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SHED MONTHLY BY THE SOCIETY OF MOTION PICTURE ENGINEER

SPRING CONVENTION

Society of Motion Picture Engineers

Hotel Roosevelt

Hollywood, Calif.

May 24th to 27th, Inclusive

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In the *New Supper Room*, schedule to be announced later. Several sessions will be held in the evenings to permit those to attend who might otherwise be unable to do so. Symposiums, General Discussions, Lectures, Demonstrations, and Open Forums, dealing with all phases of motion picture technic.

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SOCIETY OF MOTION PICTURE ENGINEERS
HOTEL PENNSYLVANIA, NEW YORK, N. Y.

(*For further details see p. 117*)

Papers for the Spring Convention

Manuscripts of papers received before April 1st will be given immediate consideration by the Papers Committee and the Board of Editors. The best of these manuscripts will be selected and given preferred positions upon the program of the Convention, with ample time for presentation and discussion, or about thirty minutes to one hour. The remaining manuscripts will be considered for the program, but with limited time for presentation.

The remainder of the program will be filled as manuscripts are received, until May 1st, after which date no papers will be accepted unless the subject matter contained therein is particularly outstanding or timely. Titles and abstracts of all papers will be published in the May issue if received by April 15th.

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SYLVAN HARRIS, EDITOR

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See p. 112 for Technical Committees

THE DEVELOPMENT OF THE ART AND SCIENCE OF PHOTOGRAPHY IN THE TWENTIETH CENTURY*

C. E. K. MEES**

Summary.—*An account of the developments in practical photography during the last thirty-five years and of the progress that has been made in our knowledge of the scientific principles of photography.*

Written history has its origin in contemporary documents, documents written by those who have taken part in the events described. Later, these documents are compared critically by writers who have no first-hand knowledge of the events but who summarize the earlier writings and prepare descriptions of the events as they appear to them at the later date, and the verdict of history is the verdict of these writers. It is too early to render a verdict on the progress of photography in the first third of the Twentieth Century, but it is not too early for one who took part in many of them to describe the events.

An account of this kind is likely to be one-sided. The events described in detail are not necessarily those of greatest importance. Equally important and interesting events may be ignored or dismissed with a brief reference because in them the writer played little or no part. However, it is in the hope that this paper may form a contribution to the history of photography that it has been written.

The turn of the century marked a distinct turning point in both the science and the art of photography. The earlier scientific workers —Abney and Hurter and Driffield, in England; Eder and Valenta in Austria—were ceasing their work, and a new group of students, armed with the methods of modern physical chemistry, were just beginning to direct their attention to the problems of photographic science. In the practice of the art, the field camera with plate equipment and the print-out processes were being displaced by hand

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

cameras using films, from which prints were made on developing-out paper by the methods that have persisted ever since.

The year 1901, therefore, is a suitable date for the beginning of a history of the modern era in photography, and it was in that year that Dr. S. E. Sheppard and the author started the study of photographic science at University College, London. The technical methods of photography used at that time depended upon the use of gelatin dry plates, mostly of the blue-sensitive type, without any dye sensitizing, although a certain proportion of so-called "orthochromatic" plates sensitized with erythrosine were in general use.

Most photographers having any pretention to skill and interest in their work developed their own plates, although the time when a photographer would attempt to make his own plates was already long past. Prints were usually made by the printing-out processes, which required long exposure to daylight; bromide paper was widely used for enlargements. Skilled and enthusiastic photographers made many of their prints on platinum paper and on carbon tissue, which gave very beautiful prints of great permanence. The carbon process and the analogous gum bichromate process enabled a good deal of hand control to be introduced into the development of prints and were therefore favored by the pictorialists. In the United States and Germany, the reigning printing process was the collodio-silver chloride paper printed out by daylight and toned with gold, which was known in this country as Aristotype. In England the gelatin paper was preferred, and trade brands, such as P.O.P. and Solio, were used generally. Velox was just coming into use as the first of the gaslight papers. It had the advantage that it could be operated without special precautions in the dimly lighted living rooms of that era.

The cameras generally used were field cameras on tripods, and were fitted with rectilinear or convertible anastigmat lenses and with mechanical shutters. Almost all the new types of hand cameras that were being introduced at the beginning of the century used plates. The most elaborate and expensive were the twin-lens cameras and the reflexes, of which a great variety were made, especially after the higher aperture anastigmats became available soon after 1900.

There were some very interesting local developments. In France, for instance, there was a great vogue for small stereoscopic cameras, of very good workmanship, taking plates 45 × 107 mm. in size. The best known of these was the Verascope made by Richard, and almost all French amateurs at that time were devotees of stereoscopic photography. It is curious that this type of camera did not succeed to any great extent in any other country. The reflex camera reigned in England, while in Germany portable cameras with focal plane shutters, used at eye level, were popular.

In the first years of the Twentieth Century, Kodaks employing film had a wide sale but were regarded by most serious photographers as being rather in the toy class. After 1910, however, the modern roll-film camera developed rapidly. The second decade, filled as it was with the years of war, was characterized by a rapid growth of the use of roll films in small and portable cameras, and of professional photo-finishing. After 1910, the apparatus and material had been largely standardized, as had the finishing procedure, the films being developed in deep tanks and printed upon developing-out chloride papers, of which Velox was the prototype. The field camera on a tripod ceased to be used generally except by the commercial and professional photographers. This trend continued to grow until the latter half of the third decade, when a new element was introduced by the appearance of large numbers of very small, "miniature," cameras using film of motion picture width. This revived interest in the practice of the photographic processes by the photographer himself.

The shift in general photography through this period, therefore, may be summarized as being from the large-size plate camera to the portable film camera, with commercialized and mechanized finishing methods, and then, to some extent, to the use of miniature cameras, with a concomitant emphasis on developing processes and methods of enlarging the pictures so as to obtain the best possible definition.

In this development, an important part was played by improvements in the methods of sensitizing emulsions to the longer wavelengths of light. Apart from the use of erythrosine for orthochromatic plates, practically no color-sensitive materials were manufactured before 1900, and, although in 1902 the isocyanine dyes were found to be sensitizers, and pinacyanol was made in 1904, the first commercial plates employing these new dyes were not produced until 1906.

The history of the introduction of panchromatic plates may be of interest. About 1905, the Neue Photographische Gesellschaft was using a process of portrait photography in colors. This involved the taking of three separation negatives by means of a mechanically operated repeating back, the prints being made upon celluloid films coated with dyed gelatin, which was sensitized with bichromate. After printing and development by washing out, the three images were transferred in register to one support, as in the carbon process. This process had been worked out in collaboration with Meister, Lucius, and Bruning, later known as the Hoechst Dye Works and now a part of the I. G. Farben-Industrie. It was at Hoechst that Dr. E. König made a number of the isocyanine dyes and that Homolka, his colleague, discovered pinacyanol. König made the plates for the N. P. G. by bathing commercial plates in solutions of pinachrome and pinacyanol. The bathed plates did not keep very well, gave a good deal of trouble with fog, and were very expensive, but they were far more sensitive than any plates that had been made previously.

In 1906, having taken my examination for the final degree at London, I joined the little firm of Wratten & Wainwright in Croydon, and the first problem that was referred to me was the preparation of plates similar to those that were being made in Germany by Meister, Lucius, and Bruning. The English affiliates of the N. P. G., the Rotary Photographic Company, like the N. P. G., specialized in the manufacture and mechanical printing of bromide paper for the preparation of commercial prints and picture postcards. They had fitted out a studio in Dover Street, London, for the practice of commercial color portraiture. For this work, they needed plates; and as the German plates gave some trouble and were very expensive, they desired to obtain plates made in England, and the English agent of Meister, Lucius, and Bruning approached Wratten & Wainwright. The idea was that the plates should be made by bathing, following the methods worked out by König. I had had a good deal of experience with the difficulties attending the preparation of bathed plates, so that it seemed to me that it would be better to attempt to coat a sensitized emulsion.

It is now rather hard to realize how difficult it was to start the coating of panchromatic plates without any experience in such a thing. We had no safelights, of course, and we had to get the coating machine running by red light, so that the emulsion covered the plates properly. Then we turned out the light as the plates were running through, and pushed over to the side of the machine the plates coated in red light, so that the girl at the other end of the coating machine would know that they had been fogged and would put them on a separate rack. When the first plates coated in total darkness came to her, she started to pick them off the machine and put them into racks to dry. All went well for a few minutes. Then *crash* went a plate on the floor, and the girl gave a squeal. Then *crash* went another, and she gave another squeal; and when a third plate did the same, her nerves gave way, and she curled up on the floor in hysterics while the machine showered her with sticky plates. Wratten* shot through the pitch darkness straight toward those hysterical squeals, shoved their producer ruthlessly aside, and collected the precious plates. The next morning the plates were dry. My laboratory was at home, seven miles off, so I came down on my motorbike, picked up a few plates, took them back and tested them. They were fine, so I shot back to tell Wratten the good news, and the next day took the plates up to London and sold them.

One of the troubles was inspecting the plates. We had to make sure that they were covered with emulsion, so we put a candle at the end of a long passage and found out by trial that when our eyes were rested we could see the plates by the candle light and that it took five or six seconds to produce a visible fog on them. We inspected the plates by picking up one from a pile in darkness on one side of the passage and transferring it rapidly to darkness on the other side, looking at it in transit. That insured that the plates would not be left in the light. Within a few weeks, of course, we had designed green safelights and proper coating and inspection methods, and the technic of panchromatic material making was well on its way.

I am afraid that the first plates supplied to the Rotary Photographic Company were labelled *bathed* plates. Photographers were very conservative then, as now, and although the emulsion sensitized plates were better than the German plates, the users would not have touched them if they had known how they were made. Within three months, however, we found methods for combining the pinachrome and pinacyanol in one emulsion, and made the Wratten panchromatic plate which has been on the market ever since.

Soon after we made the panchromatic plates, the question of light filters came up. Not many commercial light filters were made at that time. A few were made commercially in England and Germany, and enthusiasts prepared filters for themselves. Freiherr von Hübl, Dr. König, and Professor Miethe had published formulas for preparing them. Most of the yellow filters used were made of brownish yellow glass having very poor correcting power, and when I got to Wratten & Wainwright I found that we were selling filters of that

* S. H. Wratten, son of the founder of the firm, F. C. L. Wratten.

type. Mr. Wratten, however, was experimenting with filters made of gelatin by coating upon a polished glass plate a thick solution of gelatin dyed with tartrazine and then, after drying the plate, stripping off the gelatin. This was an excellent scheme for supplying cheap filters, and, in a short time, we were marketing both the gelatin filters and the same filters cemented between glass plates.

Early in 1907, Novak published an account in *Photographische Korrespondenz* of a new dye, filter yellow *K*, developed at the Hoechst Dye Works, which was greatly superior to tartrazine for use in filters. I read the article when it appeared and cabled to Dr. König for a sample of the dye, which arrived on a Friday evening. A few tests showed that it was all that Novak had claimed for it, and Wratten and I worked through the week-end, first testing the dye and measuring its properties, and then preparing coatings of gelatin filters and examining them. When the *British Journal of Photography* appeared on Thursday that week, with an article on the new dye, it also carried the Wratten advertisement of a series of Wratten *K* filters—*K-1*, *K-2*, and *K-3*—which have since been famous in photographic circles. A set of gelatin tricolor filters had been made in 1906, and after the *K* filters were made, a very considerable proportion of the present Wratten filters was worked out and placed upon the market, including filters for all sorts of scientific work, such as photomicrography and spectroscopy.

At that time darkrooms were generally lighted by simple oil lamps fitted with red or yellow glass of very doubtful safety and efficiency. As a result of a study of the properties of darkroom safelight filters in relation both to vision and to the effect produced upon materials exposed to them, a series of darkroom lamps and of safelight filters were introduced that proved entirely satisfactory and are now universally adopted.

In 1908, the first process panchromatic plates were made, and the English photoëngravers adopted these for making three-color halftone separations by the direct process instead of using collodion emulsion. It is curious that collodion emulsion maintained its position against the panchromatic dry plates for a much longer period in the United States than it did in England.

Panchromatic plates were used first by the commercial photographers for the photography of colored objects—paintings, furniture, and so forth—and also by enthusiastic amateurs who liked to get correct color rendering in their pictures. During the War, panchromatic plates were used with color filters for photography from the air, because through haze they gave very much better pictures than those taken on the non-color-sensitive materials. After the War panchromatic plates were firmly established, and they began to find wider use by both amateur and professional photographers.

The first commercial panchromatic film was made as early as 1914 for use in color motion picture processes, but was not used generally for motion picture work until 1925. Panchromatic motion picture negative film was then introduced generally throughout the trade and displaced the older orthochromatic film very rapidly, the change being accelerated in 1928 by the adoption of sound recording and of tungsten lamps in the place of arc lamps in the studios. This film, however, like all those before it, was still sensitized with the pinacyanol dye introduced as long ago as 1904. Although a certain amount of research on sensitizing dyes had been carried on in the manufacturers' laboratories, nothing really new had been produced until in 1928 it was realized that the thiocarbocyanines that had been studied by W. H. Mills and F. M. Hamer represented a type of dye having great advantages over those previously known. L. G. S. Brooker was successful in making carbocyanines from naphthathiazole instead of from benzothiazole, which had been used by Mills and Hamer, and these dyes sensitized very strongly for the red, so that for the first time sensitizers for the red had been produced that were superior to pinacyanol.

Whereas the earlier dyes tended to decrease the general speed of the emulsion and to give a certain amount of fog, the new dyes increased the total speed and at the same time made the emulsion resistant to fog. It was possible, therefore, to prepare a new type of panchromatic film, which became known as "supersensitive" film. This at once affected the methods used for the production of motion pictures in the studio: it gave the photographer a much simpler control of his lighting and made possible the development of studio photography to a previously unheard of degree.

The same type of emulsion is used for making films for portraiture, and films and plates for commercial photography and three-color work, so that with the very general use of panchromatic materials in the last few years, the art of photography has entered a new phase.

The introduction of the new dyes produced a change in photographic practice in another direction: they increase the general sensitivity of slow, fine-grain emulsions to a much greater extent than they do that of high-speed emulsions, so that while a fine-grain emulsion, even after sensitizing, is slower than a sensitized emulsion having grain of average size, the two are much more nearly alike in speed than before sensitizing. This made it possible to prepare films of satisfactory effective speed of which the image structure allows a considerable degree of enlargement, and this, in turn, produced satisfactory results from miniature cameras taking very small pictures. As a result, there has been a great rise in the popularity of cameras taking pictures about an inch by an inch and a half in size. The portability and mechanical excellence of these cameras make them attractive, while the fine-grain films available for their use give results comparable with those attainable with the larger instruments.

The rise of amateur cinematography dates from 1920, at which time a number of experimenters were making small cameras, generally using 35-mm. film slit down the center, which gave pictures a quarter of the standard size. No general use was possible, however, unless facilities were available for having the film processed speedily and effectively. The motion picture laboratories could not be expected to devote to the short lengths of amateur film the attention bestowed upon the commercial film, of which millions of feet are processed every week; and the general public did not know where to send the film. The use of motion pictures by amateurs, therefore, was at first confined to a few enthusiasts.

One of the difficulties with the ordinary negative and positive process is that making a single print of high quality is quite difficult. In professional work, the rush prints often require reprinting, and it is only after a negative has been assembled and tested carefully throughout that prints of high quality can be made at a low cost. Moreover, the use of smaller pictures on standard film involved more evident graininess than that shown by the standard pictures.

