration specks of silver sulfide.

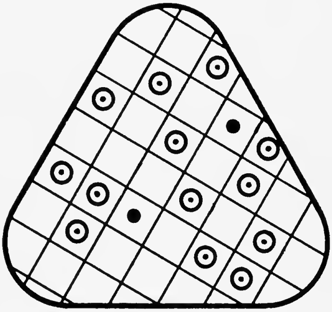


FIG. 6. Schematic idea of mosaic-like surface of a sensitized silver halide grain.

Nothing has been said so far as to why only certain adsorbed dyes are color-sensitizers, others not; nor why certain dyes are desensitizers. We can make a general hypothesis, *viz.*, that sensitizing dyes in light (and on silver halide) have their redox potential raised by light absorption, and that desensitizing dyes have it lowered; *i. e.*, they become stronger oxidizers. But this, although useful as suggesting an experimental attack, is not specific enough. We must probably wait until a later correlation of chemical constitutional factors with both photographic properties and redox potentials is available.

(*5*) Such obvious factors as concentration of silver salt, and thickness of layer are mentioned, as affecting actual photographic sensitivity (speed), but require no discussion here.

EXTRINSIC FACTORS (EXPOSURE CONDITIONS)

The factors so far discussed may be regarded as inherent in or, at least, predetermining ones implicit in the make-up of the sensitive layer. I shall now discuss briefly certain extrinsic factors, which either are or may be operative during exposure.

(*1*) First, the character of the light: We may disregard the quality, for our purpose, since it is quite obvious that the apparent sensitivity of a material of given spectral sensitivity distribution will depend upon the quality of the light, *i. e.*, on the distribution of energy in its spectrum. This is well understood, and is being increasingly provided for in sensitometric investigation and control. It is the obvious complement to color-sensitizing. Again, the question of

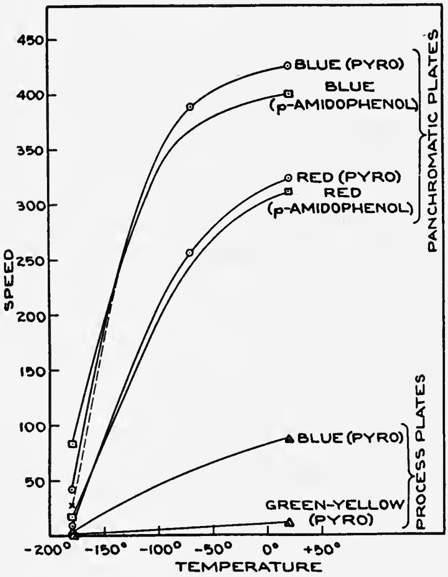


FIG. 7. Effect of temperature upon speed.

intensity level, as determining apparent sensitivity, recently has been very fully investigated by Jones and his collaborators.[11] The so-called "reciprocity failure" takes the form of an optimum intensity, *i. e.*, an intensity at which the efficiency of latent-image formation is a maximum. The efficiency of the process is a function of the time-rate of energy input. Assuming that the radiation is absorbed by the silver halide in quanta, as previously discussed, the process is, in any case, an intermittent one; but the utilization in latent-image formation is dependent upon the number of quantum processes per unit area per unit time. The discussion of nucleation indicates probably that reciprocity failure is connected in some way with the mechanism of concentration of the photo-product. The investigations of Webb,[12] together with a mathematical analysis of the observations by Silberstein and Webb,[13] indicate that what may be called the effective grain area approaches (for blue-violet light) the actual projective area. This is a result postulated by the orientation theory of the concentration speck. But for longer wavelengths than the definite absorption region of $AgBr$, this effective area appears much smaller than the projective area. This also is what we should expect from a consideration of optical sensitizing. (*Cf.* Fig. 6.) It is only the patches of sensitizing ion or dye that count.

There are two interpretations of this reciprocity failure which involve the function of the nucleus. One would require the nucleus not only to orient or concentrate the photo-product, but also to

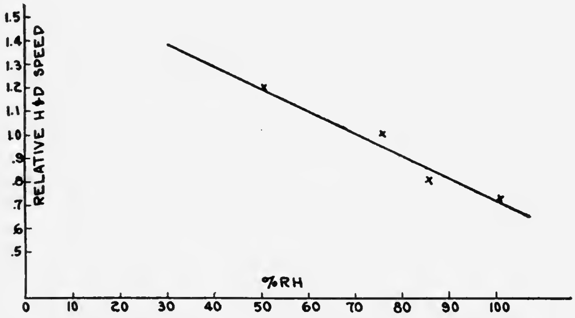


FIG. 8. Effect of relative humidity upon speed: high-speed film.

stabilize this, for example, by halogen acceptance. On this view, for *some reason not evident from statistical theory*, halogen acceptance is a maximum for a certain flux-density of quanta, *i. e.*, regression is a minimum for this. Another interpretation would consider the *interval* of the photochemical absorption act (the quantization) evidenced by electron displacement phenomena as the locus of the failure. This would require that the impedance to photon concentration depend upon the flux-density, for which the statistical theory can again give no criterion. Finally, it may be that the quantization is not regulated by purely haphazard (microscopically) independence, but that the statistics are such that with increasing intensity (flux-density) the probability of 2, 3 .... i ($i > 1$) quantization occurring (completing) in a minimum area (*e. g.*, within 3Å. of each other) increases, instead of remaining independent of the flux-density. It can be shown that this behavior, in combination with the competitive aspects of the concentration speck theory, would give all the observed phenomena of reciprocity failure.

(*2*) The effect of temperature at time of exposure upon sensitivity is not very marked for the temperature range which ordinarily obtains. Some of the variations reported are unquestionably due to changes of humidity, which are dealt with next.

Measurements of Eggert and Luft[14] indicated for a number of different emulsions (apparently none optically sensitized) an ill-pronounced maximum of density between −40°C. and −10°C. (though with some emulsions at temperatures lower than −40°C.). Above +60°C. irreversible changes, such as after-ripening, again raised the density. Recently, the writer and Wightman[15] have made some investigation of the subject, particularly with regard to a possible differentiation of natural (blue-violet) and optical (long-wave) sensitivity due to dyes. The general results are shown in Fig. 7. They do not permit comparison with Eggert and Luft's results from 40°C. to −40°C., experiments on which are in progress, and hence leave unaffected the possibility of a maximum at the temperatures they indicate. They show, however, that while there is little drop between +20°C. and −75°C., a very large fall occurs between −75°C. and −180°C., but that the optical (dye) sensitivity is not very much more affected than the blue-violet. The conclusion is that the temperature effect is connected with the secondary processes rather than the primary one in latent-image formation. It appears that considerably more investigation is required, particularly in the region −30°F. to +120°F., with regard to practical sensitometric variation of sensitivity and contrast.

(*3*) The effect of *humidity* variation is frequently confused with that of temperature. Not enough is known of the variability of sensitivity in different emulsion types with changed humidity, *i. e.*, with change of water-content of the gelatin. Fig. 8 shows some results with high-speed film obtained by Sheppard and Wightman.[16] A change of relative humidity between 40 per cent at 25°C. and 100 per cent produced a change in sensitivity of about 50 per cent. Accommodation was relatively slow, about 40 to 50 minutes being required to reach equilibrium.

It is quite possible that the effect of humidity (moisture content) is different for different emulsions. The effect is entirely reversible and is possibly connected with the reversible adsorption effects of $B\bar{r}$-ion and pH already discussed.

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DISCUSSION

MR. CRABTREE: Do you deal at all in the paper with the effect of age upon the growth or decay of the latent image?

DR. SHEPPARD: No. I restricted my paper to the actual sensitivity, rather than to the theory of the latent image as such. The growth of the latent image bears most of the hall-marks of corresponding very much to the intensification of the latent image by peroxide. If we treat an underexposed plate with a very minute amount of peroxide vapor, an amount insufficient to produce fog, we can intensify the latent image. Processes take place by which a larger or more effective nucleus is built up. I believe, myself, that the growth of the latent image is a peroxide effect, but that may not be the case.

MR. BANDERMANN: Has anything ever been found out about the tensions in the photographic silver halide gelatin coatings and their effect upon a silver halide grain? Are there indications proving or suggesting that such tensions represent a factor in photographic sensitivity, referring particularly to the tensions in the gelatin and around the grain?

DR. SHEPPARD: They are very large, unquestionably, according to optical measurements and it is possible to show that the silver halide crystals themselves are optically anisotropic. So I think it is quite a legitimate supposition that they may have some effect.

On the other hand, we have made some measurements of a very peculiar effect in desensitizing silver halide by exposure to momentary flash, you might call it, or a puff of superheated steam, only long enough to make the surface of the gelatin tacky and then leaving the plate in an atmosphere of water vapor until it is saturated. If either of those two phases of the procedure were omitted, there would be a relatively small depression of sensitivity. But where they were combined, we have cut the sensitivity down to two-tenths or more of what it was originally. Now we suspected that that might have something to do with a release of tensions in the gelatin. But I have not been able to prove this and it must be remembered that, without giving that jet of steam to the plate or film, if you swell gelatin that was originally strongly doubly refracting to light in water, the double refraction largely vanishes, or is greatly reduced. Apparently, just doing that doesn't depress the sensitivity.

In answer to Mr. Bandermann's question, it is very possible that these strains in the silver halide crystals induced by the gelatin play a part in the sensitivity. The orientation of the gelatin molecules, of which the so-called strain is an indication, if you look at that from a molecular point of view, means that certain groups and molecules of the gelatin are all pointing in a certain direction. That is what we mean by strains in the gelatin. It is probable that they also play a part in the sensitivity, but so far we have not been able to ascertain how large it is.