All these problems were solved by the introduction of the reversal process. The reversal of a photographic image by the use of potassium permanganate as a solvent for the developed silver, and the redevelopment of the positive, was introduced by Namias. The process was greatly improved by the suggestion of Capstaff that the re-exposure after bleaching should be controlled in amount, which made it possible to use thickly coated material and, at the same time, to correct for differences in the initial exposure in the way that such differences are compensated for in ordinary printing from the negative.

The reversal process with controlled second exposure was an instant success and, as a result, processing stations in which the amateur could have his film processed were installed all over the world. There is little doubt that it was this development that determined the success of the 16-mm. program of amateur cinematography.

A later improvement was the use of automatic compensation in the second exposure by the use of photocells, which operate so quickly that change occurs within a few frames on 16-mm. film. The development of portable, spring-driven cameras and of extremely convenient and reliable projectors has been very remarkable, and amateur cinematography is now an important division of the photographic industry.

This brief account of the development of general photography during the first third of the Twentieth Century is, of course, very incomplete. Nothing has been said of the advances made in photographic optics, in which progress has been continuous, and only a passing mention has been made of the introduction of sound recording, which has revolutionized the production of motion pictures.

Many of the great applications of photography have, perforce, been ignored. Radiology, aerial photography, documentary photography, and the whole field of the graphic arts would each require a separate article to do justice to them. But one division of the photographic art is of so distinct a nature, and holds so much promise for the future, that a section of this paper must be devoted to it. This is the field of photography in color.

While rapid and continuous advance has characterized the art of photography during the first third of the Twentieth Century, this can not be said of color photography, although at the present time there is great activity in that field. The many processes of color photography that have hitherto been introduced, both experimentally and commercially, must be regarded as the early and, on the whole, unsuccessful forerunners of the processes that will eventually succeed. The nature of the really practical processes of color photography are probably only just beginning to be understood.

Before 1900, indeed long before, the various additive and subtractive processes of color photography had been outlined clearly, and attempt after attempt was made to realize them in practice. In the first years of the Twentieth Century, there was much activity in the design of one-exposure, three-color cameras intended for portraiture and commercial work. The negatives were made in special cameras or in ordinary cameras fitted with repeating backs. The prints were usually made by some modification of the carbon process, depending upon the sensitizing of gelatin with bichromate and the superposition of the three dye layers so obtained. The process used by the Neue Photographische Gesellschaft in 1905 has already been mentioned. At about the same time, the Hoechst Dye Works worked out the pinatype process and another process, using the leuco bases of dyes, which was termed "pinachromy." More recently, similar processes have been placed upon the market as "Carbro" and "Wash-off Relief" processes, all of them depending upon the printing of the three images in dyes and the superposition of the dyes in one image.

The screen-plate processes, which had been attempted commercially by Joly and McDonough, reached the apex of success in the Lumière Autochrome process, in which the filter units were composed of dyed grains of rice starch, and with which beautiful color transparencies can still be obtained. Other screen-plate processes depended upon the use of dyed particles of resin or of regular screens made by printing bichromated fish glue or albumen. An application of the screen-unit process to film is provided by the Dufaycolor process, in which resist lines are printed mechanically upon a dyed cellulose base, so that the units can be bleached and dyed in different colors.

In the field of color cinematography, the first practical process was Kinemacolor, a two-color additive process, in which the unit pictures were taken successively through red and green filters and projected in the same manner. Numberless minor variants on this theme have been protected by patents and exploited on an experimental commercial basis. An attempt at a complete three-color additive process was launched by Gaumont as early as 1914, but the difficulties in projection proved fatal. In all processes that require a special projector, it has been a formidable difficulty that it is hard to persuade exhibitors to provide the projection equipment until they are assured of a continuous supply of films, and that it is impossible for producers to provide films until a sufficient number of theaters are equipped to project them.

About 1915, there was much activity in the field of subtractive two-color motion picture processes. Two negatives are taken either through two lenses by means of a beam-splitter or a bipack system, and these are printed upon opposite sides of double-coated film, one side being transformed by chemical treatment into a green image and the other into a red image. So active were the patentees in this field that two patents covering films of this type issued independently from the United States office within a few weeks of each other, but satisfactory arrangements having been made with the patentees, the development of this work went forward on a small-scale, commercial basis.

The ingenuity shown in overcoming the practical difficulties of making color pictures has been quite remarkable. The Lumière Autochrome process was a triumph of technology. It seems quite impossible that dyed starch grains of so small a size could be made into a layer of colored filters with the precision shown in the Lumière plates. The earliest Technicolor process, again, in which thin films carrying wash-off relief images were cemented in register back to back was a triumph of technical skill; while the imbibition process of the Technicolor Company represented the first really practicable process for the production of motion pictures in large quantities at a cost at which they could be sold. In this process, the wash-off reliefs or matrices are used to form dye images, which are transferred by imbibition to a gelatin layer, and after this operation was carried out successfully with two colors, the Technicolor Company was able to produce three-color images, which today represent the furthest commercial development in the production of color motion pictures.

One other process, which is distinguished both by the simplicity of its operation and the beauty of its results, is that invented by Berthon in 1908, in which microscopic embossed lenses are used to form the optical equivalent of screen units both in taking and in projection, so that a color picture is produced by the simple use of a triple filter on the lens and the special lenticularly embossed film. This process is particularly convenient for amateur cinematography since it is extremely suitable for use with the reversal process. Its development in the professional field is quite feasible, but still presents the difficulty that some modification is required in the projection machines and that special precautions must be taken in view of the loss of light occasioned by the filters.

Throughout this development of color photography, a silent but very important role has been played by the emulsion maker, who has provided the special sensitizing required for all the color processes in turn. The new prospects that are opening up to us in the field of color photography are rendered possible to a very great extent by the discovery of the new sensitizers referred to previously.

From time to time, it has been suggested that instead of using three separate negatives and then superimposing the prints, color photographs might be taken on specially prepared multiple layers of emulsion—each one sensitive to one of the primary colors. The colors are separated in the depth of the film. After exposure, each layer produces a colored image, so that a subtractive picture is obtained directly.

An even more attractive suggestion is the mixed-grain process, in which it is suggested that the silver bromide grains themselves be differentiated in sensitivity and in their capacity for forming a final colored image upon being developed, so that grains that were sensitive to red would become blue, and grains in the same layer sensitive to green or blue would become respectively magenta and yellow. Up to the present, no one has been able to realize this last suggestion, but workers in several directions have been able to realize the multipack processes of color photography.

In the early part of 1935, a multicoated film was placed upon the market under the name of "Kodachrome" and has been successful for amateur cinematography. It is possible to take 16-mm. or 8-mm. pictures in color with no more complication or difficulty than if they were taken in black and white. Bela Gaspar has succeeded in realizing another multilayer process, in which the light-sensitive layers of emulsion contain the dyes that form the final images, and the dye is destroyed by chemical treatment in proportion to the silver image produced in development as a result of exposure.

The multilayer processes are developing very rapidly, and it would appear that we are on the verge of an era of great activity in color photography.

When we turn from the art of photography to its science, the progress made in the Twentieth Century as compared with what had gone before is very significant.

The chief phenomena of photography were discovered in the Nineteenth Century. Abney had observed the failure of the reciprocity law, and the intermittency effect; he had also studied the color-sensitivity of the silver salts; Vogel discovered the phenomenon of optical sensitizing; and Eder had investigated the sensitizing power of a very large number of dyes. The earliest work on sensitometry was due to Abney, who studied the relation between the transparency of a photographic image and the exposure; and a great deal of work had been done on the reactions of the latent image, so that the literature contains much discussion of the structure of the latent image and of its chemical reactions. The simple chemistry of development had been studied, and the types of organic developing agents defined, but very little was known of the chemistry of the development process, a matter that is still to some extent obscure.

By far the most important work on the theory of photography was that due to Ferdinand Hurter and V. C. Driffield, who in 1890 published their "Photo-chemical Investigations," in which they laid the foundations of sensitometry and, at the same time, outlined the general theory of the photographic process. This was followed in 1898 by a second paper, dealing largely with the chemistry of development, and by a series of shorter articles in which they discussed the general principles of tone reproduction.

Hurter and Driffield were amateur photographers who became interested in the application of scientific methods to practical photography. Hurter was a competent physical chemist engaged in the manufacture of alkali, and Driffield was an engineer in the same business and had a thorough grasp of mathematical methods. They desired to place the exposure of their pictures on a scientific basis, and to that end they designed a chemical photometer by means of which they could measure the variation of sunlight throughout the day and throughout the year. Having obtained this information, they constructed an exposure calculator, which they termed the "Actinograph," and at this point they found that they needed information with regard to the intrinsic sensitivity of the photographic plates that they were using. They then started their photochemical investigations. They exposed plates to known quantities of light, expressed in candle-meter-seconds, developed them under controlled conditions, and measured the opacity of the developed image on a photometer of their own devising. They showed that the logarithm of the opacity, which they termed the "density," is proportional to the mass of silver obtained. They then plotted the density obtained after development against the logarithm of the exposure given, getting a curve which they termed the "characteristic" curve of the material. They showed that as development is increased, the straight-line portion of the curve rotates about a point upon the exposure axis, which they termed the "inertia point." They used this inertia as a means for calculating the now well known "H&D sensitivity" of the materials, which they expressed as the value $34/i$ in order to get a convenient factor for use with their actinograph. They termed the slope of the characteristic curve γ, and showed that density increases during development as an exponential function of the time, finally reaching a limiting density.

When Dr. Sheppard and I took up this subject in 1901, advances could be made in two directions: better apparatus than that used by Hurter and Driffield could be designed, and the development of physical chemistry made it possible to study the statics and dynamics of the development much more thoroughly than had been possible for Hurter and Driffield. Hurter and Driffield's light-source was at first an actual spermaceti candle, and later a pentane standard lamp. This was replaced by acetylene burners in which a screened portion of the flame gives a convenient, uniform light-source, which is much more convenient. A thermostat was designed to control the temperature of development, so that a long series of experiments could be made without any danger of a variation in temperature. The primitive H&D sector-wheel was placed by a better made instrument in which the light-source was enclosed and the plates could be inserted in plate holders, while the whole instrument was used in an ordinary room. Various photometers were employed in place of the primitive instrument designed by Hurter and Driffield. The Hüfner spectrophotometer was adopted for a considerable time and gave satisfactory results although it was unnecessarily complicated and very expensive.

These improvements in apparatus were of considerable importance in the development of sensitometry. The instruments designed at that time are now obsolete, but at no period since has any change in the apparatus used in sensitometry been comparable in importance with that made at the beginning of the century. Our repetition of Hurter and Driffield's work on the relation between the density and the mass of silver, the shape of the characteristic curve, the effect of development upon density, *etc.*, merely extended and verified the conclusions to which the two pioneers had come in the course of their work. The increase in γ during development was correlated with Hurter and Driffield's work on density, and the importance of γ_∞ was established. Our first paper was published as early as 1903 and dealt with the development factor (γ).

This was followed by a series of publications dealing with the physical chemistry of development and with the microscopic structure of the image. The work on development was a fundamental study of the chemical statics and dynamics of the reactions both in the ferrous oxalate developer, which had been used by Hurter and Driffield, and in the alkaline developers, especially hydroquinone.

Another series of investigations established the nature of the inorganic desensitizers* and of the reactions that destroy the latent image, the whole of this work being collected and published in book form.

This first collaboration of Dr. Sheppard and myself ended in 1906, when I joined Wratten & Wainwright and started work on panchromatic plates and light filters. The introduction of panchromatic plates and the marketing in 1907 by the Lumière Company of the first direct color-plate, the Lumière Autochrome, directed general attention to the subject of color photography, and the chemistry of the photographic process was rather neglected for some years. There were, however, a number of contributions relating to the physics of photography. In 1909, I published the first paper on photographic resolving power, and this was followed by articles by several workers, notably by Dr. Scheffer. A. Callier made systematic measurements of the scattering power of photographic deposits and established the conditions that should be used for the measurement of photographic densities.

When the research laboratory of the Eastman Kodak Company was established in 1912, the immediate problems of photographic theory could be divided into four main sections:

The first was the theory of tone reproduction—the study of how closely a photographic reproduction resembles the original in the distribution of brightness, and the prediction from the sensitometric characteristics of photographic materials of their ability to reproduce tone values with more or less correctness. The first step required in this work was an investigation of the sensitometry of printing papers. The results were published in the form of a paper in 1914 and prepared the way for a general study of tone reproduction. This was undertaken at about the same time by workers in Germany, England, and the United States. Dr. Goldberg in Germany, F. F. Renwick in England, and L. A. Jones in the United States published a series of papers that completed the work that Hurter and Driffield had started in 1890—clearing up the nature of the photographic process from the standpoint of physical optics. It is now standard practice

* Desensitizers of another kind were discovered later by Luppo-Cramer, who found that dyes such as phenosafranine are powerful desensitizers and can be used for the treatment of an emulsion before development, so that more light is possible in the darkroom.

to compute the reproduction that will be obtained from any subject by using the characteristic curves of the materials. This solution of the problem of tone reproduction has been particularly valuable in connection with sound recording, and promises to be of even greater importance in connection with the problems of color photography.

Another group of photographic investigations is that which deals with the structure of the photographic image, involving the whole question of resolving power, the sharpness of images, and the distortion of the position and shape of small images. A considerable series of papers, largely from the Kodak research laboratories, seems to have placed these problems on a firm footing, so that the general physics of photography may be said to be well understood.

A part of the physics of photography that is of great importance in the applications of photography to scientific work, such as spectroscopy and astronomy, is the relation between the exposure produced and the intensity of the light. It was shown by Abney more than fifty years ago that the image produced is not independent of the intensity, and that if a photographic material is exposed to a weak source for a long time, the image produced is weaker for the same amount of energy than if the light were more intense and the exposure shorter. This has always been known as "the failure of the reciprocity law" since Bunsen and Roscoe stated that for photochemical reactions, time and intensity were interchangeable and that the same amount of energy produced the same result. The failure of the reciprocity law has been a favorite subject for photographic investigators since Abney's discovery. It was studied exhaustively by Englisch at the beginning of the Twentieth Century, but measurements of the necessary precision were first made in the Kodak laboratories soon after their establishment. Our knowledge of the subject has recently been improved very much by the work of J. H. Webb, who showed that Abney's intermittency effect can be explained in the terms of the reciprocity failure, and that the reciprocity failure depends upon the temperature at the time of exposure. The reverse action, which produces the failure, has apparently a high temperature coefficient and is therefore presumably of a chemical nature. It is probable that the full explanation of the reciprocity failure will come when we understand the nature of photographic exposure itself.

Far less progress has been made in dealing with the chemistry of photographic development. After the work by Sheppard, the chemical reactions in an alkaline developer were studied by a number of German workers, notably by Luther and his students. Frary and Nietz attempted to measure directly the reduction potential of developers, and this work was continued by Nietz in the Kodak laboratories, who carried on an extended series of investigations on the physical chemistry of development. Quite recently, Reinders and Beukars in Holland have published some important work on this subject, and this has been followed up in the Kodak laboratories, so that it is quite possible that in the near future we may attain to a satisfactory understanding of the general chemistry of development.

The classical problem of photographic science is, of course, the phenomenon of exposure and the nature of the latent image produced, and to this must be added the structure and properties of the light-sensitive silver compound. This problem was attacked intensively in the years immediately following the War, both in the Kodak laboratories and by the British Photographic Research Association in England. The first work, however, was published by Dr. T. Svedberg, of Sweden, who made a statistical study of the number of grains that became developable after exposure. Sheppard and Trivelli in the Kodak laboratories engaged in a laborious and difficult analysis of the distribution of grain sizes in emulsions, and showed that the sensitivity was associated with the size of the grains and that the distribution of different sizes of grains conditions the photographic properties of the emulsion, a possibility that I had suggested some years before. It was already known that development proceeded from specific centers in the grains, and the English work at this time showed that the centers were in all probability specific specks of some substance, other than silver halide, present on the grain before exposure and acting as sensitizing specks.

For many years, it had been known that photographic gelatin differed very much in its ability to produce sensitive emulsions, and it was suspected that this was due to some small impurity. As the result of a series of brilliant investigations, Sheppard showed in 1925 that the substance in gelatin that is responsible for sensitizing contains sulfur in a labile form, and that in all probability the sensitizing specks consist of silver sulfide.

Following this, there was a very active discussion, in which all countries took part, as to the phenomenon of exposure, and a number of theories were advanced as to the action of light upon the silver bromide grains.

In connection with this subject, it should be mentioned that the investigations of Sheppard and Vanselow showed that the first effect of light was to liberate an electron from the bromide ion of the silver bromide crystal; this electron then united with a silver ion to form an atom of silver. At about the same time Toy and Harrison showed that the wavelength of the light that produced photoconductivity in silver bromide could be reconciled with the spectral sensitivity of the material. The recent work of Hilsch and Pohl on the primary photoelectric effect is in agreement with the earlier results, and seems to be on the point of yielding a simple and clear theory of the action of light upon the photographic material and of the nature of the exposed grain. While the investigations on grain distribution and Sheppard's work on sensitizing have added greatly to our knowledge of the structure of silver halide emulsions, and while the properties of the silver halide grains themselves were clarified by the work of Sheppard and Trivelli, who published a monograph on the subject, the actual properties of photographic emulsions and their relation to the methods of preparation are still quite obscure, and it will undoubtedly require many years before these matters are cleared up.

In the last thirty-five years, there has been developed a coherent theory of the photographic process. At the beginning of the century, the gaps in our knowledge were so many and so deep that a science of photography could scarcely be said to exist. Today, many of those gaps have been filled and the structure of photographic science is continuous. The further development of that structure is a task for the future—a task full of promise and of interest.

DISCUSSION

MR. RICHARDSON: How was the graininess of film reduced?

DR. MEES: The main factor in diminishing the graininess of negative materials was the use of sensitizers to increase the speed of the finer-grained emulsions. As I mentioned, the sensitizers increase the speed of fine-grained emulsions to a greater extent than that of coarse-grained emulsions. I do not mean that they get up to the same speed finally. As a general rule, a coarse-grained emulsion when sensitized is faster than a fine-grained one, but the difference is much less when sensitized than before sensitization. By making finer-grained emulsions and then sensitizing them, it was possible to obtain sufficient speed without undesirable graininess for the motion picture screen.

REPORT OF THE STANDARDS COMMITTEE*

During the spring and early summer a series of meetings have been held dealing largely with the details of the new drawings prepared for the revised standards under the direction of Mr. G. Friedl, Jr.

These drawings have been designed to fit better into the plan of the American Standards Association, and it is hoped that they will serve as models for future drawings so as to avoid misunderstandings similar to those encountered in connection with the 16-mm. sound-film standards.

The serial numbers used in the past for the Standards drawings have been given up, and it is proposed to use a classification such that the drawing of a given standard will retain its number through any series of revisions by changing only the final number, indicating the number of the revision. It is believed that the new numbering will be useful not only to those consulting the charts, but to the Standards Committee itself, inasmuch as the numbering system will show any standards that are missing or have been neglected. Each drawing will contain the American Standards Association number as well as the SMPE number.

The question of the single type of perforation adopted by the Society for both positive and negative is being studied intensively by a subcommittee under Mr. J. A. Dubray, Chairman of the West Coast Branch of the Standards Committee. Although no final report has been prepared, it appears that the difficulties involved in changing to the standard SMPE perforation for the negative are very considerable, chiefly because of the background negatives being used at the present time. Mr. Dubray is again going into the question of changing the longitudinal dimension of the positive type of perforation, reducing it from 0.078 to 0.073 inch, so that the film will fit upon positioning pins and other apparatus designed for the old Bell & Howell perforation.

The proposal has been received from the German Standards Association that 16-mm. sound-film spools be standardized with square holes on each side instead of with one square and one round hole,

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* Presented at the Fall, 1936, Meeting at Rochester, N. Y.

as is common practice in this country to prevent the amateur projectionist from putting the spool on backward. This proposal has been referred to the Non-Theatrical Equipment Committee, which has made careful inquiry among the various manufacturers and has received opinions from most of them. There has been no meeting of the Standards Committee since the report of the Non-Theatrical Equipment Commitee was received, and, therefore, no action has been taken upon it. Standardization of the 2000-ft. reels has been withheld pending further recommendations from the Exchange Practice and Laboratory Practice Committees.

Two items have been discussed at considerable length at many of the Standards Committee meetings, one in regard to the standardization of sprockets. Many members feel that the Committee should not standardize sprockets of any sort but that their design should be left to the projector and camera designers to achieve the best results with standard film. The second question has to do with better methods of obtaining complete uniformity in standardization throughout the world. Even when the intention of the various standards committees is the same, small differences invariably occur, sometimes due to the fact that tolerances chosen in one country are different from those in another; and sometimes in this country the tendency is to round off figures in inches, whereas in France and Germany the figures are rounded off in terms of millimeters. No satisfactory conclusions have been reached in either of these matters.

Requests have been sent to various manufacturers for data on 8-mm. film, sprockets, and film gates in order that standards may be drawn up for 8-mm. equipment.

The question of a standard reduction ratio for reducing 35-mm. film to 16-mm. film has been discussed, and the Standards Committee has requested Mr. Friedl to prepare a paper on the subject to be presented at the Fall, 1936, Meeting at Rochester, in order to evoke discussion from the members of the Society. The question is fairly complicated, and necessarily involves compromises of some sort, since the shapes of the pictures are not identical. Members of the Society having special interest in or knowledge of the question are requested to send their opinions to the Standards Committee.

E. K. CARVER, *Chairman*

P. ARNOLD	L. N. BUSCH	A. COTTET
F. C. BADGLEY	W. H. CARSON	L. DE FEO
M. C. BATSEL	A. CHORINE	A. C. DOWNES

J. A. DUBRAY	E. HUSE	C. N. REIFSTECK
P. H. EVANS	C. L. LOOTENS	H. RUBIN
R. E. FARNHAM	W. A. MACNAIR	O. SANDVIK
C. L. FARRAND	K. F. MORGAN	H. B. SANTEE
G. FRIEDL, JR.	T. NAGASE	J. L. SPENCE
H. GRIFFIN	N. F. OAKLEY	A. G. WISE
R. C. HUBBARD	G. F. RACKETT	I. D. WRATTEN
	W. B. RAYTON	

DISCUSSION

MR. PALMER: One of the new drawings specifies 26 frames between the sound aperture and the picture aperture. I thought it was 25 frames.

DR. CARVER: Twenty-five is the present standard. The standard in Europe is 27, and the Standards Committee is proposing that we compromise on 26.

It seems only fair that, since the European Committees have generously agreed to adopt our standard in regard to the side of the film for the sound-track, we should meet them half-way in respect to this item. I think that the change from 25 to 26 is advisable. The Standards Committee is unanimous on this point.

REPORT OF THE SOUND COMMITTEE*

In one of the projects upon which the Sound Committee has been working considerable progress has been made—namely, the elimination, through the use of a Standard Frequency Reference film, of the wide differences in recording characteristics that have occurred in the past. As stated in the last report of the Sound Committee,[1] a Primary Frequency Reference Standard has been made, and twelve Secondary Standards made and calibrated in terms of the Primary Standard. The calibrations of the Secondary Standards were given in the previous report.

The Secondary Frequency Reference Standards have been sent to the various studios on the East and West Coasts, and, through the courtesy of the heads of the various studio sound departments and with the coöperation of the Academy of Motion Picture Arts and Sciences, the recording frequency characteristics of the various studios have been determined and referred to this Frequency Reference film, and the results from the various studios have all been plotted upon the same sheet of paper. This is the first time, to our knowledge, that comparable data from the various studios have been assembled into one set of curves. The results bring to the attention of recording directors in a forceful, graphic, and quantitative form the reason for the large variation in the quality of the sound-track from the various studios when reproduced in the theater.

It was hoped that it would be possible to present copies of these curves at this time, but a study of the results seems to arouse considerable doubt as to whether certain studios followed precisely the procedure laid down by the Sound Committee in obtaining the data at present available. Consequently, it is the opinion of both the SMPE Sound Committee and that of the Academy of Motion Picture Arts and Sciences that publication of the data should be withheld until such time as its accuracy has been checked carefully. It is safe to say, however, that the data collected have already given

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* Received October 12, 1936; presented at the Fall, 1936, Meeting at Rochester, N. Y.

great impetus to the desire for greater uniformity in the sound recording characteristics of the various studios.

The Primary Frequency Reference Standard, originally measured in 1935, is being remeasured this year, in order to determine the extent to which aging of the film has affected the level of the sounds recorded. Microdensitometric measurements made by the Eastman Kodak Company do not show deviations in excess of the experimental error that may reasonably be expected.

P. H. EVANS, *Chairman*

M. C. BATSEL	K. F. MORGAN	R. O. STROCK
L. E. CLARK	O. SANDVIK	H. G. TASKER
F. J. GRIGNON	E. I. SPONABLE	S. K. WOLF

REFERENCE

[1] Report of the Sound Committee, *J. Soc. Mot. Pict. Eng.*, **XXVI** (Jan., 1936), No. 1, p. 21.

DISCUSSION

MR. TASKER: I should like to bring to this Committee the appreciation of the Sound Directors of Hollywood, as expressed at their meeting some ten days ago for the work that has been initiated by the Sound Committee, which, as Mr. Evans said, has very definitely stimulated a great deal of interest in solving this problem.

We must realize that some of the differences in sound quality between the various studios are caused by the fact that our review rooms have substantially different characteristics. After hearing four or five outside pictures in one of our review rooms one of my men recently said, "Why is it that all the other studios have such bad sound and ours so good?"

Although we must always expect differences of opinion, it is obvious that many of the differences that he had noted must have resulted from adjusting our recording characteristic to match our reviewing room characteristic, and certainly our product would not appear so favorably in another review room. As a result of this condition we are trying to get together on the reviewing room characteristic, which is the yardstick we apply to our respective products. When we have chosen some one yardstick, we shall then eliminate all but our wished-for differences in sound quality by making the corresponding revisions of our recording characteristics.

MR. EVANS: The Sound Committee appreciates that this is a complicated problem, and is not only a matter of recording characteristics; the microphone characteristic is included, as well as the characteristics of the reproducing equipment, amplifiers, and loud speakers in the theater, and the acoustics of the theater.

It was necessary to start somewhere on the problem, and apparently the Sound Committee chose a good point in getting the recording characteristics down on paper.

REPORT OF THE COMMITTEE ON NON-THEATRICAL EQUIPMENT*

At the request of the Standards Committee, steps have been taken to determine the preference of the industry with regard to the square-round or square-square combination of holes in reels used for 16-mm. film. The investigation followed as a result of publication[1] of the recommendations of the Deutsche Normenausschuss für Kinotechnik, which follow:

(*1*) Spools having square holes on both sides are adaptable to all apparatus; whereas, the other spools do not fit on apparatus having square mandrels. Most German equipment has square mandrels.

(*2*) Spools made according to the American system are based upon operating the reproducing apparatus from the right, viewed in the direction of the light-beam. However, of late some apparatus operating from the left has been produced; on such equipment only spools having square holes on both sides can be used, in order to be interchangeable on both left- and right-hand apparatus.

(*3*) As there are two different standards for 16-mm. sound-film, distinguished by the position of the sound-track, it may be necessary in some cases to reverse the spool, if the film to be projected is of the standard other than the one for which the apparatus had been designed. This possibility is offered only by a spool having square holes on both sides.**

A majority of the members of the Committee support the square-round combination, because it prevents rewinding or placing the film incorrectly upon the projector. Another point that seems to have been overlooked in the German publication is that an extremely great number of spools having the square-round combination are in every-day use throughout the world, and can not be employed upon projectors adapted to the square-square combination. If the spindles of the projectors are made square-round to accommodate reels of both types, a square-square combination will allow the reel to wobble, due to the inability to seat itself properly upon the spindle.

Although it may appear that greater weight is on the side of the

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* Received October 15, 1936; presented at the Fall, 1936, Meeting at Rochester, N. Y.

** Since this report was written, the SMPE standard fixing the position of the 16-mm. sound-track has been approved by the International Standards Association, and thus has become a world standard.

square-round combination, there is sufficient acceptance of the square-square recommendation to indicate that we may be forced to consider two alternatives, possibly making the square-round combination the recommended standard and the square-square as an acceptable alternative. It may perhaps, be questioned whether a double standard would carry any serious objection; perhaps in the interests of international agreement a double standard might provide a necessary compromise. However, it is in order to point out that those who favor the square-square combination imply at least that that is not all that is desired, as their statements indicate that the film can be wound upon the reel the wrong way. Attention has been called to the patent situation; one company holds patents on both the square-round and the square-square combinations here and abroad. Licenses on equitable basis could undoubtedly be arranged irrespective of what standard is finally employed.

REEL CAPACITIES AND DIAMETERS

There seems to be a considerable body of opinion that the Society should standardize reel capacities: for projector reels the sizes should be 400, 800, 1200, and 1600 feet, and possibly 2000 feet. This recommendation does not regard the 100-ft. return spools sent from the laboratory as requiring standardization. However, the 100-ft. spool might be discussed separately with the film manufacturers, who are primarily interested.

The following hub and overall diameters are recommended for standardization:

Capacity (*Feet*)	Diameter (*Inches*)	Hub Diameter (*Inches*)
400	7	$1^3/_4$
800	$10^1/_2$	$4^7/_8$
1200	$12^1/_4$	$4^7/_8$
1600	$13^3/_4$	$4^7/_8$
2000	15	5

PROJECTOR SPROCKETS

The Committee has recently been asked for suggestions as to the desirability or possibility of standardizing projector sprockets. Although the Committee has not yet gone very far into the subject, it is well to emphasize the fact that such standardization presents great difficulties. For instance, the Bell & Howell Company employs two sprockets having slightly different pitch diameters. Other manufacturers employ only one sprocket. A detailed report on the subject will be offered in due course.

EDUCATIONAL

The use of motion pictures, particularly 16-mm. sound pictures, in the educational field continues to grow apace. At the recent N. E. A. Convention at Portland, this phase of educational activity received major attention; and at a subsequent meeting at Hollywood, the newly formed Hollywood Educational Motion Picture Forum concentrated its entire efforts upon considering the applications of motion pictures to educational problems. The applications of motion pictures have reached the point at which the regular theatrical producers can recognize the possibility of widening the outlets for their products or of supplementing their regular productions with education material.

The U. S. Department of Education has just published the new *National Visual Education Directory*,[2] which is a very complete survey of motion picture projectors and other visual aids in use throughout the country. However, even since the book has been placed upon the press, progress has been so rapid that its figures are rapidly becoming obsolete.

BIOLOGICAL STANDARDS

The following has been extracted from a report of the Committee on Standards for Motion Pictures of Biological Material, of the Biological Photographic Association:[3]

(*1*) *Size.*—For general use, the 16-mm. size will usually be found preferable because of the lower cost and the more generally available projection facilities. Modern 16-mm. projectors give adequate size and brilliancy.

For photographing, the choice between 35-mm. and 16-mm. film depends upon the subject and upon the finances available. The 16-mm. film has proved adequate for many biological subjects. It is recommended that 16-mm. prints of all subjects related to the biological sciences be available.

(*2*) *Color-Films.*—Color-films are preferable to black-and-white pictures when the colors of the objects photographed are important features. As the technical difficulties are reduced, more use should be made of color processes. Judicious use of stained or toned film or toned positives relieves the monotony of black-and-white, but any tendency toward "nature faking" is to be avoided.