THE USE OF THE MOTION PICTURE FOR VISUAL INSTRUCTION IN THE PUBLIC SCHOOLS OF NEW YORK*

RITA HOCHHEIMER**

Summary.—*The use of motion pictures in the educational program of the New York City schools is described under the headings: equipment; results attained by using motion pictures; sources of films; available supply of films; the question of sound-films; what can be done to expand the use of motion pictures in education; and the future of visual education.*

Equipment.—The standard visual instruction equipment for a school so far as the showing of motion pictures is concerned consists of a silent 16-mm. motion picture projector and a beaded screen. If we had the money, we should equip every school in New York with this minimum equipment out of public funds. At present, however, many motion picture projectors are given to schools by outside organizations (Parents Associations, *etc.*) and purchased out of private funds. Some schools have two projectors, many have none.

Motion picture machines for class-room use are part of the equipment of approximately 300 schools, or 45 per cent of the total number. They represent a total value of approximately $45,000. The Bureau of Visual Instruction annually supplies as many projectors as its funds permit. This year 46 motion picture projectors and 80 screens have been purchased by the Bureau and assigned to schools.

Film Library.—A central film library is maintained by the Bureau, which serves approximately one hundred schools, sending three reels to each school each week. In addition, there are seven district film libraries, each serving from twenty to forty schools in a given neighborhood. These take about 500 reels. We also have two sets of Yale history films, each about 100 reels, generously given to us by The Sun Printing and Publishing Association and Devoe & Raynolds. These reach an additional group of about fifty schools.

The Bureau now has a film library of approximately 875 reels of

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* Presented at the Fall, 1934, Meeting at New York, N. Y.

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16-mm. motion pictures suitable for class-room use. In addition to films purchased by the Bureau, these figures include approximately sixty reels on loan. Of these, copies of thirteen films on Canada, useful for grade 6*A* Geography and Nature Study, were presented by the Motion Picture Bureau of the Canadian Government. The remainder are industrial films, many of which are very valuable.

Through one type of distribution or the other, regular weekly film service has been extended during the past year to 33 schools in Manhattan, 13 in the Bronx, 35 in Brooklyn, and 10 in Queens. The pictures used are those that are closely related to the regular course of study. There are 175 separate films covering geography, nature study, health education and biology, and suited to class use for children from the 4th year through the high school. Films are widely used to teach safety. Dangerous street traffic situations and how to avoid them are shown. The total pupil contact for the year is approximately 1,000,000. The films are organized into courses, each covering a term's work in a given subject and listed so as to show where they fit into the course of study.

We now have films covering the following subjects in the course of study:

TABLE I

Subject	Grade	Subject	Grade
Geography	5*A*	Nature Study	4th yr. Spring
Geography	5*B*	Nature Study	5th yr. Fall
Geography	6*A*	Nature Study	6th yr.
Geography	7*A*	Health Education	6th, 7th, 8th yrs.

The demand for some of these is so great that six copies are required to fill the needs. The material is selected from the list of visual aids approved by the Board of Education and the Board of Superintendents, and our good judgment in choosing is constantly checked by reports of teachers and principals based upon class-room experience. Films are selected to fit into the course of study, for class-room teaching. They are usually one or two reels long. For them to be of value a teacher's guide and a pupil's guide are often developed, to be used in connection with the film. The films are all 16-mm., and are projected by the teachers. It is very necessary that the teachers be familiar with the film, and they are instructed to preview and prestudy them. For that purpose, the film is allowed to remain in the school for a full week.

A school usually receives three film lessons a week, the choice of courses and of lessons within the film course being left to the principal of the school. Thus, a given school may elect for this term weekly film lessons in the 6th-grade *Nature Study*, in *Health Education*, and in 8*A*-grade *Geography*. The lists of films available in these courses are sent to the schools. The principal selects 15 of each, indicating his choice as to which is appropriate for each week. On appointed days the Bureau's messenger delivers the film lessons and takes away the three delivered the previous week. The new film material is distributed to the appropriate teachers in the school, who study it by previewing it in advance of the class lesson.

Results.—As a result, the children in the 6th year of that school during a given week see, through the magic of the cinema, butterflies emerging from their cocoons when they are studying that topic in *Nature Study*. The boys and girls in the 7th year have animated microscopic views of the blood stream to help them in their health work. The 8th-year class sees the *Rubber Industry of South America*, thus breaking down the barrier of distance through the magic of the film. In addition to factual knowledge acquired, the use of visual aids perceptibly changes attitudes and adds largely to the children's vocabulary through making word-study intelligible. For instance, children who have only thought of the Japanese as strange people with almond-shaped eyes, when they see the film *Dolls of Friendship* which shows the doll festival celebrated by the children of Japan, are given a feeling of the oneness of the human race, and an appreciation of the fact that children around the world are much the same. Similarly, a girl or boy to whom the word *pasteurization* has heretofore been unfamiliar, is not likely to forget its significance once it has been connected with the impressive scenes in the pasteurizing plant typical of the milk industry.

Although there are among school people, as elsewhere, some ultraconservatives who wish no change under any circumstances in the present school set-up, the large majority of the teachers and principals in the New York schools realize that the motion picture is a tool of inestimable value to them and feel keenly the deprivation to which they and the children are subjected because of our present inability to give them all they need when, and as, they need it.

Sources of Films.—We are not interested in the source of the film. We are interested in obtaining the best suited material regardless of its source. For this purpose, a list of approved films is promulgated by the Board of Education from which selections are made for purchase. All producers are invited to submit samples.

Supply of Films.—Are there enough films available? No. We should like more submitted, but the lack of a sufficient appropriation means that it is difficult to induce producers to submit additional films because we give them such small orders. If every school were doing its maximum visual instruction work, we should probably need and order twenty-five prints at a time. That would be worth while from the producer's point of view. Now we order one or two prints, rarely more. Also, the disappearance of films which the industry regards as "old," but which we should continue to use if we had them, presents a difficulty. We have, for instance, two prints of a given film of which we should like six, but the producer has discontinued his Educational Department and it is impossible to purchase additional prints at present.

The Question of Sound-Films.—There are some so-called teaching films with sound, but there are several reasons why we do not use them. In the first place, although sound reproduction from 16-mm. film is vastly better than was at first possible, the results are still far from satisfactory in our older school buildings where there are no heavy draperies to muffle the sound and where the walls are not sound-proofed. Also, there is no valid pedagogical reason for the additional expenditure of public money which the purchase of sound equipment and sound-films represents. The films on musical topics obviously require sound, but a running comment which merely duplicates what would otherwise be in written titles is not sufficiently valuable for us. It is, indeed, questionable whether the simultaneous multiple sense-appeal is not psychologically a deterrent in the learning process.

The Present—What Can Be Done?—While it is true that the school people intimately connected with visual instruction appreciate its value and wish for its extension, this will not be possible until there is an aroused public opinion demanding the right for our children to be taught in the schools by means of such modern methods. A demonstration of a Visual Instruction Centered School is now being made in Westchester County, N. Y., which has aroused much favorable public opinion in that neighborhood. Something similar in New York City would undoubtedly arouse a public opinion that would become vocal and eventually secure adequate appropriations so that every child in our schools would reap the maximum benefits of teaching through motion pictures.

The Future—The Use of the Radio.—What is the future in regard to the educational use of the motion picture in our schools? Do the results attained thus far show a tendency to increase or decrease its present use? To my mind, there is no doubt that it is merely a question of time when *every* school will be built at the beginning so as to permit films to be used by each teacher in her class-room as needed; when the school authorities will consider a motion picture projector as commonplace a part of school equipment as blackboards. Probably by that time 16-mm. sound-films will be satisfactory, and we shall go from silent to sound as needed. Perhaps, too, by that time we shall have television for use in some of our work. Certainly, the school use of radio will be accepted, and all the sense appeals that science has made possible will be interwoven for school purposes in order to shorten teaching time and to broaden the outlook of our children upon a world that grows increasingly difficult and complex. When will that be? When enlightened public opinion makes itself felt and is reflected in the form of adequate appropriations; when progressive steps in public education are no longer considered "fads" and "frills."

NEED FOR UNIFORM DENSITY IN VARIABLE-DENSITY SOUND-TRACKS*

F. H. RICHARDSON**

Summary.—*Attention is directed to the fact that projectionists work in sound-proof rooms and must rely wholly upon an observer for graduations in sound volume.*

Wide variations in the density of variable-density sound-tracks occur in various scenes of productions. Under such conditions consistently good sound reproduction is often impossible in the theater, especially with one-man projection rooms. Steps should be taken to remedy the condition in order that the projection may do full justice to the efforts of the producer.

It is naturally the desire of the motion picture industry that its finished product be placed before its consumers, the theater-going public, in the best possible manner, both as to visual and sound effects. Otherwise, the product will not be able to exert its maximum power of attracting patrons to the box-offices, and the business will suffer loss of income. If the patrons view a production that is well projected, both as to picture and sound, it is only reasonable to assume that their inclination to visit the theater again will be decidedly stronger than would be the case were the production less perfectly placed before them.

Apart from the excellence of the recording impressed upon the film, unless the projection be so done that the recording is made to reproduce with all the excellence it contains, then, in so far as concerns the audience, the artistry of the recording automatically becomes lost. It is not the original production that the audience sees and hears, but what the projectionist is able to get out of the films upon which the original was recorded.

It is axiomatic that unless a perfect recording be delivered to the projectionist, he can not possibly place it before his audience in a perfect form. He may, by inexpert work, present to the audience a perfectly recorded sound or picture in such a manner that it appears very far from perfect to the audience; but he can not possibly achieve per-

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fect results from an imperfect recording, or from a recording which, though its visual scenes may be excellent, yet varies so widely and suddenly in sound-track density as to make it often impossible, particularly in one-man projection rooms, to adjust the sound apparatus quickly enough to keep the reproduction uniform.

It often happens that neither the manager nor the projectionist does everything that he possibly can to derive the utmost entertain-

FIG. 1. Illustrating a wide difference in the density of sound-tracks in two scenes of a single production.

ment value from the productions delivered to him. On the other hand, we also find producers sending out to the theaters prints from which it is utterly impossible to project excellent sound or picture. That this is the fault of the producer is evidenced by the fact that one print of a production may be excellent throughout, whereas another print of the same production may often be, and often is, far from excellent. It is obvious that this must be due only to carelessness or lack of control in the processing laboratories.

This is a situation that has been permitted to endure since the beginning of the industry. It would seem to point to the fact that there is a lack of competence in inspecting prints at the laboratories, and a failure to reject those containing imperfections that might be remedied.

The projectionist is located in what is supposed to be, and usually is, a sound-proof room. He is completely out of touch with the sound he is producing except for a monitor horn, which has no value whatsoever in advising him as to the sound level in any part of the auditorium. He therefore must depend wholly upon signals from an observer located in the auditorium; if an observer be provided, which is not by any means always the case. Moreover, even if there be an observer, the projectionist has no means of knowing whether he is competent or not; though if the observer be incompetent the projectionist well knows that he, the projectionist, will be the one who will be blamed by the audience for any faults that may occur. Under such a condition it is obvious that if acceptable results are to be expected, a sound-track having the proper volume level throughout its length must be provided. By "proper" volume level is meant a degree of uniformity such that, if properly adjusted at the beginning of the picture, the fader will require little or no readjustment throughout the entire production—exclusive, of course, of some variable auditorium factors. As projection is today, that is the only possible way in which consistent excellence in results can be attained.

The fact is, however, that productions are delivered to the theaters which, apart from auditorium conditions, require wide and often very sudden changes in the fader; and not infrequently the variations exceed the very limit of the fader to handle them properly. Fig. 1 shows two sections of sound-track clipped from a single production, of such wide range that the fader would not soften the sound sufficiently in one case, or permit it to become sufficiently loud in another. Wide variations do, of course, occur in sound-track density due to the variations in the sound itself; but the variations in Fig. 1 are not accounted for by that. How can acceptable results be attained when, with one sample, the dense one, it is necessary to jack the fader up to its limit and then not be able to make the sound loud enough; and then with the light print, to turn the fader in the other direction almost to the limit in order to make the sound soft enough?

Consider now the effect of such a variation, assuming a one-man projection room, the number of which is large and rapidly increasing. Assume also that scene *B* is being projected, and the projectionist is away from the working projector, threading up the idle one, trimming its carbons, or performing some other duty. The fader is, of course, set at its upper limit. The observer, if there be one, may be ringing for more volume. The audience is straining its ears to understand the softly spoken words, when suddenly scene *A* appears.

Imagine the roar of sound (the sound as recorded was of the same order of loudness in each case) that will occur; until the projectionist in the sound-proof room, possibly with no observer to advise him, discovers what is happening, returns to the working projector, and fades the sound down.

Suppose scene *A* were on, and similarly scene *B* arrived. The sound level, of course, instantly drops to almost nothing; but the projectionist, having no knowledge of the fact if there be no signal from an observer, permits the audience to miss a considerable amount of the dialog or music before remedying the situation by adjusting the fader.

In order to correct this serious fault, the sound-track level of negatives first should be such that proper development of prints made from them would provide sound-tracks that would require little or no change of fader position, except such as may be made necessary by variable conditions in the auditorium; and, second, that every print made from such negatives be so developed and controlled as to maintain that condition.

The projectionist, upon the excellence of whose work the producer and, in fact, the entire industry is wholly dependent for delivering the results of their efforts and expenditures to the public, insists that such sound-track be delivered to him. It is difficult, and often impossible for him to achieve consistently good results with such variable products; and, by the limitations of his equipment, he is utterly unable to rectify the errors that have gone into the product before it comes to him at the theater.

DISCUSSION

DR. GOLDSMITH: There is a point in this connection that is interesting. If reels are printed to different densities and if the corresponding loudness of reproduction is different, that would not be so serious as it is at present if only the monitoring system in the theaters were simple, instantly available, and effective. In other words, if a skilled person were sitting in the body of the house with a volume control under his fingers, and the instant the first spoken syllable or the first musical note were heard to be too loud, he could turn the control back to the necessary extent, or turn it up if it were too soft, that would not be so serious.

If we are going to have unequal densities and unequal loudness on changing from one system of recording to another, it is necessary to have instantaneous and effective monitoring in the body of the house. If we are not going to have printing errors rectified, then we must have that type of monitoring.

CHAIRMAN SHEA: I understand that the Sound Committee at one time considered monitoring methods of that kind and ran into difficulties. They found it very difficult to recommend a satisfactory monitoring method.

DR. GOLDSMITH: With automatic or manual control?

CHAIRMAN SHEA: Either automatic or manual.

DR. GOLDSMITH: The control-room operator in a broadcasting station is able to monitor a broadcasting program and keep it within proper limits without the least difficulty; and I do not understand why a good broadcasting control-room operator seated in the body of the house with a volume control in front of him and a trained pair of ears on him can not correctly monitor a program.

MR. RICHARDSON: There is only one trouble with that: the impecunious type of manager won't pay such a man. If he has any observer at all, he usually makes an untrained usher the observer. The only practical solution, I believe, is for the producer to mark the sound level upon the leaders.

MR. TANNEY: Some years ago the squeeze-track was used. Wasn't that an attempt to modulate the sound to a constant level?

CHAIRMAN SHEA: The squeeze-track method related to the studio. It was to be used either in recording or in editing. The difficulties mentioned here have relation to the laboratory that makes the release prints, or the projection difficulties encountered in the theaters. There is a somewhat similar condition in radio, in that the broadcasting studios are about as particular as the motion picture studios, because their work is done only once; but the work of each individual theater, like the adjustment of a radio receiver, affects only one group of listeners.

RULINGS OF THE U. S. SUPREME COURT IN RECENT PATENT CASES OF THE AMERICAN TRI-ERGON CORPORATION

In view of the great interest that has attached to the recent litigation between Paramount Publix Corp. and Altoona Publix Theaters, Inc., vs. American Tri-Ergon Corp., the Board of Editors of the S. M. P. E. deemed it desirable to make them a matter of record in the Journal and readily accessible to the members of the Society. They are reproduced herewith.

SUPREME COURT OF THE UNITED STATES

No. 254.—October Term, 1934.

Paramount Publix Corporation, Petitioner, *vs.* American Tri-Ergon Corporation.	Petition for Writ of Certiorari to the United States Circuit Court of Appeals for the Second Circuit.

[March 4, 1935.]

Mr. Justice Stone delivered the opinion of the Court.

In this case certiorari was granted, 293 U. S.—, to review a decree of the Court of Appeals for the Second Circuit, 71 F. (2d) 153, which held valid and infringed the process patent of Vogt and others, No. 1,825,598, of September 29, 1931, "for producing combined sound and picture films." It reversed the district court, which had held the patent invalid for anticipation and want of invention. 4 F. Supp. 462. The several claims involved relate to a method of producing a single photographic film by printing upon it a picture record and a sound record from separately exposed and developed negatives. The positive film thus produced is useful and extensively used in reproducing sound and picture records in the exhibition of "talking moving pictures."

The respondent, who was the plaintiff below, is a patent holding company, and acquired the patent by assignment. The petitioner, who was the defendant below, is a producer of motion pictures, and the defense of the present suit has been conducted on its behalf by the Electrical Research Products, Inc., a subsidiary of the Western Electric Company.

In order that the precise nature of the claims may be understood, it will be necessary first to describe briefly the procedure and the mechanisms employed in recording and reproducing talking motion pictures, although neither is embraced in the claims of the patent. Several methods have been devised for recording sound and reproducing it in connection with the exhibition of motion pictures. A familiar one is the disk system, by which the sound vibrations are mechanically recorded upon and reproduced from disks by a stylus, which receives the sound vibrations for recording and transmits them from the disk to a loud speaker in reproducing the sound.

Another method, important here, is the photographic film system, in which the sound vibrations are recorded upon a photographic record. In the typical procedure, used by the petitioner, the sound waves to be recorded are received by a microphone so devised as to produce variable electric currents whose variations correspond to the variations in the sound waves received. The electric currents thus produced are amplified and transmitted to two metal threads, arranged side by side so as to form a narrow slit about 1/1000 of an inch in width, called a light-valve. The current produces vibration of the metal threads with consequent variation of the light passing through the valve exactly corresponding to the sound vibrations to be recorded. In recording sound, a moving sensitized photographic film is exposed to a beam of light passed through the vibrating light-valve which is activated by the electric currents varying according to the sound vibrations. The exposed film is then developed and the "sound record" thus produced is printed from it upon a positive film, where it appears as a series of short parallel lines of varying light density, corresponding to the sound vibrations, which have controlled in turn the variation in the electric current passing to the light-valve and the corresponding variations of light passing through it to the sensitized film.

In reproducing the recorded sound the procedure is reversed. The positive sound film is passed before a light slit, from which the light passes through the sound record film to a photoelectric cell, which is devised to produce a variable electric current corresponding to the light variations caused by the moving record film. The electric current thus produced is amplified and passed to a loud speaker, where it is translated into sound vibrations.

Successful operation of the talking motion picture involves synchronization of the sound and picture records. The difficulties of synchronization are obvious where the recorded picture and sounds are separately reproduced by independent mechanisms. Success has been achieved, and convenience in use of the two records secured by uniting them upon a single positive film and passing it at the requisite uniform speed through a single apparatus designed to reproduce both the sound and the picture. A familiar method of securing the two records on a single film is by photographing simultaneously the picture record and the sound record side by side upon the same strip of film and then printing from the developed negative a single positive film. This method was disclosed in the Haines, British Patent, No. 18,057, of 1906; in the Ries Patent, U. S. No. 1,473,976, of 1923, applied for in 1913; in the French Patent to MacCarty, No. 448,757, of 1912; and in the Walker Patent, U. S. No. 1,186,717, of 1916. Another method is by mechanically uniting the two positive records, as by cementing them together, after they have been separately printed from negatives separately exposed and developed. This was disclosed by the Bullis Patent, U. S. No. 1,335,651, of March 30, 1920, applied for in 1915. A third method, which is that claimed by the patent in suit, is by printing the two records on a single positive film from separately exposed and developed negatives.