(*3*) *Sound-Films.*—Sound-films are of value for special programs and for historical purposes, to bring to the audience the personalities of great persons. They are valuable for recording sound phenomena such as speech, animal sounds, diagnostic sounds, *etc.*, when the original subjects can not be exhibited. Sound-films otherwise will probably have little use in college and university teaching because of their inflexibility. They can not be adapted readily to a given lecture or demonstration. Cutting and re-editing film with sound-tracks is a difficult and costly process. A course is successful to the extent that it is attuned to the time, place, and students; and a sound-film for one purpose may not be satisfactory for another purpose. This objection may be met in part by running the sound-film silently when the sound is inappropriate or not required, provided the projector is so built as not to injure the film. As sound-films are projected at a speed of 24 frames per second, more film must be used for the same interval of time. However, the pictorial material in both a silent and a sound-film may be about the same because the titles in the silent film increase the length of showing when 16 frames are projected per second. Sound on disks is another solution of the flexibility problem, as its use is adapted to both film speeds.

(*4*) *Silent Films* will probably be used more frequently in class teaching except as noted in (*3*), above.

(*5*) *General Criteria of Excellence:*

(*A*) Photographic Technic.

I. Sufficient illumination and freedom from flicker. (The latter is especially objectionable in time-lapse and animation technics.)

II. Freedom from field jerks.

III. Good placing and proper size of point of interest.

IV. Uniform backgrounds (especially when films of several similar subjects are to be combined, as is often the case in surgical films).

V. Correct composition and freedom from crowding. (The final image size upon the screen must be considered when the film is taken.)

VI. Adequate use of long-shots and close-ups, to show orientation and detail. (Dissolves are a useful means of shifting from the normal to the abnormal, and *vice versa*.)

VII. Proper color value, definition and contrast, and freedom from glare.

VIII. Proper use of accessories and related objects to produce a coördinated picture with respect to parts and to the entire film.

IX. Efficient use of special technics (*i. e.*, cinemicrography, dummy action, animation, accelerated or retarded motion, use of x-rays, stills, dissolves, *etc.*)

X. Freedom from spots, scratches, *etc.* (Meticulous care and vigilance are necessary to keep all equipment clean and in good operating condition.)

(*B*) Presentation (including editing).

I. Consistent classification and transition from the general to the particular.

II. Suitable spacing of striking phases to form climaxes.

III. Adequate, properly arranged analytical and explanatory matter, adapted to the audience for which the film is planned.

IV. Good continuity. (This may require the use of two cameras; *e. g.*, during a surgical operation.)

V. Absence of material unnecessary for good presentation.

VI. Self-explanatory titles easily read and less than 15 or 20 seconds long. Except for special instances $^1/_2$ second per word is good. White block letters upon a black field are very effective, and the letters must be large enough to be readable at all audience distances. For long titles the moving script method is preferable.

VII. Scenes long enough to justify the title, but not so long as to be tedious. (When necessary and possible, short shots should be repeated. Dissolves are useful when it is necessary to shorten a scene; *e. g.*, the first suture may be shown at the end of a surgical operation, dissolving into the last suture to avoid unnecessary repetition.)

(*C*) When films are planned for educational purposes the titles should:

I. Be adequate to name the film, to show the location of it in space and time, and to explain the script from which it was made.

II. Not be inaccurate, or so detailed that the film can not be adapted to different situations by means of running comment by the lecturer.

III. Be too few rather than too many, when the film is to be used at the college or university level of instruction.

IV. Give the proper generic and specific name to prevent inevitable confusion from common names, which usually change with locality.

(*D*) Cutting and recutting should be continued until the film can not be improved further by such means.

(*6*) *Subject Matter.*—Advantage should be taken of the motion picture technic to record what can not be shown better or more easily by other methods. A good motion picture must be more than a series of still subjects. The film should conform to professional ethics, and not contain undue commercial or personal advertising. The material should be representative, rather than special or abnormal, when the film is intended for general use. The following lists suggested material:

(*A*) Life of organisms in their natural environment or showing their adaptability to unusual conditions.

(*B*) Analysis of living processes by means of speeding or by showing at normal speeds phenomena not clearly seen; *e. g.*, (*a*) animal and plant motions and behavior; (*b*) developmental processes of both plants and animals; (*c*) progressive reactions, as in parasitism, disease, *etc.*

(*C*) Demonstrations, before an audience, of processes occurring on too small a scale for presentation or for which there is only one suitable point of view.

(*D*) For the demonstration of a process, apparatus, and the proper technics of investigation or presentation.

(7) *Intrinsic Value of the Finished Film.*—The real valueof a biological film depends upon how well it succeeds in achieving in the best way the purpose for which it was made, which can be decided only by audiences competent to judge its merits and effectiveness. Some films will have wide appeal, whereas others must be restricted to small groups of specialists. With increased dissemination of knowledge, the appeal of a really good film will increase, because what is specialized knowledge today becomes general knowledge tomorrow. Consequently, a film should be planned, when possible, so that it may make the greatest contribution to biology and medicine. Sometimes long technical films may be cut and re-edited into shorter versions of interest to more general audiences. Certainly recognition will come to the photographers responsible for the production of films of exceptional merit.

The Committee on Non-Theatrical Equipment will appreciate any comments or suggestions that may be offered to the mutual advantage of both Societies for completing an efficient standardization along these lines.

R. F. MITCHELL, *Chairman*

D. P. BEAN	E. C. FRITTS	J. H. KURLANDER
F. E. CARLSON	H. GRIFFIN	E. ROSS
W. B. COOK	R. C. HOLSLAG	A. SHAPIRO
H. A. DEVRY		A. F. VICTOR

REFERENCES

[1] *Die Kinotechnik* (June 20, 1936), p. 197.

[2] National Visual Education Directory, *American Council on Education*, Washington, D. C.

[3] "Report of the Committee on Standards for Motion Pictures of Biological Material," *J. Biol. Phol. Assoc.*, **IV** (June, 1936), No. 4, p. 215.

DISCUSSION

MR. PALMER: Considering all the various kinds of film and apparatus it certainly would be a great help to have square holes on each side of the reel.

MR. MITCHELL: In the report submitted to the Standards Committee several years ago we pointed out that the Bell & Howell Company was putting on the market reels having square holes. So many complaints were received from people who put the film on the projector the wrong way that we were forced to conclude that the disadvantages more than offset the advantages.

MR. KELLOGG: How much would be added to the cost of a reel to add a little disk that could be slid from one position to another, changing the shape of the hole from square to octagonal, so that if one accidentally had the film wound the wrong way, he would not have to rewind twice?

MR. FOSTER: The cost of an adapter inside the barrel, for making the hole either round or square, would be so small as to be negligible.

REPORT OF THE STUDIO LIGHTING COMMITTEE*

Several years ago the Studio Lighting Committee felt that it could serve the Society as well as the production branch of the industry to the best advantage by presenting a fairly complete compilation of studio illuminants, equipment, and lighting methods, with the thought that the material could be made available in the form of a handbook for cameramen and electricians. It was the plan to present the material in the form of four reports. The first was to consider the various illuminants available for studio photography, their characteristics, sizes, *etc.* The second was to discuss the equipment requirements as well as the many types available. The third report was to present data as to various sources of power, wiring systems, and control devices; and the fourth report was to discuss lighting practices, numbers of units necessary, methods of obtaining special effects, *etc.*

Three of the reports, on illuminants,[1] equipment,[2] and sources of power,[3] have already appeared in the JOURNAL; but owing to the length of time that followed the publication of the third report, succeeding reports have brought up to date the material already collected on illuminants and equipment. The fourth and final phase of the program, studio lighting methods, is discussed in this report.

For purposes of study, motion picture lighting may be broadly classified into *general* and *modelling*. General illumination refers to relatively flat lighting of fairly uniform value, usually covering an entire set. In black-and-white photography it ranges from 200 to 400 foot-candles. Its purpose is to provide sufficient light to make all parts of the set photographically "visible" and to provide a foundation upon which to build the modelling lighting. It serves to illuminate the shadows. Its counterpart in every-day life is the "skylight," or light dispersed by the atmosphere and reflected from the clouds.

The lighting units that usually provide the general light are the twin broadside, the rifle, the scoop, and the multiple-lamp overhead unit, as well as many small auxiliary lamps placed behind posts, doorways, trees, *etc.* One arrangement often employed is to place

* Received October 12, 1936; presented at the Fall, 1936, Meeting at Rochester, N. Y.

high-wattage lamps, such as the 200-, 300-, and 500-watt short tubular projection types, in table and floor lamps as well as in wall brackets on the set, to supplement the general illumination and give the impression that the luminaires are lighted. On large sets, representing ballrooms, hotel lobbies, or outdoor scenes (being photographed indoors), the usual general lighting equipment is not able to provide sufficient intensities at the distances involved, and resort is frequently made to the modelling units operated at their wider beam divergences. Of course, scenes are frequently shown in which there appears to be no general lighting, the photography being done almost entirely with the modelling sources. This, however, is done to create certain special effects called for by the story.

TABLE I

Modelling Units in Current Use

36-inch Reflector Spot	150-amp. arc
	10-kw. mazda lamp
24-inch Reflector Spot	150-amp. arc
	5-kw. mazda lamp
18-inch Reflector Spot	2-kw. mazda lamp
	80-amp. arc
	120-amp. arc
	150-amp. arc
Lens Spots	10-kw. lamp
	5-kw. lamps
	2-kw. lamps
Baby Spots	1000-w. lamp
	500-w. lamps
"Lupe" Lights	1000-w. lamps

Modelling lighting is, as the name implies, the part of the lighting that serves to create highlights and contrasts, and when properly used can serve as an excellent means of overcoming the two-dimensional limitation of the screen by producing a suggestion of depth. Its analogy in every-day life is sunlight. An additional function of modelling lighting is to place a much higher level of illumination upon the "star" or upon limited groups of actors, and thus direct attention to that part of the scene. Modelling levels of illumination are generally from two to four times as high as that of the general lighting, although in some instances the ratio may be as great as eight when necessary to produce desired effects. It is in handling the modelling lighting that the cameraman shows his ability.

A fairly common practice in many studios is for the "gaffer" or head electrician of the company to install and arrange the general lighting equipment, and then to have available an adequate supply of modelling equipment. The cameraman then devotes practically his entire efforts to placing and adjusting the latter. The customary modelling units are as shown in Table I.

These units are all characterized by their ability to produce shafts of light having beam divergences of 12 to 20 degrees and sometimes less. Beyond angles of 20 degrees the illumination begins to approach that of general lighting. By confining the light output to the relatively small angles stated, relatively high intensities can be produced over the limited areas required of this kind of equipment.

To produce the illusion of depth it is common practice to direct shafts of light downward from the rear of the set, producing strong highlights around the heads and across the shoulders of the actors and making them stand out from the background. This is frequently referred to as "back-lighting." In close-ups, the elements of general and modelling lighting are usually retained although the number of equipments is fewer.

The customary procedure in studio lighting is to place the bulk of the modelling equipment, as well as a considerable part of the general equipment, upon parallel supports, suspended from the overhead structure of the stage. The scoops and domes or overhead strip-lights are hung directly from the overhead structures. The older practice was to build the parallels atop the walls of the set, but the use of unit flats for the walls has made necessary other means of supporting the parallels.

When the camera position is approximately fixed, at least for a given series of shots, part of the general lighting units are arranged in a row extending in both directions from either side of the camera. A few modelling units are included, particularly those necessary for building up the illumination upon the star's face. There is, however, an increasing tendency toward greater numbers of "follow-up" or dolly shots, in which the camera, upon an easily movable carriage, follows the action at close range. For this type of shot the lighting units are often mounted directly upon the camera blimp, which arrangement has the advantage of maintaining balance of lighting at all times.

It is well recognized that any chart that may attempt to indicate the numbers of the various kinds of lighting equipment for sets of several kinds can afford only a rough approximation to the quantity of equipment that may be needed. The lighting needs of different cameramen vary greatly. The stories being filmed differ vastly in the quantity of light required.

The very general rule is to mount upon the parallels as much equipment as space allows. The use of more compact equipment has, because of this rule, led to placing more equipment into position, although it may not all be used at one time. One might be tempted to remark, after seeing a Hollywood stage rigged out, that the carpenters who build the parallels determine the quantity of lighting equipment to be used.

TABLE II

Lighting Equipment for Motion Picture Photography

(Black-and-White)

	Close Up		Small Room (20 x 20 ft.)		Medium Size (50 x 50 ft.)		Large Size (Larger than 50 ft.)	
Type of Set	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
General Lighting								
Broadsides	2	2	4	8	10	20	20	40
Overhead (Scoops)			2	3	5	10	12	30
Overhead Strips or Domes	1	1	2	3	2	4	8	12
Modelling Lighting								
24- or 36-inch Reflector			1	2	2	8	4	16
18-inch Reflector	1	2	4	6	6	12	10	20
Lens Spots (large)		1		1	2	8	4	16
Lens Spots (medium)	1	2	2	6	4	8	12	24
Lens Spots (small)	1	1	2	4	2	4	2	8

The dolly shot, particularly when the camera follows the action from room to room, has made it necessary to place much of the lighting equipment upon the parallels overhead in order to allow adequate clearances on the floor. It has further necessitated doubling or even tripling the lighting equipment for a given production unit, since all the rooms must be lighted simultaneously.

Lighting for color motion picture photography does not differ in essential elements from lighting for black-and-white photography. The two outstanding differences are the much greater quantity of light required because of the filter loss and the necessity of splitting the light-beam as it passes the lens, and the importance of having light of the correct color quality. Since the color aids materially in distinguishing depth, there is no necessity of creating extreme contrasts, and flatter lighting may be employed. However motion picture lighting of the past years has been characterized by strong highlights and extreme contrasts, and many of the present color pictures retain this form of lighting.

TABLE III

Equipment Covered by Table II

Broadsides	Rifle	1000- or 1500- w. lamps
	Side Arcs	Twin 40-amp. white-flame arcs
Overhead Scoops	Rifles	1000- or 1500-w. lamps
	Arc Scoops	Twin 40-amp. white-flame arcs
Overhead Domes or Strips		1000- or 1500-w. lamps (usually five lamps)
24- or 36-inch Reflector Spots		5000- or 10,000-w. lamps
		150-amp. arc
18-inch Reflector Spots		2000-w. lamps
Lens Spot (large)		120- and 150-amp. arcs
Lens Spot (medium)		2000- or 5000-w. lamp
		50-amp. arc
Lens Spot (small)		100- and 500-w. lamps

For the Technicolor process the general illumination level is about 750 foot-candles and the highlight level 1000 to 1200 foot-candles. The photographing and processing are based upon light having substantially 100 units of red, 100 green, and 100 blue, so as to permit color photography out of doors. For interiors, the white-flame arc has proved to be a fairly good duplication of daylight and has been used for general lighting. For modelling, the high-intensity arc, because of its abundance of blue-violet radiation, has been employed, although some filtering with amber gelatin is necessary to bring the blue-violet radiation into line with the red and green.[4] Incandescent lamps have been successfully employed, by using, in conjunction with blue filters,[5] high-efficiency types having a greatly increased blue output.

In spite of the widespread adoption of faster camera lenses and the development of faster photographic emulsions, the tendency is toward more light, either through increasing the number of higher-wattage lamps, or by using more efficient lighting units such as the new Fresnel lens spots.[6] An inquiry was recently made as to what use was being made of the increased exposure resulting from these developments, and the only satisfactory answer that could be obtained was that the film processing departments of several studios were taking advantage of it in respect to the greater latitude of development it afforded. In no instance was it found that the cameraman was employing this greater quantity of light and increased film sensitivity to stop down his lenses and thus attain improved depth of focus and better picture quality.