In petitioner's practice separate photographic films, moving at uniform speed, are separately exposed, so as to record a scene and the accompanying sounds, and are then separately developed. The two records are then printed, side by side, on a single positive film, used for reproducing the picture and the sound. In the typical reproducing apparatus the film passes successively through the picture projector and the mechanism for sound reproduction. Accordingly, synchronization is accomplished by arranging the two records on the positive film in such relative positions that the two records will simultaneously reach the two mechanisms for reproducing them, so that the reproduced sound will accompany the reproduced scene of the picture as it did when they were recorded.

The specifications of the patent state broadly that it is of great advantage to arrange the sound record sequences and the picture record sequences on a single film. They then describe the technical difficulties in developing the negative when the sound and picture records are photographed on a single film. They point out that the picture record is made under changing light conditions, which may result in over- or under-exposures, which will require correction and a treatment in the development of the negative different from that suitable to the sound sequence, which is recorded under different light conditions. It is said that it is practically impossible to secure the variations in treatment required for developing the two types of record where the two sequences, picture and sound, are photographed upon the same film strip. The specifications then describe the invention as follows:

According to the present invention the difficulty is overcome by either employing entirely separate films for the simultaneous photographing of the sound and picture negatives, or films which are connected during the photographing, but which are separated from one another before the developing, then separately developing the negatives if and in the manner required to remedy the difficulties, and then printing both sequences—picture and sound—on the different portions of the same positive film.

Respondent relies on Claims 5 to 9, inclusive, and Claim 11 of the patent, of which it is agreed Claim 5 is typical. It reads as follows:

A process for producing a combined sound and picture positive film, for talking moving pictures, comprising photographing a sequence of pictures on one length of film, and simultaneously photographing on another length of film a corresponding sequence of sounds accompanying the action, separately developing the two negatives in a manner appropriate for each, and printing the sound and picture negatives, respectively, upon different longitudinally extending portions of the same sensitized film, to form the sound sequences at one side of and along the picture sequence.

It will be observed that the claimed method or process is for combining sound and picture records on a single film and comprises three steps: first, the simultaneous photographing of a picture record and a record of the accompanying sound, each on a separate negative; second, the separate development of the two negatives in a manner appropriate to each; and third, the printing, either simultaneously or successively, from the two negatives of the sound record and the picture record side by side on a single positive film.

It is important to indicate the more significant features of the sound reproduction procedure and mechanisms which are not embraced in the claims. The patent does not claim either a method or a device for recording or for reproducing sound, or a method of synchronizing the two records, or the use of a single film in the reproduction of combined sound and picture records, or any method or device for printing the positive records from the two separate negatives.

While the claims speak of a process or method for producing a combined sound and picture positive film, it is obvious that the process described and claimed has no necessary connection with sound reproduction. The positive film bearing the combined sound and picture records is a product of the photographic art. The method claimed for producing it relates exclusively to that art. It is neither a method of sound recording or sound reproduction. It claims only a process, every step in which is an application of the art of photography: simultaneous exposure of the negatives, their separate development, and printing from them a single positive film. The process is as applicable to any other form of photographic record as to a photographic sound record. It is as effective in the production of the one as the other. Its importance to the sound picture industry arises only from the fact that the single film, bearing the two records, for which no patent is claimed, is of great utility in that industry.

An examination of the prior art can leave no doubt that the method, as thus described and clearly restricted by the patent, lacks novelty and invention. The only step in respondent's method, for which any advance could be claimed over earlier methods, is the process of uniting two records on a single positive film by printing them from separate negatives. The Bullis Patent, already mentioned, and the Craig Patent, U. S. No. 1,289,337, of 1918, had shown the simultaneous exposure and separate development of sound and picture films, the advantages of which, as well as the advantages of the double record on a single film, were well known. The claim to invention is thus narrowed to the single contention that the patentees secured the benefit of these well known advantages by resort to the added step of uniting the two separate photographic records, sound and picture, by printing them on a single film.

The practice of printing separate photographs from separately developed negatives upon a single positive film has long been known to photographers. Standard photographic dictionaries, published here and abroad between 1894 and 1912, describe the procedure for "combination printing" of a single positive picture from separately developed negatives.[1] The procedure is shown to have been followed in the laboratories of the Eastman Kodak Company for many years prior to April, 1921, the date claimed for the present patent, and before that date the Company had made special materials for use in combination printing.

The practice was also well known in the motion picture industry. In 1908 the American Mutoscope & Biograph Company made and released in the United States a motion picture, *The Music Master*. This picture was prepared by separately photographing two scenes. From the separately developed negatives a positive was printed, showing the two pictures on the same strip of film, from which the motion picture was reproduced. The British Downing Patent, No. 6727, of 1913, discloses methods and apparatus for producing motion pictures, accompanied by printed words used by the actors, the two records being printed on a single positive film from separately exposed and developed negatives. The Messter Patent, U. S. No. 1,286,383, of 1918, and the British Patent, No. 21,467, issued to Rossi in 1909, each discloses a method of printing two separately exposed picture records on a single film. The Craig Patent, already mentioned, calls for separate exposure and development of sound and picture negatives, simultaneously recorded, and their printing on opposite sides of a single film. The Greensfelder Patent, U. S. No. 1,254,684, of 1918, discloses a method for printing, from separately exposed and developed negatives, a sound record and a picture record on the same side of a single positive film. The function of the sound record differed radically from that contemplated by respondent's patent, but this is immaterial so far as its printing is concerned, in which the Greensfelder patent does not substantially differ from that in suit. While these patents did not specifically mention the separate development of the negatives of the two records, it appears that they were photographed separately upon separate negatives, and the record shows that at their dates the state of the art was such as to require separate development of the two negatives. The practice and advantage of separate development are also shown to be well known. This and other evidence in the record abundantly supports the finding of the trial court that as early as 1908 it was common practice in the motion picture industry to print, on standard positive film, composite pictures from separately developed negatives.

The simultaneous photographing of sound and picture records was not novel, separate development of the negatives was well known, the advantage of uniting the two records, sound and picture, on a single film was well known, and the method of uniting two photographic picture records by printing them from the separate negatives was well known.

This use of an old method to produce an old result was not invention. See *Electric Cable Co. v. Edison Company*, 292 U. S. 69, 80, and cases cited. Even if it be assumed that the Greensfelder patent did not anticipate that of respondent, because the sound record there mentioned was designed directly to operate musical instruments, rather than a loud speaker, all that was novel in the claimed method was its application in the production of a combined sound and picture record, instead of a combination of two picture records. To claim the merit of invention the patented process must itself possess novelty. The application of an old process to a new and closely analogous subject matter, plainly indicated by the prior art as an appropriate subject of the process, is not invention. *Brown v. Piper*, 91 U. S. 37, 41; see *Pennsylvania Railroad Co. v. Locomotive Truck Co.*, 110 U. S. 490, 494; *Dreyfus v. Searle*, 124 U. S. 60, 64; *Concrete Appliances Co. v. Gomery*, 269 U. S. 177, 184, 185. However wide the differences between the procedures and results of sound reproduction from film, on the one hand, and picture reproduction, on the other, the method of producing photographic sound and picture records and uniting them on the positive film are identical, for both sound and picture records, from the time of exposure of the negatives until the single film is completed. With knowledge of the well understood advantages of the union of the two records on a single film, it required no more than the expected skill of the art of photography to use an old method of printing photographically the two negatives upon a single positive.

Against this conclusion respondents throw the weight of voluminous evidence, showing the practical utility and widespread use of the patented process, which prevailed with the court below as sufficient to establish invention. It is said that, however simple and obvious the method may appear to be now that it is in successful use, no one before the patentees had used it for producing the union of a sound and a picture record. Respondents also allege that the positive film produced by its method is more useful than any it had been possible to produce by other methods, and that it has found all but universal acceptance. These considerations, it is urged, should turn the scale in favor of invention.

Laying aside the objection that it is only when invention is in doubt that advance in the art may be thrown in the scale, *DeForest Radio Company v. General Electric Company*, 283 U. S. 664, 685; *Smith v. Dental Vulcanite Co.*, 93 U. S. 486, 495, 496, we think the evidence of utility and prompt acceptance of the patented method, in the circumstances of this case, adds little weight to the claim of invention. The greater utility of respondent's film over those effecting the union of the two records by other methods does not establish the novelty of the method. Evidence of great utility of a method or device, it is true, may in some circumstances be accepted as evidence of invention. Where the method or device satisfies an old and recognized want, invention is to be inferred, rather than the exercise of mechanical skill. For mere skill of the art would normally have been called into action by the generally known want. See *Loom Co. v. Higgins*, 105 U. S. 580, 591; *Krementz v. S. Cottle Co.*, 148 U. S. 556, 560; *Hobbs v. Beach*, 180 U. S. 383, 392; *Carnegie Steel Co. v. Cambria Iron Co.*, 185 U. S. 403, 429, 430; *Expanded Metal Co. v. Bradford*, 214 U. S. 366, 381.

But the state of the motion picture art, as it is disclosed by the present record, indicates that there was no generally recognized demand for any type of film record, for the reproduction of sound to accompany motion pictures, until after the present patent was applied for. See *Hollister v. Benedict & Burnham Mfg. Co.*, 113 U. S. 59, 73. Compare *McClain v. Ortmayer*, 141 U. S. 419, 428; *Grant v. Walter*, 148 U. S. 547, 556.

Before 1926 motion pictures were silent and there was no convincing evidence that the public would prefer the sound picture. In that year Warner Brothers exhibited sound pictures produced by the disk system, provided by the Western Electric Company. At that time the Company had for some years been experimenting with both film and disk systems for recording sound, and it had electrically recorded disk phonographic records which were in commercial use. The addition of sound on disk to motion pictures involved merely the attachment of the phonographic type of turntable to the ordinary motion picture projector, without any extensive modification of the projector or the film printing machines then in use, as was later necessary in order to employ the film method. Moreover, as has already been indicated, skilfully devised mechanisms were required for successfully recording and reproducing sound by the film method, a problem distinct from any method of uniting the sound and picture records upon a single film.

Until these appliances were perfected there could be no pressing and generally recognized demand for the sound-film. It was not until after the public interest in sound pictures was disclosed, in the summer of 1926, that the mechanism for recording and reproducing sound by the film method was carried to a state of perfection which would warrant its production in commercial form. The light-valve was produced in commercial form in December, 1926, and the first installations were in 1927. A rival system, of the Fox Case Company, for recording and reproducing sound by film, was not brought to completion until after 1926. Other problems engaging the attention of experimenters in this field were the necessary improvement of the photoelectric cell, the devising of suitable emulsion for sound negatives, of apparatus for "mixing" the sound to be recorded, and the mechanical perfection of the apparatus for reproducing sound from film. See Nos. 255, 256, *Altoona Publix Theaters, Inc., et al., v. American Tri-Ergon Holding A. G.*, decided this day.

Thus there is no basis shown by this record for the contention that advance in this phase of the motion picture industry was awaiting the development of the combined sound and picture record upon a single positive film. On the contrary, the inference seems plain that the advance awaited the public acceptance of the sound motion picture; that when the public demand became manifest it was still necessary to develop suitable mechanisms, not embraced in the patent, for the reproduction of sound from film. There had long been, ready at hand, knowledge in the photographic art which would enable one skilled in the art to produce the film suitable for use in the new apparatus. Indeed, at some time before 1924, Wente, engaged in research on sound-film apparatus for the Western Electric Company, without any knowledge of the work of the patentees of the present patent, had prepared the combined sound and picture positive film by printing it from separate negatives, separately exposed and developed.

The bare fact that several inventors, in the early stages of sound reproduction, working independently, of whose knowledge and skill in the photographic art we know little or nothing, failed to resort to a method, well known to that art, for printing a combination film for which there was then no generally recognized need, does not give rise to the inference of invention.

The court below also rested its decision on the ground that the petitioner is estopped to deny the validity of the patent by the application of Wente, April 8, 1924, who was in the employ of the Western Electric Company, for a patent for an improvement in recording and printing the sound record film, which contained claims broad enough to include the method claimed by respondent. These claims were rejected by the Patent Office as reading on the British Patent 178,442 of the present patentees, and the Greensfelder patent, already mentioned. However inconsistent this early attempt to procure a patent may be with petitioner's present contention of its invalidity for want of invention, this Court has long recognized that such inconsistency affords no basis for an estoppel, nor precludes the court from relieving the alleged infringer and the public from the asserted monopoly when there is no invention. *Haughey v. Lee*, 151 U. S. 282, 285.

Reversed.

Mr. Justice BRANDEIS took no part in the consideration or decision of this case.

SUPREME COURT OF THE UNITED STATES

NOS. 255 and 256.—OCTOBER TERM, 1934.

Altoona Publix Theaters, Inc., Petitioners, 255 *vs.* American Tri-Ergon Corporation and Tri-Ergon Holding, A. G. Wilmer & Vincent Corporation and Locust Street Real Estate Company, Petitioners, 256 *vs.* American Tri-Ergon Corporation and Tri-Ergon Holding, A. G.	On Writ of Certiorari to the United States Circuit Court of Appeals for the Third Circuit.

[March 4, 1935.]

Mr. Justice STONE delivered the opinion of the Court.

These cases come here on certiorari, 293 U. S.—, to review a decree of the Court of Appeals for the Third Circuit, 72 F. (2d) 53, which affirmed a decree of the district court, 5 F. Supp. 32, holding valid and infringed the patent of Vogt and others, No. 1,713,726, of May 21, 1929, applied for March 20, 1922, for a "device for phonographs with linear phonogram carriers." The two cases were tried together and have been brought here on a single record.

Petitioners, the defendants below, are operators of motion picture theaters whose sound reproduction machines are said to infringe certain claims of the patent in suit. The Radio Corporation of America is defending both cases on behalf of its subsidiary, R. C. A. Photophone, Inc., which supplied the petitioners' machines. Respondent, the plaintiff below, is a patent holding company and owner of the patent.

Of the nineteen claims of the patent, seven are in issue. Five of them, numbered 5, 7, 17, 18, and 19, relate to a device for securing uniformity of speed in machines used for recording and reproducing talking motion pictures, and are referred to as the "flywheel claims." They may conveniently be considered separately from Claims 9 and 13 which present the flywheel claims in a different aspect. Claim 9, as originally allowed, was for the arcuate flexing of the film record; Claim 13 similarly was for a combination for a means for projecting a narrow line of light upon and through the moving film to a photoelectric cell in sound reproduction. A disclaimer, filed by respondent shortly before the trial, purports, in varying terms, to add the flywheel device to each of these claims.

While both courts below have found invention and sustained the patent, the Court of Appeals, as will presently appear in more detail, did not pass on the separate claims in issue, but found invention in a combination of elements not embraced in any single claim. In consequence, the case presents no question of concurrent findings by the courts below that the claims in issue severally involve invention; see *Concrete Appliances Co. v. Gomery*, 269 U. S. 117, 180.

THE FLYWHEEL CLAIMS

"Phonograms," or sound records, for the recordation and reproduction of sounds, are of several types. They include disks or cylinders to which, and from which, sound vibrations are transmitted mechanically by a stylus in the course of recording, and reproducing, sound. Long strips of waxed paper carrying sound record grooves, similarly made, are used. Other types are long strips of film on which sound is photographically recorded, and long steel wires on which sound variations have been magnetically recorded. The claims relate to an improvement in mechanisms for recording and reproducing sound by the use of linear photographic record carriers. The typical procedure in recording and reproducing sound by the use of photographic film strips is described in No. 254, *Paramount Publix Corporation v. American Tri-Ergon Corporation*, decided this day, and need not be repeated here.

Both in recording and reproducing sound, by any form of record, uniform speed in the movement of the phonogram is of the highest importance, in order to secure evenness and regularity in the reproduced sound. The specifications state:

> The recording and the reproduction of sound waves by the use of linear phonogram carriers such as film strips, steel wires, and so forth, can only be effected in absolutely satisfactory manner, even after the removal of all other occurring difficulties, when the speed of the record carrier is uniform both for the receiving and the reproduction, and when in both cases no variations of any kind occur. Especially in the case of musical reproductions is the record extremely sensitive to the slightest variations of speed.

They also point out that linear phonograms such as the photographic film, because of their lightness and their want of the momentum afforded by a revolving cylinder or disk record, are peculiarly susceptible to irregularities of movement caused by the play or friction in the projections and connections of the many parts of the propelling apparatus, and declare that:

> According to the present invention, this draw-back which attaches to all hitherto known propulsion mechanisms for linear phonogram records is obviated by the arrangement, that the light sound record has given to it at the controlling point the property of a weighty mass. This is attained by the arrangement that the record carrier (a film strip or the like) is firmly pressed against one or more rollers connecting with a heavy rotating mass, so that the record moves in exact conformity with the rollers and the rotating mass.

The references to a "weighty mass" or "a heavy rotating mass" used to secure uniformity of motion are to the familiar flywheel. The specified "property" of a rotating heavy mass is inertia, the tendency of matter in motion to continue in motion, the force of which is increased by the mass of the moving body. It is the property which gives to the flywheel its peculiar efficacy in securing uniformity of speed in mechanisms with which it is associated.

The first three flywheel claims, 5, 7, and 17, are apparatus claims. The others, 18 and 19, are, in form, method claims, defining the method of securing uniformity in movement of the record film by apparatus defined by Claims 5 and 17. Claim 5 reads as follows:

In phonographic apparatus in which the sound record is formed on an elongated ribbon of inconsiderable mass, having feeding perforations therein, the combination of

[a] means for supporting and progressing the record ribbon from one point to another point and past an intermediate point at which the record is made on the ribbon in recording or from which the record is taken from the ribbon in reproducing, including

(1) a toothed cylinder over a portion of which the ribbon passes adjacent to said intermediate point, the teeth of said cylinder engaging the perforations of the ribbon,

(2) a flywheel associated with said cylinder, and

(3) means for rotating said cylinder, under control of said flywheel at uniform speed.

Claim 17 is substantially the same as Claim 5, the principal difference being that it uses the word "cylinder" instead of "toothed cylinder."

Claim 7 adds to the essentials of Claim 5 "a resilient connection between said driving member [the shaft] and flywheel, and stop means for limiting the amount of yielding of said resilient connection." This so-called flexible or elastic flywheel connection, designed to overcome more gradually the inertia of the flywheel, and thus to secure an improved flywheel operation, was anticipated, among others, by the Constable Patent, U. S. No. 1,425,177, of August 8, 1922, applied for June 24, 1918, as the district court found. Its inclusion in Claim 7 may therefore be disregarded as adding nothing more to the present patent than the flywheel without it.