New Equipment.—Following the introduction of a new 2000-watt Fresnel lens spot,[6] one of Hollywood's well known equipment manufacturers has made available a similar spotlamp in the 5000-watt size, and a still larger size has been developed employing a 150-ampere high-intensity arc. Incandescent lamp manufacturers have recently placed upon the market a group of high-wattage lamps of the studio type, especially adapted, when used with a suitable filter, for Technicolor photography. They are designated *CP* as distinguished from lamps used for black-and-white photography, which carry the marking *MP*.

R. E. FARNHAM, *Chairman*

W. C. KUNZMANN, V. E. MILLER, E. C. RICHARDSON
J. H. KURLANDER, G. F. RACKETT, F. WALLER

REFERENCES

[1] Report of the Studio Lighting Committee, *J. Soc. Mot. Pict. Eng.*, **XVII** (Oct., 1931), No. 4, p. 645.

[2] *Ibid.*, **XVIII** (May, 1932), No. 5, p. 666.

[3] *Ibid.*, **XXV** (Nov., 1935), No. 5, p. 432.

[4] HANDLEY, C.W.: "Lighting for Technicolor Motion Pictures," *J. Soc. Mot. Pict. Eng.*, **XXV** (Nov., 1935), No. 5, p. 423.

[5] FARNHAM, R. E.: "Recent Developments in the Use of Mazda Lamps for Color Motion Picture Photography," *J. Soc. Mot. Pict. Eng.*, **XXIV**, (June, 1935), No. 6, p. 487.

[6] RICHARDSON, E. C.: "A Wide-Range Studio Spotlamp for Use with 2000-Watt Filament Globes," *J. Soc. Mot. Pict. Eng.*, **XXVI** (Jan., 1936), No. 1, p. 95.

DISCUSSION

MR. CRABTREE: Are any lamps available with the voltage control at the lamp, so that the cameraman can control the illumination locally without changing the position of the lamp?

MR. FARNHAM: The Vitachrome unit, used on the West Coast, has a small rheostat on the back, and quite a point is made of the light intensity control. The lamp consists of a reflector unit and a matte diffusing surface.

MR. PALMER: Is any color photography being done using a combination of arc and incandescent lighting?

MR. FARNHAM: At the present time difficulty is being experienced in getting correct balance. Incandescent lamps can be used successfully for Technicolor photography provided the light is unmixed. At the present time the incandescents seem to be a little deficient in the blue. We are engaged in the problem of correcting the difference so that the two kinds can be mixed.

MR. RICHARDSON: Since the fast emulsions have been offered to the industry there has been a tendency to decrease the general front lighting a great deal, the reason being that there is considerable reflection from walls and floors that apparently provides part of the general lighting required. In fact, many sets have comparatively few of the floor lamps that used to be so popular.

However, to meet the front-lighting problem, it is very common practice to mount two rather powerful lamps upon high standards at each side of the camera. In fact, camera bridges have been made—structures under which the camera could be operated and on top of which could be placed lamps and operators for controlling the key lighting.

The first Technicolor productions were made with a very considerable line-up of front lighting on each angle in proper balance with the camera, following the general lighting practice of three years ago. But now, in producing *The Garden of Allah*, for instance, the tendency was to utilize key lighting. Generally two 150- or 120-ampere spots were used on each side of the camera.

One thing that has made key lighting technic possible is that the new spot equipment has beam divergences so much greater than the old spot equipment, and yet it provides more satisfactory lighting than was possible with the general lighting arrangement of two lines of lamps on each side of the camera, generally diffused down to obtain the balance desired by the cameraman.

MR. CRABTREE: Is the heat from incandescent lamps any longer a problem, since the sensitivity of the films has been increased?

MR. FARNHAM: In the case of black-and-white pictures, we hear practically nothing of it any longer. For Technicolor lighting, with the increased level of illumination, heat is beginning to loom up as a problem, although the correcting, which is done by a filter blue in character and having some infrared absorption, tends to limit the heat somewhat.

A THIRD-DIMENSIONAL EFFECT IN ANIMATED CARTOONS*

J. E. BURKS**

Summary.—*A description of the Fleischer Process by which animated drawings may be photographed in stop action, while superimposed upon a moving three-dimensional background, and at the same time maintain the proper perspective for all positions.*

Since the process described here was developed at the Fleischer Studios, makers of animated cartoons, this paper will touch only upon the application of the process to cartoon production, which, however, is by no means the limit of its possibilities.

Cartoon action was first produced by photographing pen and ink drawings on white paper. The method permitted only a limited use of backgrounds, if any, and the interest was naturally restricted solely to the action. Later, with the introduction of the celluloid process, the use of backgrounds rendered in all the tones required for well finished pictures first became possible. A single carefully executed background could be used for a complete scene, while the animated drawings traced in ink and filled in with flat opaque tones on transparent celluloid sheets carried forward the action by being photographed in sequence on top of this background.

The completed picture was artistically correct only so long as the background was held in the fixed position for which it was drawn, and the perspective of the picture was necessarily determined by the camera angle.

Now in cartoon presentation, panorama action, or, more correctly, following action, is highly essential in a large number of scenes. With flat backgrounds the following action is accomplished by sliding the drawing beneath the celluloid sheets at such intervals as to suit the action. In such case the background is rendered upon a long strip of paper. By this process, however, the perspective is "frozen"; that is to say, all converging lines move along at the same fixed angle,

* Received August 22, 1936; presented at the Fall, 1936, Meeting at Rochester, N. Y.

** Fleischer Studios, New York, N. Y.

and all distant points move through the field at the same speed as those in the foreground.

In reality, in straight-line following action all points in a landscape or interior view appear to revolve about a point on the horizon at the center of vision. Actually the point is not on the visible horizon, but at the center of the field of vision at the distance of infinity. The process described here has been designed with particular attention toward simulating this apparent revolution of the converging lines in moving perspective.

A truly three-dimensional background is used. A plastic miniature setting is photographed on a revolving stage, so arranged that the center of revolution is the theoretical vanishing point of the set construction and is located in line with the center of the picture plane and the camera lens.

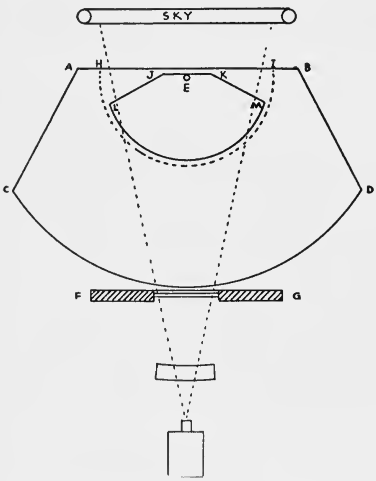

FIG. 1. Plan view of arrangement, showing camera, platen, and stage.

Fig. 1 is a plan view of the arrangement. Fig. 2 is the side elevation. *ABCD* is the stage platform, which swings about its axis at *E*. By experimentation a radius of five feet has been chosen as suitable for use with a lens of 50-mm. focal length. A cast aluminum platen, *FG*, is equipped with a double glass window and registration pegs upon which are placed the animated drawings of celluloid, the drawings being held flat between the two pieces of glass. The miniature background is constructed in an inclined plane extending from below the field at the edge of the stage to the desired horizon height on the circle *HI*, and is so arranged that the path upon which the animated figures are to appear to move is in line with the bases of the figures and the lens. Thus, when the perspective of the figures matches that of the setting, and the shadows are correctly drawn, the illusion that the action really occurs upon the setting is created. The various planes are brought into focus by using a small lens stop and a long exposure.

Since the vanishing point of this arrangement has been moved from its natural position at infinity to a distance of about seven feet from the lens, all the objects in the scene must be built and arranged in forced perspective. That is, all receding lines that are perpendicular to the picture plane must converge to the center of rotation of the stage. A setting viewed from any but the proper angle is a queer sight to behold so far as perspective is concerned.

The circle *HI*, which is the depth limit for all settings, is so selected that its diameter is somewhat larger than the limits of the camera field at that point. This permits a depth of about thirty-six inches for the horizon line of landscapes, which is ample to represent the distances of three to five miles usually occurring between the eye and the visible horizon. However, the relative speed at this circle is too fast to represent the passing action of very distant objects such

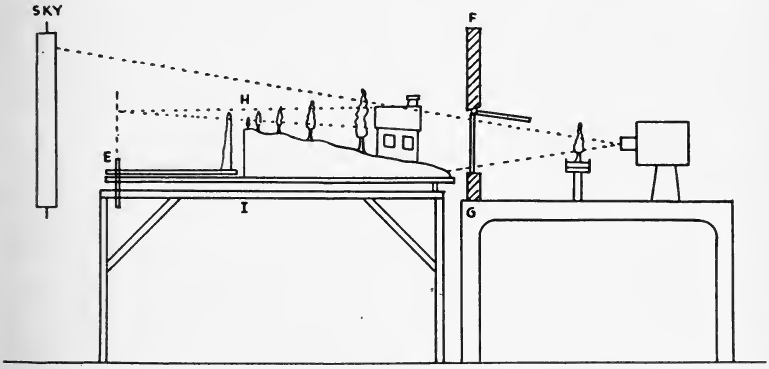

FIG. 2. Side view of Fig. 1.

as mountain peaks, which may be seen above the horizon as far away as twenty or thirty miles. We have overcome this problem by providing a secondary revolving stage inside this circle, as shown by *JKLM*, in Fig. 1. This is so geared to the larger stage as to turn at a speed half as great, and upon it are placed the mountain peaks and volcanoes. Fig. 3 shows a set with the machine ready for photographing.

There are some recent refinements to the process. One is a curved track located between the camera and the picture plane along which small automatically operated stages can move. The speed is so regulated that objects carried through the field appear to be a part of the set, but in reality are passing between the camera and the animated action.

Another refinement is a stage that rotates vertically as well as horizontally. This permits us to represent following action that rises into the air, vertically, diagonally, at any angle, or along a curved path. The additional axis is horizontal, and just back of and parallel to the horizon line AB. Thus, as the camera rises in height the foreground falls away, and the horizon line remains fixed.

It has not been our purpose to duplicate nature or simulate reality, by the use of this process with animated cartoons. A cartoon is a drawing having much freedom of style, and so should be its back-

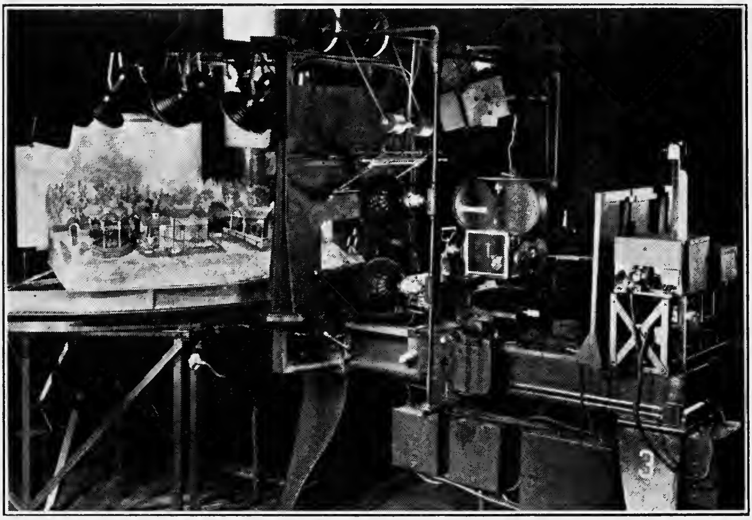

FIG. 3. View showing set and machine ready for operation.

ground. But any drawing, even a cartoon, to be correct artistically, must always be done in the proper perspective. So we build these backgrounds and paint them in the style of the cartoon, but the machine keeps the perspective in order. The result is that so long as the stage is in motion about its fixed artificial vanishing point, the observer will be led to believe that he is looking into unlimited distance instead of across only a few feet. The illusion is created by the difference of speed between the depth planes as each passes the observer, each plane moving in proper proportion to its distance from the revolving point.

(*A two-color sound picture, Musical Memories, was shown, in which appeared several scenes photographed by this process together with other scenes in which flat backgrounds were used. More recent releases use a three-color process.*)

MERCURY ARCS OF INCREASED BRIGHTNESS AND EFFICIENCY*

L. J. BUTTOLPH**

Summary.—*The characteristics of the high-pressure 85-watt mercury arc of interest to motion picture engineers are discussed, with special reference to brightness, dimensions, efficiency, utilization, and spectral quality.*

The low brightness of the Cooper Hewitt mercury arc, while an asset in industrial illumination, has kept the lamp from possible applications in which high brightness, and consequent small source area are essential for use with reflectors and refractors, and where space is at a premium. The quartz mercury arc had a brightness of 500 to 1000 candles per square-inch, compared with the 15 candles per square-inch of the Cooper Hewitt lamp, and permitted some control by large reflectors but almost none by condensers. This brightness has still been low compared with the 10,000 foot-candles per square-inch possible with incandescent lamps and the 100,000 characteristic of the crater of the carbon arc, so little serious thought has been given to this mercury arc for projection or for long-range floodlighting work.

About the only claim of the mercury arc to distinction as a photographic light-source was the efficiency resulting from a high ultraviolet spectral content coincidentally with the high ultraviolet sensitivity of the earlier photographic emulsions. With the introduction of panchromatic film, the lack of red and blue-green in the mercury spectrum became a serious fault not subject to correction by filters. While the Cooper Hewitt lamp was always, in itself, essentially a direct-current device with a simple auxiliary, the rectifier auxiliary for alternating current was rather bulky and heavy for its wattage rating.

The recently developed so-called super-high-pressure mercury arcs embody sufficiently radical changes in brightness, spectral quality,

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

and auxiliary devices to open up some possibilities of studio or laboratory application. By designing a quartz mercury arc to operate at mercury vapor pressures of 20 to 30 atmospheres instead of at 1 atmosphere, as did the older high-pressure arcs, a brightness of the order of 5000 candles per square-inch is attained in air-cooled lamps. By operating water-cooled arcs at higher pressure, brightness of 100,000 to 250,000 candles per square-inch has been attained during rather short lamp lives. Of the possibilities ranging in rating from 50 to 10,000 watts, only one unit has thus far been standardized for manufacture in the United States.

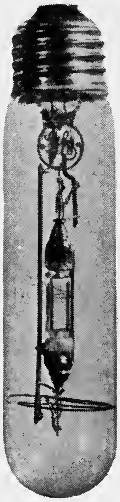

FIG. 1. Type *H-3*, 85-watt, mercury arc, base-up type (half size).

The 85-watt, type *H-3*, mercury lamp (Fig. 1) may be thought of as a small version of the type *H-1* 400-watt and type *H-2* 250-watt mercury lamps[1] standardized during the past few years, except that it is not made for limited-pressure constant arc voltage operation, and so has a volt-ampere characteristic similar to that of the ordinary quartz mercury arc. It can and may be made at any time to possess the limited mercury characteristic of the *H-1* and *H-2* types. Arc-heated, oxide-coated electrodes are carried on tungsten lead-in wires through a graded joint to a quartz-glass arc tube whose design may vary as indicated in Fig. 2. The function of the perforated diaphragms forming chambers at each end is to keep sputtered electrode material out of the arc tube. The diaphragms are not otherwise essential to the proper operation of the arc. A low pressure of argon provides the glow discharge necessary for the initial heating of the electrodes.