There is no serious contention, nor could there well be, that the combination apparatus, for moving the linear record past the translation point at which the sound is recorded or reproduced, involves invention without the flywheel. Mechanisms for moving linear strips, or ribbons, by passing the strip over a revolving drum or cylinder, are a familiar type in the arts. They have long been used in the motion picture industry when it was desired to employ the linear strips at an intermediate point for sound and picture reproduction, and the like. Such a mechanism, for moving a picture film past the translation point in a motion picture projector, is shown by the Holst Patent, U. S. No. 587,527, of 1897. A like mechanism for recording or reproducing sound, or both, by the use of linear photographic records, is shown in the British Duddel Patent, No. 24,546, of 1902, and the Reis Patent, U. S. No. 1,607,480, of 1923, filed May 21, 1913. Still other mechanisms, like two of the figures attached to the specifications of the patent in suit, show the translation point at the film-carrying cylinder. Examples are the patents of Bock, U. S. No. 364,472, of 1887; Byron, U. S. No. 1,185,056, of 1916; and Pedersen, British Patent No. 115,942, of 1918. The gist of respondent's contention, as is shown by the claims and the parts of the specifications already quoted, is that by the addition of the flywheel to this familiar mechanism the patentees have succeeded in producing a new type of machine for recording and reproducing sound by the photographic film method. It is insisted that the new device, because of its greater accuracy and precision of film movement, is so useful and constitutes such an advance in the sound motion picture art as to entitle it to the rank of a patentable invention.

The flywheel set upon a revolving shaft is an ancient mechanical device for securing continuity and uniformity of motion when brought into association with any form of machinery moved by intermittent force or meeting with irregular or intermittent resistance.[2] So universal is its use for that purpose in every type of machinery that standard treatises on mechanics, long before the application for the present patent, gave the mathematical formulas for ascertaining the appropriate weight and dimensions of a flywheel, moving at a given speed, required to overcome known variations in force resistance, and prescribed the standard procedure for locating the flywheel in as direct association as possible with that part of the mechanism at which the intermittent resistance occurs. See article, Mechanics, § 121, Encyclopaedia Brittanica, Eleventh Edition, 1911; Angus, Theory of Machines, pp. 261–272, 1917.

The specifications of the patent recognize that disk and cylinder records themselves operate as flywheels and proceed to show how a want of a similar control may be supplied, in mechanisms used for motion picture film records, by the addition of the flywheel. But this was specifically taught by the prior art for the reproduction of sound both from phonographic and film records. There are in evidence two Edison commercial recording machines with cylindrical records, which were used at the Edison Recording Laboratory in New York before 1921. Each has a heavy flywheel mounted directly on the shaft of the record-carrying cylinder. These flywheels produce a high degree of "speed constancy." An application for a patent by

Edison in 1879 on a claim for a combination "with the phonograph cylinder and its shaft, of a flywheel" was rejected by the examiner April 7, 1879, as covering the "use of a flywheel as ordinarily used with machinery for the purpose of securing uniformity of motion." Upon reconsideration the claim was again rejected on the ground that the adaptation of the flywheel required only the exercise of "ordinary good judgment" and not the inventive faculty.

The Underhill Patent, U. S. No. 995,390, of 1911, exhibits a phonograph machine with a flywheel to secure uniformity of motion of the record. The specifications state that the flywheel is used for that purpose. The patent of Alexander Graham Bell and others (Bell & Tainter), U. S. No. 341,213, of 1886, discloses a mechanism for recording sound on a photographic plate rotated at uniform speed under the control of a flywheel. Another patent of the same inventors, U. S. No. 341,214, of 1886, discloses a flywheel used in association with a mechanism for moving a linear, wax-coated phonograph record at uniform speed for recording and reproducing speech and other sounds. That the record used was not photographic is unimportant. The problem of securing uniformity of motion of the record is the same for either type of linear sound record, as the present patent itself establishes, by classing together all types of linear records as exhibiting the "problem" to which the patent is directed. The French Dragoumis Patent, No. 472,467, of 1914, shows a film record moved by a cylinder turning on a shaft carrying a large wheel, obviously acting as a flywheel, though not described as such. See *American Road Machine Co. v. Pennock & Sharp Co.*, 164 U. S. 26, 38. The flywheel was mounted on the shaft of the record-carrying cylinder at the translation point. Finally, the British Pedersen Patent, already referred to, shows a photographic sound record carried by a cylinder as it passes the translation point. His specifications, after pointing out that sound is "exceedingly sensitive to variation in rotating speed," and that it is necessary to obviate this during the recording and reproducing operations, state that this may be done "by providing particularly large flywheels."

There are numerous patents showing the like use of the flywheel in apparatus for reproducing motion pictures from film. That of Holst, already noted, shows in detail an apparatus exhibiting every element of Claim 5 except that its use is for reproducing motion pictures instead of sound from film. The toothed cylinder is located adjacent to the intermediate point which is the point of translation.

The flywheel is associated with the cylinder by being attached to the rotary shaft carrying the cylinder.

An improvement to an apparatus or method, to be patentable, must be the result of invention, and not the mere exercise of the skill of the calling or an advance plainly indicated by the prior art. *Electric Cable Joint Co. v. Brooklyn Edison Co.*, 292 U. S. 69, 79, 80. The inclusion of a flywheel in any form of mechanism to secure uniformity of its motion has so long been standard procedure in the field of mechanics and machine design that the use of it in the manner claimed by the present patent involved no more than the skill of the calling. See *American Road Machine Co. v. Pennock & Sharp Co., supra*, 41. Patents for devices for use both in the motion picture art and in the art of sound reproduction, notably the Holst, the Bell & Tainter, the Dragoumis patents, and the Edison application, already noted, plainly foreshadowed the use made of the flywheel in the present patent, if they did not anticipate it. The patentees brought together old elements, in a mechanism involving no new principle, to produce an old result, greater uniformity of motion. However skilfully this was done, and even though there was produced a machine of greater precision and a higher degree of motion-constancy, and hence one more useful in the art, it was still the product of skill, not of invention. *Hailes v. Van Wormer*, 20 Wall. 353, 368; *Grinnell Washing Machine Co. v. Johnson Co.*, 247 U. S. 426, 432–434; *Powers-Kennedy Contracting Corp. v. Concrete Mixing & Conveying Co.*, 282 U. S. 175, 186. Its application in recording sound or reproducing it, by use of a particular type of linear record, the photographic, analogous so far as the problem of uniformity of motion was concerned to other types used by Bell & Tainter and Dragoumis, was not invention. See *Paramount Publix Corporation v. American Tri-Ergon Corporation, supra*.

There is some suggestion in respondent's brief and argument that the location of the flywheel adjacent to the toothed cylinder is an element in the invention which contributed to the success of the mechanism. But as has already been indicated such location is but the teaching of the art. In any case, the claims call only for the flywheel located upon the shaft or in association with the cylinder. No particular location is mentioned.

The Court of Appeals, in upholding the patent, made no examination of its separate claims, but treated the patent throughout as though it were a combination of five distinct elements, the photoelectric cell, the arcuate flexing of the film, the flywheel, the flexible connection of the flywheel and the optical slit, although nowhere in the patent is any such combination claimed. The patent thus upheld is one which was neither claimed nor granted. Under the statute it is the claims of the patent which define the invention. See *White v. Dunbar*, 119 U. S. 47, 51, 52; *McClain v. Ortmayer*, 141 U. S. 419, 423–425; *The Paper Bag Patent Case*, 210 U. S. 405, 419; *Smith v. Snow*, decided January 7, 1935. And each claim must stand or fall, as itself sufficiently defining invention, independently of the others. See *Carlton v. Bokee*, 17 Wall. 463, 472; *Russell v. Place*, 94 U. S. 606, 609; *Leeds & Catlin Co. v. Victor Talking Machine Co.*, 213 U. S. 301, 319; *Symington Co. v. National Malleable Castings Co.*, 250 U. S. 383, 385; *Smith v. Snow, supra;* Walker on Patents, § 220, 6th Ed. As none of the flywheel claims as drawn define an invention, none can be aided by reading into it parts of the specifications, or of other claims, which the patentees failed to include in it.

The court below, attributing the rapid development of the sound motion picture industry to the invention in the patent in suit, thought, as respondent earnestly argues here, that its utility and commercial success must be accepted as convincing evidence of invention. But we think that want of invention would have to be far more doubtful than it is to be aided by evidence of commercial success, indicating that it brought realization of a long-felt want. *Smith v. Dental Vulcanite Co.*, 93 U. S. 486, 495, 496; *Grant v. Walter*, 148 U. S. 547, 556; *DeForest Radio Co. v. General Electric Co.*, 283 U. S. 664, 685; compare *McClain v. Ortmayer, supra*, 428. Moreover, the record fails to show that there was any long-felt or generally recognized want in the motion picture industry for the device defined by the flywheel claims, or that the use of sound motion pictures was delayed by the inability of those skilled in the art to add a flywheel to the apparatus in order to give the desired uniformity of motion to linear phonograms. See *Paramount Publix Corporation v. American Tri-Ergon Corporation, supra*. There was no public demand for sound motion pictures before 1926, when the disk system of the Western Electric Company was first publicly used in conjunction with moving pictures. Before change to the photographic film system could be accomplished, it was necessary to await the development of numerous electrical devices not embraced in the present claims. Among them were adequate amplifiers, loud speakers and microphones. Progress in the perfection of these appliances was achieved rapidly, after the public acceptance of the sound picture in 1926, through the efforts of many independent workers in the field. When the need arose for a mechanism suitable to move film records with such speed-constancy as to reproduce the sound successfully, it was forthcoming. Only the skill of the art was required to adapt the flywheel device to familiar types of mechanism to secure the desired result.

CLAIMS 9 AND 13

The court below made no reference to the contention of petitioner, urged here and below, that the patent was rendered invalid by the disclaimer filed shortly before the trial of the present suit. The patent as issued contained the following claims:

9. The method of translating sound or similar vibrations to or from a film record by the use of light varied in accordance with the sound, which comprises flexing the film arcuately longitudinally at the point of translation and rapidly and uniformly moving the film in a circumferential direction past said point.

13. An apparatus for reproducing speech, music, or the like sounds from vibrations recorded on a film, by the use of a line of light varied in accordance with the sound, comprising a photoelectric cell, means for imparting to the film a rapid and uniform motion longitudinally of the film past said cell, a source of light projection for providing said light, and an objective lens in the path of said light and spaced from the film for directing said light as a converging narrow line impinging on the film at a point in the region of the focal point of said lens, said light passing through the film and on to said cell, the space between said lens and the film being free of obstructions to said light.

In 1933 respondents, by appropriate procedure, disclaimed:

(b) The method as set forth in Claim 9, except wherein the uniformity of movement of the film past the translation point is effected by subjecting the portion of the film passing said point to the control of the inertia of a rotating weighty mass.

(c) The combination as set forth in Claim 13, except wherein a flywheel is operatively connected with the film through means which imparts uniformity of motion of the flywheel to the film.

While the effect of the disclaimer, if valid, was in one sense to narrow the claims, so as to cover the combinations originally appearing in Claims 9 and 13 only when used in conjunction with a flywheel, it also operated to add the flywheel as a new element to each of the combinations described in the claims. The disclaimer is authorized by R. S. § 4917, which provides that when "through inadvertence, accident, or mistake . . . a patentee has claimed more than that of which he was the . . . inventor . . . his patent shall be valid for all that part which is truly and justly his own," provided that he or his assigns "make disclaimer of such parts of the thing patented as he shall not choose to claim . . . stating therein the extent of his interest in such patent." While this statute affords a wide scope for relinquishment by the patentee of part of the patent mistakenly claimed, where the effect is to restrict or curtail the monopoly of the patent,[3] it does not permit the addition of a new element to the combination previously claimed, whereby the patent originally for one combination is transferred into a new and different one for the new combination.

If a change such as the present could validly be made, it could only be under the provisions of the re-issue statute, R. S. § 4916, which authorizes the alteration of the original invention in a re-issued patent, upon surrender of the old patent, for its unexpired term. Upon the re-issue "the specifications and claim in every such case shall be subject to revision and restriction in the same manner as original applications are." A patent amended by disclaimer thus speaks from the date of the original patent, while the re-issued patent, with respect to the amended claim, speaks from the date of re-issue. If respondent could thus, by disclaimer, add the flywheel to the arcuate flexing claim and to the optical claim, he would in effect secure a new patent operating retroactively in a manner not permitted by the re-issue statute and without subjecting the new claims to revision or restriction by the customary patent office procedure required in the case of an original or re-issued patent. Such transformation of a patent is plainly not within the scope of the disclaimer statute, and the attempted disclaimer as applied to Claims 9 and 13 is void. *Hailes v. Albany Stove Co.*, 123 U. S. 582, 587;[4] see *Union Metallic Cartridge Co. v. United States Cartridge Co.*, 112 U. S. 624, 642; *Collins Co. v. Coes*, 130 U. S. 56, 68; compare *Grant v. Walter*, 148 U. S. 547, 553. It is unnecessary to consider whether the flywheel claim, if added to the original Claims 9 and 13, is such a part of the patentee's original conception as to entitle it to the benefit of the re-issue statute. See *Miller v. Brass Co.*, 104 U. S. 350, 355; *Hoffheins v. Russell*, 107 U. S. 132, 141; *Gage v. Herring*, 107 U. S. 640, 645; *Ives v. Sargent*, 119 U. S. 652, 663; *Corbin Cabinet Lock Co. v. Eagle Lock Co.*, 150 U. S. 38, 41–43.

With the invalid disclaimer must fall the original claims as they stood before the disclaimer. The disclaimer is a representation, as open as the patent itself, on which the public is entitled to rely, that the original claim is one which the patentee does not, in the language of the statute, "choose to claim or hold by virtue of the patent." Upon the filing of the disclaimers, the original claims were withdrawn from the protection of the patent laws, and the public was entitled to manufacture and use the device originally claimed as freely as though it had been abandoned. To permit the abandoned claim to be revived, with the presumption of validity, because the patentee had made an improper use of the disclaimer, would be an inadmissible abuse of the patent law to the detriment of the public.

While the precise effect of an invalid disclaimer upon the original claim seems not to have been judicially determined, analogous principles of the patent law are so well recognized as to leave no doubt what our decision should be. It has long been settled that a claim abandoned or rejected in the patent office with the acquiescence of the applicant can not be revived in a re-issued patent. *Yale Lock Co. v. Berkshire Bank*, 135 U. S. 342, 379; *Dobson v. Lees*, 137 U. S. 258, 263–265. Nor can an interpretation be given the allowed claims which would revive the claims which were abandoned in order to obtain the patent. *Shepard v. Carrigan*, 116 U. S. 593, 597; *Roemer v. Peddie*, 132 U. S. 313, 317; *Royer v. Coupe*, 146 U. S. 524, 532; *Corbin Cabinet Lock Co. v. Eagle Lock Co.*, 150 U. S. 38, 40; *Morgan Envelope Co. v. Albany Paper Co.*, 152 U. S. 425, 429; *I. T. S. Co. v. Essex Co.*, 272 U. S. 429, 443; *Smith v. Magic City Club*, 282 U. S. 784, 789, 790; *Smith v. Snow, supra.* Similarly, where, in order to secure a re-issued patent, a disclaimer is made of a part of the original claims, the part so disclaimed can not be revived by a second re-issued patent, *Leggett v. Avery*, 101 U. S. 256, nor where the disclaimer is for the purpose of securing an extension of the original patent, *Union Metallic Cartridge Co. v. U. S. Cartridge Co., supra*, 644. See *Collins v. Coes, supra*, 68; compare *Gage v. Herring, supra*, 646. The settled rule that unreasonable delay in making a disclaimer invalidates the whole patent, *Ensten v. Simon Ascher & Co.*, 282 U. S. 445, 452–458; compare *O'Reilly v. Morse*, 15 How. 62, 121; *Seymour v. McCormick*, 19 How. 96, 106; *Silsby v. Foote*, 20 How. 378, 387; *Gage v. Herring, supra*, 646; *Yale Lock Mfg. Co. v. Sargent*, 117 U. S. 536, 554; *Minerals Separation, Ltd., v. Butte & Superior Mining Co.*, 250 U. S. 336, 354, rests upon the similar principle that misuse of the patent, or a part of it, by the patentee in such a manner as to mislead the public or operate to its detriment, deprives the claim of the benefit of the patent laws. The part of the patent disclaimed can stand in no better position because the disclaimer was an unsuccessful misuse of the disclaimer statute.

As Claims 9 and 13 must be held invalid because of the improper disclaimers, and as the remaining claims in issue, the flywheel claims, are held invalid for want of invention, it is unnecessary to determine whether the improper disclaimers as to some of the claims render the entire patent void, as petitioners contend, and as has been intimated but not decided. See *Hailes v. Albany Stove Co., supra*, 589; *Marconi Wireless Telegraph Co. v. DeForest Radio Tel. & Tel. Co.*, 243 Fed. 560, 565 (C. C. A. 2d); *Seiberling v. Thropp's Sons Co.*, 284 Fed. 746, 756, 759 (C. C. A. 3rd).

Reversed.

Mr. Justice BRANDEIS took no part in the consideration or decision of this case.

REFERENCES

[1] Wilson's Cyclopaedic Photography, published by Edward L. Wilson, New York, 1894; Encyclopaedic Dictionary of Photography, by Woodbury, published by Scovill & Adams Co., New York, 1896; Konig, published by Dawbarn & Ward, Ltd., London, 1906; Cassell's Cyclopaedia of Photography, by Jones, published by Cassell & Company, Ltd., 1912. (The references, with quoted portions of the texts, were made a part of the record by stipulation.) The publication last mentioned states that "combination printing had its origin in 1855, when Berwick and Annan, of Glasgow, exhibited a picture printed from two different negatives—a figure and a landscape"; numerous later examples of the practice are given.

[2] The addition of the flywheel to the steam engine, in 1758, was said to be "a very important addition to the engine and, though sufficiently obvious, it is ingenious and requires considerable skill and address to make it effective." Robison, Mechanical Philosophy, Vol. 2, p. 105, 1822.

[3] The disclaimer and re-issue statutes were adopted to avoid the rule that if one claim is invalid the whole patent is void. Moody *v.* Fiske, 2 Mason 112, 118; see Ensten *v.* Simon, Ascher & Co., 282 U. S. 445, 452; Hailes *v.* Albany Stove Co., 123 U. S. 582, 589. The use of the disclaimer has been upheld where the elimination from the patent of the matter not relied upon did not operate to enlarge the monopoly of the patent, but narrowed it, as by eliminating in their entirety some of the claims of the patent, Sessions *v.* Romadka, 145 U. S. 29, 40; see Union Metallic Cartridge Co. *v.* United States Cartridge Co., 112 U. S. 624, 642, or by striking out an alternative method or device, Dunbar *v.* Myers, 94 U. S. 187, 192, 194; Hurlburt *v.* Schillinger, 130 U. S. 456; Carson *v.* American Smelting & Refining Co., 4 F. (2d) 463, 469, 470 (C. C. A. 9th), or by limitation of a claim or specification by deletion of unnecessary parts, Carnegie Steel Co. *v.* Cambria Iron Co., 185 U. S. 403, 435, 436; Marconi Wireless Telegraph Co. *v.* DeForest Radio Telephone & Telegraph Co., 243 Fed. 560, 565 (C. C. A. 2nd), or by limiting the claim to a specific type of the general class to which it was applied,

Minerals Separation, Ltd., *v.* Butte & Superior Mining Co., 250 U. S. 336, 354; United Chromium, Inc., *v.* International Silver Co., 60 F. (2d) 913, 914 (C. C. A. 2nd); Seiberling *v.* Thropp's Sons Co., 284 Fed. 746, 756, 757 (C. C. A. 3rd).