As with the *H-1* and *H-2* arcs, the *H-3* is operated by a reactive transformer providing 440 volts for starting and 250 volts at the arc terminals at a normal arc current of 0.4 ampere. It is rated at 35 initial lumens per watt in the arc, and for a life of 500 hours. The quartz tube of the arc proper is enclosed in an outer insulating bulb of glass that limits the short-wave radiation by absorption. Neither the shape nor the material of this bulb is critical, but a tubular bulb of hard glass is standard for the lamp at present, the dimensions being about those shown in Fig. 3. The glass limits the spectrum to about 320 millimicrons. Through the visible and the near-ultraviolet range the spectral distribution is similar to those of other high-pressure mercury arcs except for the unusual intensity of the 365-millimicron lines, which are as relatively strong as in the case of the standard Uviarcs.

Although the dimensions of the arc tube are as shown in Fig. 2, the discharge is of the constricted type, giving a higher maximal brightness than the dimensions would indicate in calculation. As a light-source the constricted discharge is comparable with that of a ribbon filament incandescent lamp, and has the same advantages

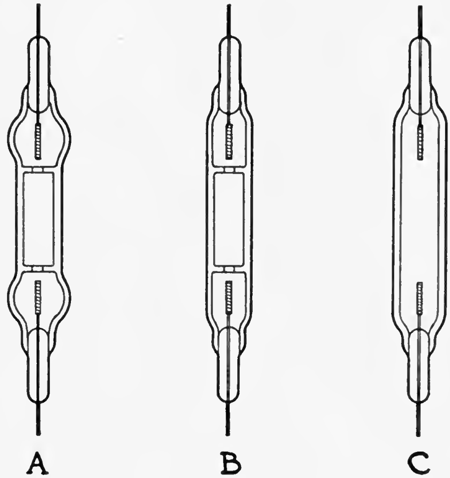

FIG. 2 Quartz-glass arc of *H-3* lamp (full size): (*A*) original Philips type; (*B*) G. E. V. L. Co. and W. L. Co. type; (*C*) possible alternative without diaphragms.

and limitations for use with optical systems. Aside from the effect of the size of the source upon the size of the optical system required to utilize it with practical efficiency, there is another relationship of similar significance, having to do with the effect of the length of a line-source upon the variation of intensity with distance. The theoretical relation is shown graphically in Fig. 4 in terms of foot-candles emitted by the 50-inch Cooper Hewitt, and by the $^3/_4$-inch *H-3* lamp, per hundred watts of total input. Even after adjustment is made for the difference of efficiency, it will be found that the smaller size of the source of itself permits obtaining a higher illumination. The limit, in each case, to the illumination attainable is the brightness of the source as it approaches contact with the surface illuminated. The relation applies also when expressed, for example, in microwatts per cm.[2] as a function of distance, but foot-candles were used in Fig. 4 because of their easy translation into actual illumination problems.

While this arc is of the oxide-coated electrode type designed for a-c. operation, it may be operated on direct current by providing 500 volts or more on a high induced voltage for starting and a series ballast resistance unit of about 600 ohms. The arc has a practically constant-voltage dynamic characteristic and so an approximate

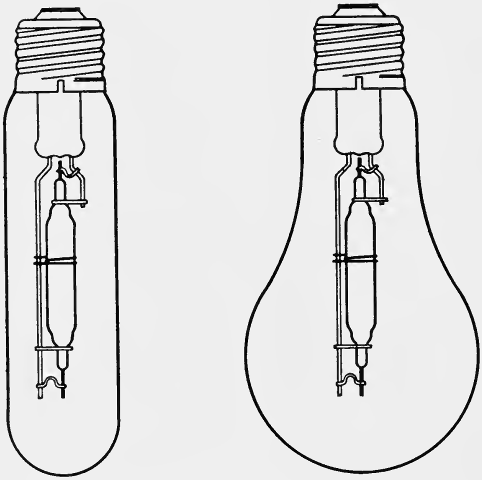

FIG. 3. Complete type *H-3* lamp in two possible bulbs (half size).

sine wave current. Since the light output follows approximately the a-c. arc current, its intensity is variable, and although the flicker is not noticeable directly, it is such as to produce stroboscopic effects upon moving objects and may be a limitation in photography or projection where motion is involved. As a further result of these characteristics, the arc current and light might be modulated to some extent by applying a variable supply voltage, subject to the limitation that the minimal current must not be so low as to extinguish the arc, because the arc can not be restarted until it has cooled for several minutes.

The relative energy distribution in the spectrum of the lamp is not closely comparable with that of any of the other standard mercury arcs, as shown graphically in Fig. 5, which is based upon unpublished data from B. T. Barnes of the G. E. Lamp Development Laboratory, and a recent paper by Elenbaas,[2] and by the spectrograms of Fig. 6,

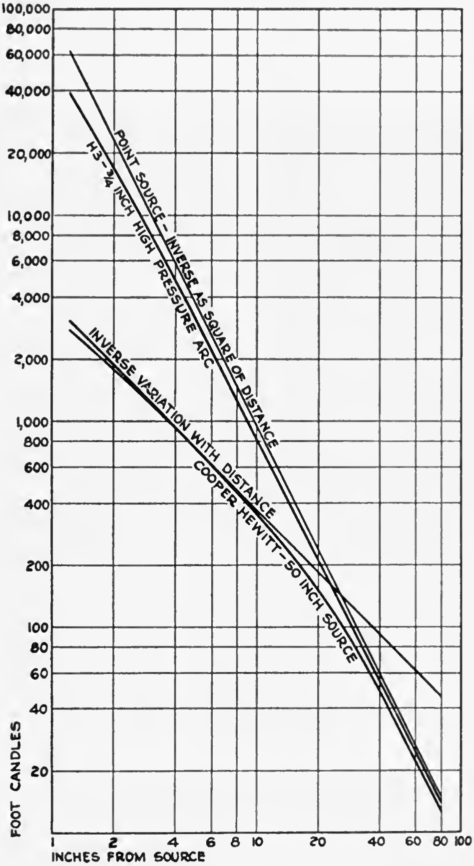

FIG. 4. The effect of source dimensions upon the variation of radiation intensity at various distances.

which do not, however, do justice to the red end of the spectra. The most notable difference is in the red and in the *365* line, whose intensity is equalled only in the quartz Uviarc. The graphic comparison in Fig. 5 is based upon an equal over-all energy input of 100 watts to each lamp, and so gives directly the relative efficiencies. Some of these data, as calculated from the Barnes data, are given in Table I.

TABLE I

Microwatts per Sq. Cm. at 1 Meter, per 100 Watts Over-All Input, Based upon Reactive Ballasting of A-c. Units

Wavelength	Source				
	C.H.	*H-1*	*H-2*	*H-3*	*Uviarc*
7–600		2.5	1.4	6.1	0.3
578	5.9	28.2	18.3	19.2	17.8
546	18.1	29.1	19.2	33.5	16.1
54–490		1.7	0.9	4.3	
49–440			0.4	4.8	
435	18.5	20.4	14.8	27.1	14.2
405	13.1	9.9	7.9	14.5	8.7
365	6.5	9.1	7.5	25.7	25.1
Overall Watts	450	450	300	100	410

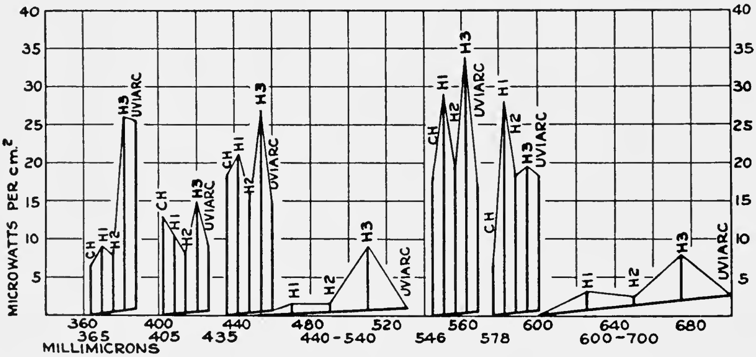

FIG. 5. A comparison of the relative energy distribution in the principal lines of typical mercury arcs.

Apart from applications of the *H-3* lamp to conventional types of projection enlargers and to high-fidelity ultraviolet sound recording of a nature beyond the scope of this paper, no unique application to motion picture engineering is suggested. It is believed, however, that the high intensity of the *365*-millimicron line and the high brightness of the source may permit application of the lamp to certain of the more highly specialized lighting problems of the industry.

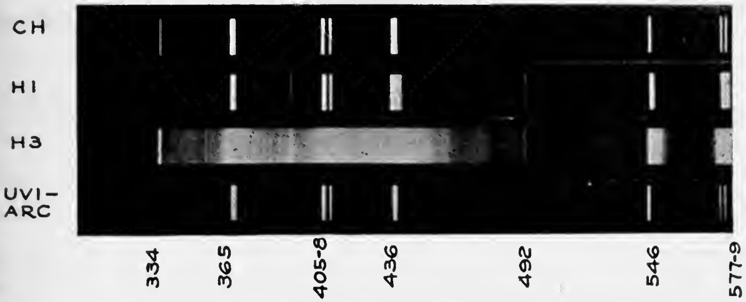

FIG. 6. Spectrogram of the arc.

REFERENCES

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

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

[2] ELENBAAS, W.: "Die Intensitatsverteilung und die Gesamtsrahlung der Super-Hochdruch-Quecksilberentladung," *Physica* (Holland), **3** (Aug., 1936), No. 8, p. 859.

DISCUSSION

MR. TASKER: When the lamp is operated on direct current, at 500 volts and with 600 ohms ballast resistance, is the life reduced to less than what it would be on alternating current, or is it about the same?

MR. BUTTOLPH: Probably reduced; the reason being, of course, that the cathodic functioning of the electrode is the more severe, and on direct current it is continually on one electrode.

MR. WOLF: I am rather disappointed to learn that this high-intensity source has not found wider application in projection and photography. What are the real reasons for the inability to use it? Is it the spectral characteristic, or the variation in intensity?

MR. BUTTOLPH: I did not mean to suggest that it could not be used for projection. That is one of the possibilities. Even this little source might be used in some forms of projection. The Philips Company anticipates extensive application of the water-cooled type of arc for projection.

MR. TASKER: Do they expect to attain greater screen illumination than we can attain with other types of arcs, or merely an economy in electrical power?

MR. BUTTOLPH: I should say both, but the water-cooled type of arc seems to open up interesting possibilities of increasing the intrinsic brilliancy. Apparently, brilliancies can be attained quite comparable to those attained with the higher-intensity carbon arcs.

MR. BRENKERT: Did you refer to the possibility of the alternating current producing a flicker in the projected image?

MR. BUTTOLPH: Yes. The a-c. arc causes flicker at the rate of 120 cycles per second.

MR. BRENKERT: Has the flicker been found to be objectionable?

MR. BUTTOLPH: I am not in a position to discuss the technicalities of projection, but I understand that by synchronizing the shutter to the flicker of the light-source the results are very satisfactory.

MR. BRENKERT: But without such an arrangement, is the flicker discernible on the screen?

MR. BUTTOLPH: I do not know.

MR. WEBER: How does the heat from the arc compare with that from the incandescent lamp for a given candle-power? Is it a cooler source of light than what we are using now?

MR. BUTTOLPH: Yes, by perhaps one-half. That is an advantage inherent in all arcs.

MR. de JONG: When using direct current, the idea is to change the polarity every time the arc is used.

The Philips Company is developing a system of projection without any shutter by causing the dark periods of the lamp to occur at the right instants. The system is not yet ready to be disclosed, but that shows how things are progressing. As far as the light is concerned, I can not present figures on our tests and trials, although we have created some very high intensities on the screen.

MR. TASKER: By "very high intensities" do you mean higher than are attainable or comparable with the highest otherwise attainable?

MR. de JONG: Comparable with the highest we had in mind.

MR. DILLEMUTH: What is the voltage of the Philips lamp?

MR. de JONG: Between four and six hundred, across the arc.

MR. JOY: Must the diameter of the light-source always be small compared with the length?

MR. BUTTOLPH: In general, yes, to attain these high brilliancies and high efficiencies. Since with arcs of this type we utilize only a limited source area, the arc can be shortened. There is a definite limit to the extent to which the arc can be broadened and yet operate efficiently and supply high intrinsic brilliancies.

MR. JOY: Would it depend upon the voltage of the arc?

MR. BUTTOLPH: No, it depends upon the thermal instability of the gas through which the discharge occurs. If we were to build the lamp in the form of a bulb, and then attempt to operate it at these high pressures, a constricted discharge would wander throughout the bulbular space. It would not take the shortest line between the two electrodes. In other words, the wall of the arc physically defines the position of the discharge. At high pressures, even in a large bulb, the discharge would be of this very ribbon-like character.

MR. SPONABLE: When operating a water-cooled arc is it customary to obtain the water from the regular water supply, or do you use a closed system?

MR. de JONG: We use a closed water-cooling system, and use the same quantity of water all the time. Water from the city mains is not harmful over very long periods of time. The water absorption is very low.

MR. KELLOGG: Speaking of using the arc for projection, is it not necessary to supplement it with some other form of light, or to use a filter in order that the color distribution will be reasonably satisfactory for the eye?

MR. BUTTOLPH: I assume that the arc would be limited to some extent to black-and-white projection. There is considerably more red, and the ratio between the yellow and the green is changed so that the light is definitely yellower, not quite daylight, and yet not incandescent light.

MR. KELLOGG: If it is desirable to mix the light with that of tungsten, it is quite conceivable that you could produce an optical image of a tungsten filament practically coincident with the arc itself. If that were done, suppose the tungsten filament were directly behind the arc; would the arc absorb a great share of the light of the tungsten filament, or is the absorption discontinuous, and effective over only limited ranges of wavelength, so that the tungsten filament would contribute a good deal of light?

MR. BUTTOLPH. I believe that most of the tungsten light would go through, so to speak. There might be some absorption in the portion of the spectrum where the mercury lines lie, but it would not be serious. Why not do the reverse: why not put the image of the mercury arc in the plane of a tungsten filament grid?

MR. WOLF: Can Mr. de Jong tell us something about the extremely high-intensity light-sources being used on airplane landing fields in Holland, and whether or not they are applicable to photography? I saw one at Eindhoven, and I never saw a source that could equal it in brilliancy.

MR. de JONG: We have some lights that are used for landing fields, which can be concentrated very nicely, and will light up almost the entire field. I can not tell exactly how the system works.

As to photography, very good pictures can be made with the lamp, especially by combining floodlights and spotlights with the vapor lamps. The lamp is now at the point of coming into practical use, and I do not believe that I can tell very much more about it.

MR. JOY: Why is it not possible to start the lamp immediately when it happens to go out?

MR. BUTTOLPH: Starting an arc of this kind is a matter of ionizing the mercury vapor. We have no way of doing so at a pressure of more than a fraction of an atmosphere, even with very high voltages. What all the reasons are, I am unable to say. The deionization time is fairly long, and will carry over nicely even on 25 cycles. But once the arc is entirely out, it is difficult to reëstablish it.

MR. FARNHAM: Answering Mr. Kellogg's question, in some experimental work on the lamp, when we tried to project incandescent light through the arc screen, the lens characteristics of the quartz tube interfered somewhat. Possibly more can be accomplished by using a better shape of tube, perhaps in the form of a cylindrical lens.

We have had some success in starting the arc immediately after it has gone out, by using the high-frequency discharges of an ultraviolet ray machine, which start the arc immediately.

MR. BUTTOLPH: That is our regular laboratory practice. We have been unable to apply it practically to lamps operating at full temperature.

MR. KELLOGG: When we were discussing the possibility of superimposing the arc image upon a tungsten filament, it did not occur to me that the hot tungsten might be used as a mirror to reflect the arc, in addition to producing its own radiation. Such a plan, however, seems to me to present some practical difficulties, whereas the other should be quite easy.