[4] Albany Steam Trap Co. *v.* Worthington, 79 Fed. 966, 969 (C. C. A. 2d); Strause Gas Iron Co. *v.* Wm. H. Crane Co., 235 Fed. 126, 129, 130 (C. C. A. 2d); Graselli Chemical Co. *v.* National Aniline & Chemical Co., 26 F. (2d) 305, 310 (C. C. A. 2d); Hudson Motor Car Co. *v.* American Plug Co., 41 F. (2d) 672, 673 (C. C. A. 6th); Corn Products Refining Co. *v.* Pennick & Ford, Ltd., 63 F. (2d) 26, 30, 31 (C. C. A. 7th); General Motors Corp. *v.* Rubsam Corp., 65 F. (2d) 217, 222 (C. C. A. 6th); Consumers Tobacco Co. *v.* American Tobacco Co., 66 F. (2d) 926, 927 (C. C. A. 3rd); Fruehauf Trailer Co. *v.* Highway Trailer Co., 67 F. (2d) 558, 559, 560 (C. C. A. 6th); White *v.* Gleason Mfg. Co., 17 Fed. 159, 160 (C. C.); Cerealine Mfg. Co. *v.* Bates, 77 Fed. 883, 884 (C. C.); Westinghouse Air Brake Co. *v.* New York Air Brake Co., 139 Fed. 265, 267–270 (C. C.).

BOOK REVIEWS

Applied Acoustics. HARRY F. OLSON and FRANK MASSA. *P. Blakiston's Son & Co.*, Philadelphia, Pa., 1934; 228 pp., $4.50. A well balanced combination of theory and practice of acoustics, covering very completely the many devices, instruments, and methods of the modern science. Two chapters are devoted to the fundamental equations and the theory of dynamical systems. The remainder of the book is devoted to the more practical subjects such as the design of equipment and the methods of measuring various acoustical phenomena.

It is surprising that no mention is made of the mechanical phonograph which, although it may be considered a thing of the past in the minds of the authors, was the forerunner of modern loud speakers. Many important contributions to the science of acoustics came *via* the phonograph, and references to these works are missing because of the omission of this subject.

On the whole, the treatment of the subject is excellent. The book is well written and contains such a wealth of material as to be a valuable and useful scource of reference to any worker in the field of acoustics. C. R. HANNA

The Projectionist's Handbook. R. PITCHFORD and F. COOMBS. *The Watkins-Pitchford Technical Publications*, London, 1934; 351 pp., 18s. 6d. The preface states, "This work, primarily intended for projectionists in all parts of the world, will also be of interest to their seniors in the industry and to those of the general public who like a peep behind the scenes." The opening chapters of the book are concerned with elementary and applied electricity and magnetism. Following are chapters devoted to the various phases of the projectionist's work and duties: the care and handling of film; the care and operation of projectors; and the numerous other responsibilities of the projectionist as regards continuity, showmanship, theater and stage lighting, *etc.*, as well as the care of any other equipment such as fans, organs, and the like.

Three chapters give detailed descriptions of the construction, operation, and care of typical picture projectors, particularly the Ross (British) and the Simplex. Likewise, five chapters are devoted to the more popular type of sound reproducing equipment.

Perhaps the most original part of the book is the chapter entitled "The Arc," which is very enlightening on the subject of proper screen illumination. As a "handbook" in its stricter sense, the book may be criticized from the standpoint of the rather illogical sequence and organization of material in some parts and seemingly unnecessary repetition in others. Moreover, the absence of real technical data, tables, or formulas reduces its value to the seasoned operator. However, the layman, the novice, and particularly the apprentice projectionist should find the book unusually valuable as a text and reference work. J. STREIFFERT

Motion Pictures in Education in the United States. C. M. KOON. *The University of Chicago Press*, Chicago, Ill., 1934; 106 pp. This handbook represents a report compiled for the International Congress of Educational and Instructional Cinematography, held at Rome, April, 1934. The data were collected from representatives of 65 agencies at the request of Mr. George F. Zook, United States Commissioner of Education. The main body of the report is divided into the following subjects:

(*1*) The educational influence of motion pictures.
(*2*) The motion picture in the service of health and social hygiene.
(*3*) The motion picture in governmental service and patriotism.
(*4*) The use of motion pictures in vocational education.
(*5*) The motion picture in international understanding.
(*6*) Motion-picture legislation.
(*7*) The technic of making and displaying motion pictures.
(*8*) The systematic introduction of motion pictures in teaching.
(*9*) The educational problems of a general nature resulting from the introduction of motion pictures in teaching.

The general conclusions drawn are:

(*a*) The theatrical motion picture is becoming a powerful force in national life.
(*b*) Non-theatrical uses of motion pictures are varied.
(*c*) The instructional use of motion pictures is quite limited at the present time because less than 10 per cent of the public schools make systematic use of the motion picture.
(*d*) A strong national film institute is needed in the United States.

An extensive bibliography is included which reports the exhibits that were assembled for presentation of the report. G. E. MATTHEWS

La Technique Cinematographique (4th Ed.). M. LOBEL; revised and extended by M. DUBOIS. *Demod*, Paris, 96 frs. The volume deals very comprehensively with the making and projection of silent and sound films.

Part I is devoted exclusively to materials, apparatus, and equipment. Detailed and valuable information is given on the control and use of electricity, the mechanism of projection, the various types of lenses, *etc.*, the relation between the intensity of the light used and the distance between the screen and the projector and the aperture of the lens.

The thirteen chapters of Part II deal with the various factors involved in the making of a film. The arrangement and lighting of the studio, the use of artificial light as an assistance in outdoor work, and the choice of apparatus are considered in detail. The actual taking of the negatives is examined from the purely photographic point of view, their editing, and the production of the positive films, including methods of printing. Tinting of the film and toning, with practical formulas, conclude this section.

Part III deals with sound films, their production and methods of synchronizing sound and picture. The entire work is very fully illustrated with nearly 400 diagrams and half-tone reproductions, and a very complete table of contents facilitates easy reference.

SOCIETY ANNOUNCEMENTS

PACIFIC COAST SECTION

At the regular monthly meeting of the Section, held on April 18th at the Norman Bridge Laboratory of the California Institute of Technology, Dr. I. S. Bowen, of the Institute faculty, presented a demonstration lecture on the subject of spectroscopy.

Dealing with light and color, and particularly in view of the current interest in color photography, the meeting was very interesting and instructive, and was well attended.

MID-WEST SECTION

On May 2nd the regular monthly meeting of the Section was held at the Exchange of the Paramount Picture Distributing Corp. in Chicago. As this exchange is regarded as perhaps the finest of its kind, the members of the Section were provided an insight into the operation of a modern up-to-date exchange, under the guidance of Mr. H. Busch, followed by a showing of selected new films. Prior to the meeting an informal dinner was held in the Japanese Room of the Stevens Hotel.

NEW YORK SECTION

The New York Section held its regular meeting on April 17th in the review room of the Fox Film Corp. at New York. A paper entitled "Progress in the Development of Sound Recording and Reproducing Equipment" was presented by Mr. E. I. Sponable, chief engineer of Movietone News, describing and illustrating, step by step, the advances that have been made in recording and reproducing since the earliest times. Some of the work of the early pioneers was illustrated by means of lantern slides; some of the actual equipment of the Tri-Ergon group of investigators was available for inspection; various types of flashing lamps developed by Theodore Case were demonstrated; and samples of old and modern newsreel cameras and other equipment were displayed to the members.

Following the presentation, the Section was entertained by a preview of *Ten Dollar Raise*, courtesy of the Fox Film Corp.

PROJECTION PRACTICE COMMITTEE

Meetings of the Committee were held on April 18th and May 2nd, at the Paramount Building in New York. The report of the Committee to be presented at the Hollywood Convention, May 20th–24th, was drafted and approved. The projection room layouts have received the severe scrutiny of the Committee, and a number of changes and additions have been made to bring it thoroughly up to date and to make it quite complete in its specifications.

SOUND COMMITTEE

The question of producing a frequency standard for variable-width and variable-density film was discussed at the meeting of the Committee held at the General Office of the Society on April 12th. Prints of such standards are being made, which will be calibrated periodically against the master positive, and eventually reference standards of frequency will be available for checking and comparing recording and reproduction by various methods and types of equipment, and in various studios.

The question of where, in the complete scheme of transmission of sound from the microphone to the loud speaker, frequency characteristic compensation should be effected, received the serious consideration of the Committee and is to be investigated further at subsequent meetings. Other items of the agenda include: a definition of "volume range"; a proposal to mark the proper sound level upon release prints; possible standardization of processing, as to density measurements, *etc.;* and theater and review room characteristics.

PROGRESS MEDAL AWARD

The Progress Medal Award Committee will meet on June 27th, at which time any suggestions received from the membership of the Society or from any other interested persons will receive consideration. A description of the medal, with photographs, was published in the April, 1935, issue of the JOURNAL, p. 378. It is to be awarded "in recognition of any invention, research, or development which, in the opinion of the Progress Award Committee, shall have resulted in a significant advance in the development of motion picture technology." All proposals of recipients of the medal must reach the Chairman of the Committee not later than June 20th, and shall be addressed to the General Office of the Society.

The medal will be awarded at the Annual Fall Convention.

A. N. GOLDSMITH, *Chairman*
M. C. BATSEL C. DREHER
J. CRABTREE W. B. RAYTON

HOLLYWOOD CONVENTION

As this issue of the JOURNAL goes to press at the time of the Spring, 1935, Convention at Hollywood (May 20th–24th), details concerning the Convention will be published in the July issue. The tentative program and general plans of the Convention will be found in the May issue of the JOURNAL on p. 465.

The Society regrets to announce the death of one of its members:

MAX RUBEN

April 26, 1935

AUTHOR INDEX, VOLUME XXIV

JANUARY TO JUNE, 1935

CLASSIFIED INDEX, VOLUME XXIV

JANUARY TO JUNE, 1935

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