STANDARDIZATION OF MOTION PICTURE MAKE-UP*

M. FACTOR**

Summary.—*The use of make-up is traced briefly from its earliest application in the theaters of ancient Greece to the present time, and the relation between make-up and the various forms of lighting from one period to another is alluded to.*

The paper continues with a detailed discussion of the relation between the characteristics of the present make-up components and the color-sensitivities of various types of film. Data are given for the various make-up materials in units of color according to the Lovibond tintometer glasses; photographic reflecting powers are given; and curves are presented showing the spectral transmittance curves of the Lovibond glasses to match various make-up materials.

HISTORICAL

The use of make-up dates back to the earliest historical times. We know that it was used in all the ancient civilizations. During the Golden Age of Greece, the leisure classes used the various make-up mediums such as are used today. They knew of powder, foundation creams, lip pomade, mascaro, and nail staining. In Rome, during the time of Christ, the application of make-up became an art. The hair was bleached as well as dyed, and certain portions of the body were tinted; for example, the knee-caps and the bottoms of the feet were colored and the toes were tinted. The make-up powder known as *Cyprius*, came from the island of Cyprus.

In the theaters of both Greece and Rome, make-up had a position of lesser importance. The players, instead, depended upon masks for the various characterizations. However, during the revels of Dionysius, certain of the revelers, who were to mourn for dead persons, stained their bodies in appropriate symbolic colors. From these revels sprang the Greek tragic plays and the origin of the theater. In the Grecian theater, make-up was not used for character protrayal; but instead, the characters were indicated by the use of masks of various shapes and colors to symbolize the characters. In the beginning, by changing masks, one actor portrayed all the various parts.

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

** Max Factor, Inc., Hollywood, Calif.

Primitive masks were used in the ceremonial dances and theatricals of aboriginal peoples. In the Aleutian Islands, New Zealand, Siam, and other countries, the masks may still be seen. In the ceremonials, in addition to the masks, the bodies were often covered with grease and earthy pigments. The American Indian, who did not use masks as a rule, painted his features for war dances. In certain ceremonies he used masks representing animals.

The use of masks continued in practically all forms of dramatic entertainment until about 1600, the time of Queen Elizabeth, when they were discontinued and pigmented powders substituted for them.

Between 1500 and 1600 the art of make-up was indeed crude. The actors at that time very carelessly made themselves up to represent Harlequin, Punchinello, and other characterizations of the period. They often used white chalk dusted over their bodies, and wigs for their heads. Make-up was of secondary importance.

The theaters were crudely lighted by oil-burning lamps, tallow candles, and iron baskets with resinous woods. Because of the subdued lighting, make-up in light tones was used, and from that time on actors handed down their make-up secrets from generation to generation.

After 1800, stage lighting changed from crude oil illumination to the better, more efficient gas lighting. Through the passing years the art of make-up and theater illumination depended upon each other. Prior to 1850, dry colors were applied directly upon the natural skin or dusted upon a grease foundation.

About 1880, when the electric light was invented, a new impetus was given the theater and a new demand placed upon make-up. It was about this time that stick grease paint made its first appearance, as an invention of a German actor touring the United States.

By 1890 the making of stage make-up materials came into such wide use that their manufacture attained a commercial scope. About 1900, when the first motion pictures were in practical use, make-up, borrowing the technic from the stage, came into use when the first studios installed electric lights.

The first *motion picture* make-up was of a pink color, due to the fact that the photographic emulsions were of the orthochromatic variety. However, since orthochromatic emulsion is not sensitive to the yellow-red of the spectrum, the faces of the players with pink make-up photographed in an artificial looking tone.

It may be recalled that the very early motion pictures were centered around more or less standardized types of characters, among which were the villain, the hero, the heroine, and perhaps the father. The villain usually did not apply a coat of make-up—that would have improved his appearance a little too much: a dark blemished skin was more to be desired. The villain usually wore a long mustachio, and heavily painted eyebrows. The hero, on the contrary, applied make-up in quantities. His lips were usually elaborately painted, and his face was as white as the heroine's, which was, indeed, white. The heroine affected long curls and bore much make-up.

The secondary players in those early dramas depended upon a coat of the pinkish grease paint and penciled eyebrows.

In the photographic processes, make-up is used to add certain pigmentations to those of the human face so that the photographic reproduction will coincide with the visual; that is, for correct and natural photographic reproduction, the face must monochromatically reproduce in a range such as the eye normally visualizes.

The eye sees yellow more readily than any other color, with a relative proportion of more red than blue. The photographic emulsion, on the other hand, does not record in the same manner. As is known, the panchromatic photographic emulsion has a high sensitivity in the blue, with a proportionately lesser sensitivity in the red.

The characteristics of the Mazda illumination, on the contrary, as used on the motion picture sets are relatively low in the blue and very high in the red end of the spectrum. The characteristics of photographic emulsions that are particularly sensitive to the blue give rise to the condition of a too dark color rendering in the red end of the spectrum and too light in the blue.

The human face without make-up does not photograph smoothly because of the irregular distribution of the pigmentation that gives color to the skin. This difficulty is remedied in still photography by suitable retouching. Make-up in motion picture photography serves to correct the condition by presenting to the camera a well balanced and uniform distribution of color tones that reproduce upon the screen in monochrome an effective interpretation of what the eye would normally see. The purpose of make-up, then, is to add to the face sufficient blue coloration in proportion to red in order that the photographic tonal rendition will be such as the eye sees in real life, and to prevent excessive absorption of light by the face.

The psychological problem must also be considered. A combination of the correct blue-violet and yellow-orange with sufficient blue in a range that would be desirable for a correct panchromatic recording would result in a brownish make-up. On the motion picture set before the camera, this brownish make-up would distinctly affect the psychological responses of the players; for example, if two players were enacting an emotional scene and had to look at each other in unnatural colors, a certain interference of response would result. Even though containing the desirable panchromatic colors in the make-up composition, the make-up must be sufficiently natural to overcome this psychological factor.

This is accomplished by adding to the composition of the make-up a medium that has a comparatively high reflection in the yellow-orange range (about 6000 Å). In compounding the make-up with

TABLE I

Make-Up Composition According to the Lovibond Tintometer Glasses

Make-Up Material	Units of Color		
	Minus Green	*Minus Blue*	*Minus Red*
No. 31 Panchromatic foundation	9.5	7.00	1.00
No. 31 Panchromatic powder	4.70	3.00	0.06
No. 21 Panchromatic foundation	3.00	0.95	0.00
No. 21 Panchromatic liner	10.00	1.70	4.21
No. 5 Moist rouge	10.00	1.70	4.80
No. 9 Moist rouge	16.00	10.00	7.00
No. Studio Special rouge	14.00	7.00	6.00

this problem in mind, the dominant hue of the make-up material is held as near 6000 Å as possible; at the same time sufficient pigments of the valuable photographic colors are added to assure correct photographic rendition while still maintaining a semblance of natural visual coloration of the skin.

This problem is solved to an extent by balancing the colors in the make-up; that is, a certain relative proportion between the yellow and blue in contrast to the red is maintained. To give body and to hold make-up in a natural skin color range, sufficient quantities of the red-yellow and non-color-selective material are added.

The different densities and panchromatic values of make-up are controlled by thus balancing the three unit colors. The effect of these three colors in relatively equal concentrations results in a gray or black when applied to the face, as they act as subtractive colors, while a lesser color concentration of any one of the elements alters the hue in favor of the other two. For example, in the panchromatic moist rouges, series *5* to *9*, the color concentration increases proportionately more in the yellow and red than in the blue (very little blue is needed to affect the make-up color materially). The increase in color results in a make-up that is darker both visually and photographically.

This proportionate increase may be seen in Table I. The data were obtained with the Lovibond tintometer and glasses,* for analytical studies by the subtractive method, and the researches and comparisons were conducted by Capt. H. B. Haselden of the Henry E. Huntington Library, R. E. Farnham, G. A. Chambers, and W. E. Theisen in collaboration with the Max Factor staff.

The Lovibond tintometer glasses were used in lieu of other color analyzing systems because of their practicability. The color absorption of the glasses was analyzed and data presented by Gibson and Harris[1] of the U. S. Bureau of Standards. According to these authors, certain irregularities appeared in the graduation of the Lovibond glasses, although for purposes of the present study of make-up these errors are too small to be of sufficient importance.

In making the analysis of the color compositions of the make-ups in terms of the Lovibond tintometer glasses, a Bausch & Lomb comparison microscope was used. The usual calcium sulfate screen, which is employed as a standard white in the Lovibond tintometer, was placed in position so that light reflected from it filled one-half of the two-part comparison field. A sample of the make-up to be measured was likewise positioned so that light reflected from it filled the other part of the comparison field. The calcium sulfate screen and the sample were both illuminated by sunlight. In order to obtain a color balance in the comparison field, suitably selected Lovibond tintometer glasses were positioned so that the light reflected from the calcium sulfate screen was filtered thereby, thus modifying the color of the comparison field until it matched the part of the field illuminated by light reflected from the make-up sample. From a knowledge of the spectral absorption of the various Lovibond glasses found necessary to produce a match, it was possible to compute the spectral composition of the light in the comparison field. These spectral absorption data were taken from those published by Gibson and Harris.[1]

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* J. W. Lovibond, Salisbury, England.

In Fig. 1 the dotted curves represent the spectral transmittance values for the 3.0 minus green and the 1.0 minus blue Lovibond tintometer glasses which were found necessary to match the No. *21* panchromatic foundation. By multiplying together the ordinates of the two curves, wavelength by wavelength, the solid curve is obtained, which gives the spectral transmittance of the combined glasses. This curve shows the spectral distribution of radiant energy that will produce a subjective match with the No. *21* panchromatic foundation. It should be kept in mind, however, that the spectral reflectance of

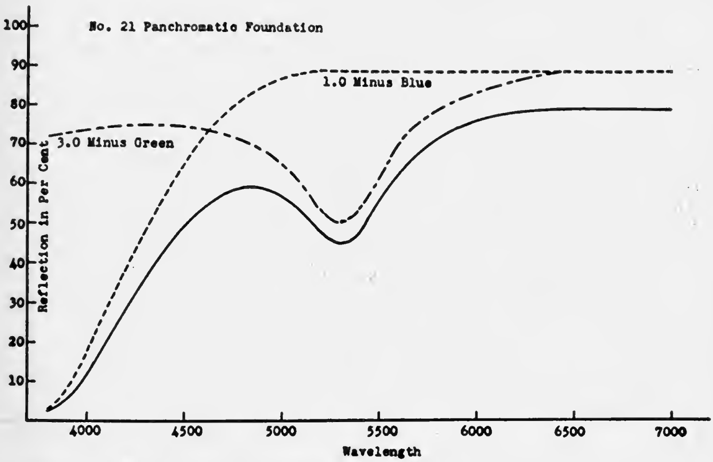

FIG. 1. Spectral transmittance curves for 3.0 minus green and 1.0 minus blue Lovibond tintometer glasses to match No. *21* panchromatic foundation.

the No. *21* panchromatic foundation may not necessarily be the same as that indicated by the solid curve of Fig. 1. It is quite possible to find different spectral distributions of radiant energy that will produce a subjective match with the distribution as indicated by the solid curve. This follows from the fact that the eye, in terms of which the color match was made, is not an analytical sensitive receptor. It is well known that two colors that appear identical to the eye may differ markedly in spectral composition. However, the solid curve of Fig. 1 is of considerable value as an indication of the appearance of the No. *21* panchromatic foundation. For instance, the fact that the ordinates of this curve in the region between 5500 and 7000 Å are relatively high, as compared with the ordinates in the region between 4000 and 5000 Å, indicates that the No. *21* panchromatic foundation is reflecting a predominance of the longer wavelengths, and is absorbing rather strongly the shorter wavelengths of the visible spectrum to which panchromatic photographic materials are relatively quite sensitive.

In Fig. 2 is shown a similar analysis of the data relative to the No. *31* panchromatic foundation. In this case three Lovibond tintometer glasses were required to produce the desired color match, and the dotted curves represent the spectral transmittance of the three glasses

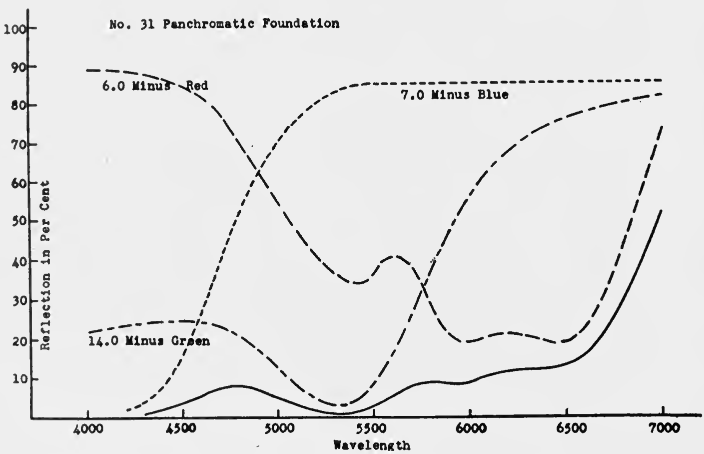

FIG. 2. Spectral transmittance curves for 3.0 minus green and 1.0 minus blue Lovibond tintometer glasses to match No. *31* panchromatic foundation.

used, while the solid curve is computed by multiplying the ordinates of all three of the components together, wavelength by wavelength. Here again the solid curve gives the spectral distribution of the light transmitted by the three glasses combined, and hence indicates a spectral distribution (but not necessarily the only one) that will match the No. *31* panchromatic foundation.

In Fig. 3 the same analysis is shown for the studio special rouge. The fact that the ordinal values of the solid curves of Figs. 2 and 3 are appreciably less than those of the solid curve of Fig. 1 indicates that the No. *31* panchromatic foundation and the studio special rouge have appreciably lower total reflectances than the No. *21* panchromatic foundation. This conclusion is verified by the data shown in Table II.

In order to ascertain the photographic reflecting power of the make-up, L. A. Jones, of the Kodak Research Laboratories at Rochester, N. Y., furnished data obtained with the photographic reflectometer, described in 1932[2] in the JOURNAL. The Lovibond readings give a subjective evaluation of the color of the make-up materials as seen by the eye, while the photographic reflectometer values translate these colors into their relative monochromatic brightness as seen by the photographic emulsion.

In measuring the photographic reflecting powers of the samples, the

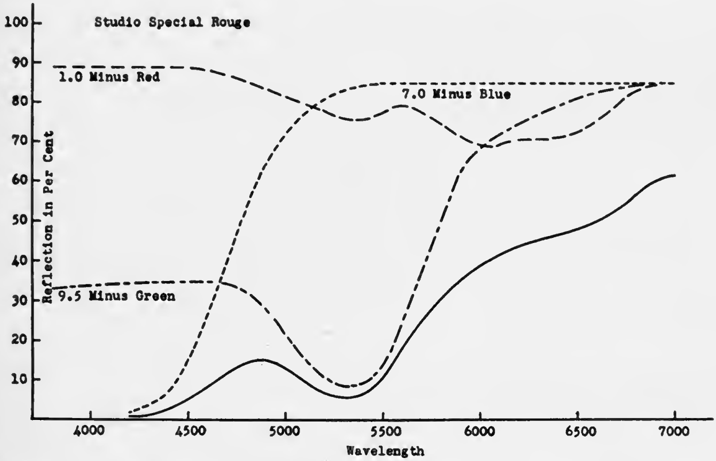

FIG. 3. Spectral transmittance curves for 3.0 minus green and 1.0 minus blue Lovibond tintometer glasses to match studio special rouge.

illumination of the samples was derived from a tungsten lamp operating at a color temperature of approximately 3400°K. This illumination was incident at an angle of 45 degrees from the normal to the surface, and observation was along the normal to the surface. The photographic material, in terms of which the evaluation was made, is the Eastman supersensitive panchromatic motion picture negative.

The rouge and foundation were used in layers sufficiently thick to be practically opaque. The powders were dusted over a thin film of the foundation, the application being quite generous so as to attain a fairly complete coverage with the powder. Table II shows the values obtained.

Although the measurements were not made under what might be called practical studio conditions, the quality of the light was virtually identical to that of the Mazda illuminants used upon the set. The readings, therefore, represent the integrated actinic effect of the color with respect to the light-source and the color-sensitivity of the emulsion used for the determination.

The need of a standard make-up was particularly emphasized with the introduction of the panchromatic emulsion. As the result of a series of experiments made at Warner Bros. Studio in Hollywood in February, 1928, the Max Factor panchromatic make-up was adopted. Subsequently to these experiments, the panchromatic film, the Max Factor panchromatic make-up colors, and Mazda illumination were introduced.

TABLE II

Photographic Reflecting Powers

	(Per Cent)
No. 5 Moist rouge *390* light	14.2
No. 9 Moist rouge *390* dark	7.6
Moist Studio special rouge	5.2
No. 21 Panchromatic foundation	61.9
No. 31 Panchromatic foundation	23.3
No. 21 Panchromatic powder	70.5
No. 31 Panchromatic foundation powder	38.8
No. 22 Panchromatic liner	6.1

To assist with these problems the author set out to introduce a standardized series of make-up colors. At that time, because of lack of suitable colorimetric instruments and a knowledge by the industry of its needs in this respect, a trial-and-error method was used to develop a practicable motion picture make-up. The primary purpose was to balance the make-up colors correctly, and to recognize the relations between the motion picture mediums. Second, it was necessary to present a make-up material in a form that would be practicable. Because the old theatrical stick make-up was not easily applied and was unsanitary, the unguent form of make-up, with a base composed of vegetable oils, was introduced in a collapsible tube. Soon the old theatrical stick make-up was discarded in favor of the unguent panchromatic foundation color.

The unguent base aided in the manufacturing processes since the pigments could be introduced in closer balance and could be added in finer and smoother forms. This makes possible a thinner application, permitting a freer use of the facial muscles and leading to better acting by the players. Because of the fineness of the pigment in the unguent panchromatic make-up, it is possible to apply a desired protective color coating adequately without an unduly heavy application of the make-up.

By experiment it was found that a range of panchromatic colors, numbered from *21* to *31*, would be sufficient for motion picture use. From the *21 pan* foundation make-up, with no blue in its composition, the photographic absorption increases proportionately up to the *31 pan*. Referring to Table I, this increase from the *21* to the *31* is in the photosensitive colors; that is, in the blue end of the spectrum. In this range the photographic reproduction of the progressive numbers becomes proportionately darker. As the colors darken their yellow and blue contents increase, with relatively less increase in the red pigmentation.

The panchromatic powders ranging from No. *21* to *31* correspond in color pigmentation to the unguent foundation of the same numbers. Visually, because of the weaker total light absorption of all the spectral colors, they appear relatively lighter than the corresponding pan foundation. The powder serves the purpose in make-up practice of eliminating sheen and reflection, and of fixing the unguent foundation. It is desirable to use the powder of the same number as the foundation.

The moist rouges in a paste-like unguent are designed chiefly for lip make-up. The red and blue are balanced sufficiently to attain the desired photographic tonal contrast with respect to the foundation colors. The studio special rouge, which is widely used in motion picture practice, visually appears redder than the series *5* to *9* rouges, due to the greater proportion of red and yellow in its composition.

Correct application of make-up and subsequent correct balance of illumination and photographic exposure result in the desired photographic image in monochrome. When this balance is correctly attained the features of the players are well defined, and a certain roundness or perspective is maintained. Because the camera records in a two-dimensional plane, it is one of the problems of make-up so to control the photo-reproduction of the features of the players that their faces reproduced upon the screen have the appearance of roundness. The natural facial form is suggested by building contrasts of light and shadows, and the make-up composition is such as to give a correct photographic rendering in monochrome.

Throughout the various cinematic moods and characteristics of the settings, there is a great variation of intensity of illumination upon different parts of the set. For example, the face in strong, direct light reflects more yellow and orange, while the blue is, to an extent, absorbed. By contrast, in indirect illumination this condition is changed, and the reproduction has a tendency to be darker than natural. The results are different, too, in light containing an abundance of infrared, as is the case with certain of the studio lights and not so with other lights upon the same setting. The make-up provides a protective coloration that is theoretically a balance for a variable lighting condition.

It is the problem of make-up so to compose its colors and inherent characteristics that a wide photographic tonal range can be covered. That is, the player must be able to progress through light beams from various sources without too sharp contrasts. The made-up face must reflect relatively more light in the shadows than in the direct lighting.

Make-up, besides furnishing the necessary protective coloration for the photographic processes, is also used to aid characterization. Angular faces may be softened by a cleverly balanced use of light and darker patches of make-up. Wide faces may be made to seem narrower by artificially adding shadows to the sides of the face. Certain features must be defined and outlined in keeping with the desired characterization. Many effects and results, which are beside the point of this paper, are gained by an artistic application of make-up. Make-up is an artist's tool, and for clever characterizations its application depends upon artistic skill. The make-up artist must have a sense of light and shade, facial contours, and the relationship of the face to the desired characterization, all based upon the photographic reproduction in monochrome.

The author is particularly indebted to Mr. E. W. Theisen and Dr. L. A. Jones for assistance in the preparation of this manuscript.

REFERENCES

[1] GIBSON, K. S., AND HARRIS, F. K.: "The Lovibond Color System; a Spectrophotometric Analysis of the Lovibond Glasses," Scientific Paper No. 547 (Feb. 17, 1927), p. 1, *U. S. Bureau of Standards,* Government Printing Office, Washington, D. C.

[2] JONES, L. A., AND MCFARLANE, J. W.: "The Precise Measurement of Filter Factors and Photographic Reflecting Powers," *J. Soc. Mot. Pict. Eng.,* **XIX** (Oct., 1932), No. 4, p. 364.

A RECORD WORD-SPOTTING MECHANISM*

R. H. HEACOCK**

Summary.—*The record word-spotting mechanism described here places the pick-up needle upon a predetermined spot on a phonograph record by pressing a remotely located release button after three reference readings, previously established by the trial and error method, have been properly set. The pick-up arm is held poised above the record by a direct electromagnetic pull upon the back end of the pick-up arm. When the electromagnet is de-energized, the pick-up falls due to the pull of gravity. The speed of fall may be controlled by means of an adjustable exhaust port on an air dashpot. No catches or latches are used in releasing the arm. A manually operated open-circuiting release button is in parallel with a second open-circuiting switch in the electromagnet circuit, the second switch being opened each revolution of the turntable by a cam. To release the pick-up, the manually operated button is depressed, but the pick-up is not released until the second switch is cammed open by the turntable. In this way the device is indexed with relation to the radial position of the record so that not only may the correct groove be repeatedly selected, but the desired portion of the groove may be consistently repeated. The effect of eccentricity of the center hole of the record with relation to the recorded grooves is also eliminated. Variations in the size of the record hole are accommodated by means of a tapered centering pin. Each of the mechanical parts, with the exception of the cammed turntable switch, is rigidly located on the single pick-up arm unit. All necessary electrical parts for complete operation of the mechanism on 105- to 125-volt, 50- to 60-cycle alternating current are located on the under side of the motor board.*

HISTORICAL

One of the main differences between an entertainment program of today and that of ten years ago is the naturalness of atmosphere of the presentation. This is true whether the source be the stage, talking picture, or broadcast studio. On the stage, sound reinforcing systems assure clear reception of every sound by each patron in the theater, no matter how far he may be from the footlights, and these systems also permit the easy introduction of certain background and supporting sounds which greatly add to the realism of the performance. Naturally, talking pictures and broadcast studios are

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* Received September 21, 1936; presented at the Fall, 1936, Meeting at Rochester, N. Y.

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

faced with broader sound effects requirements since many of the scenes portrayed are supposedly happening under unusual conditions, as in aeroplanes, automobiles, trains, or upon busy highways, where it is essential that background sounds provide the necessary "color" in the establishment of the idea of seeing and hearing these actual occurrences. We are all familiar with the many sounds that are later dubbed into the final sound-track. What leaves Hollywood with only an original dialog on the sound-track may have many different sounds dubbed in to indicate a change of scene from a busy street to a quiet lobby and then to a hilarious night club dance floor. In the broadcast studio, Captain Henry's "Showboat" with its churning paddle wheel and deep whistle, Fred Allen's cheering crowd as it enters Town Hall and the Town Hall News with its falling curtain, "lights out," and clicking projector add a very necessary touch of realism to the performances.

Many of the simpler sounds are made by special gadgets. When sheet cellophane is lightly crumpled it gives the cheery crackle of the campfire. If crumpled more slowly with somewhat greater pressure, the sound becomes that of frying bacon and eggs. When a clothesbrush is drawn very, very slowly across a taut drumhead, a downpour of rain is reproduced, and eccentric swishing of the brush upon the drumhead produces the ocean's roar on the beach. Two plumber's vacuum cups, when beaten upon the demonstrator's chest, reproduce Paul Revere's horse, and when transferred to a table top the horse's pounding upon a wooden bridge is accurately reproduced. In addition to many of the simpler sounds, it is essential for the proper presentation of many programs that sounds that are much more complex be obtained from already existing phonograph records, *e. g.*, a record is cut in immediately following an actor's cries of "Fire!" reproducing the roaring motors, screaming sirens, and yells of the excited crowds.

In the past, sound effects devices have been constructed in an attempt to make the recorded sounds available for use in the regular program. In general, the limiting and most disappointing feature of such devices has been the spotting mechanism for placing the needle upon the record at a predetermined point. Units have been constructed with high-gain amplifiers and high-fidelity speakers so that it has been possible to control the volume satisfactorily, as well as the response, through the use of convenient mixer networks to mix and control the overall output level properly when actual sound is desired or by means of mixer network alone when it is desired to mix electrically.

The spotting mechanism, however, has generally been a rather complicated and not entirely trustworthy device. Latches that are supposed to be released when, and only when, an associated electromagnet is energized frequently engage the pick-up arm release so securely that the electromagnet can not disengage the latch, and instead of the expected sound, nothing but an empty period of silence, lasting until some quick-thinking person steps in to "cover up," follows the moment the sound effect device has been cued in. If the contact face of the latch has been altered to permit easier disengagement, frequently the arm will drop upon the record ahead of the time desired if a slight jolt should disturb the equipment.

Since other spotting mechanisms used in the past have been released entirely independently of the radial position of the turntable with relation to the pick-up arm, it is evident that if a record is used, the center hole of which is eccentric with relation to the recording grooves, a variation in the point of contact between the needle and the record will be introduced, which is extremely serious and which may amount to several grooves, one way or the other, depending upon the radial position of the record with relation to the pick-up arm.

DESCRIPTION

The difficulties that have been outlined above have been carefully considered in the design of the spotting mechanism, and it is felt that each has been overcome. The record word-spotting mechanism is a device that will, with extreme accuracy, place the pick-up upon a predetermined spot on a record, so that the sounds recorded at this predetermined spot may be reproduced and mixed with the regular program. The mixing process may be accomplished acoustically or it may be accomplished electrically. Acoustical mixing involves the use of amplifiers and speakers, while electrical mixing makes use of a proper mixing network to feed the pick-up output into an external line.

The pre-locating tone arm (Fig. 1) consists essentially of an upright tone arm support in which is mounted the swivel arm member of the tone arm. A tilting member, at the outer end of which is affixed the turntable pick-up, is mounted in a horizontal swivel in the divided portion of the swivel arm. The tilting portion of the tone arm is held up, by means of an electromagnet, in such a manner that as the tone arm is swung laterally the pick-up may be poised, at any point in its swing, over the record. An adjustable counterweight is provided on the tilting arm to regulate the pressure at the needle point.

A release push-button (Fig. 1) is connected in parallel with another switch located on the motor board (Fig. 2). When the release push-button is depressed, and the latter switch opened by means of a fixed cam on the under side of the turntable, the magnetic circuit is opened, thus permitting the tilting arm to fall and the pick-up needle

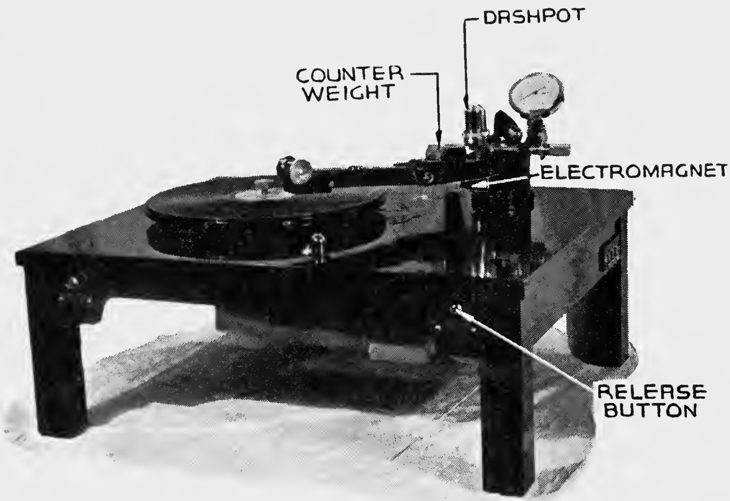

FIG. 1. Mechanism in operating position poised above record.

to engage the record. Since the cam switch opens the circuit of the electromagnet always at the same radial point on the turntable, regardless of the time within the revolution that the release push-button is depressed, the pick-up needle always engages the record at a fixed radial angle from the switch-opening cam.

A white spot on the edge of the sound effects record (Fig. 2) is indexed with relation to engraved figures upon the turntable rim. The record is centered and excess clearance eliminated by means of a tapered centering pin (Fig. 2).

The speed of fall of the pick-up is determined by the adjustment of a small dashpot attached to the rear of the tilting arm (Fig. 1). In order to locate the radial position of the arm accurately with relation to the record, there is located on the top of the vertical pivoted portion of the tone arm and rigidly attached thereto a gear engaged by a pawl (Fig. 3). This pawl is supported by a pawl plate located immediately above the gear so that a notch in the plate will expose one, and only one, tooth of the gear at a time (Fig. 4). Each exposed tooth is of a different color, permitting indexing the tone arm for radial position.

A tilting adjustment (Fig. 3) is provided upon the upright support of the tone arm so that when the pick-up is at rest (*i. e.*, not playing

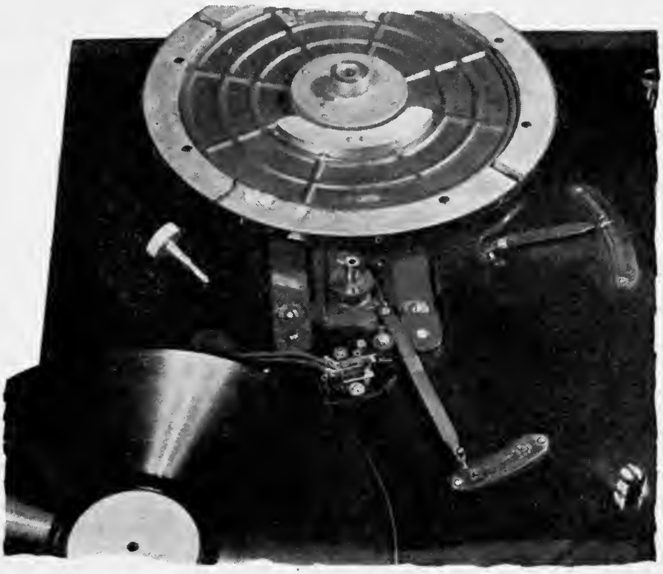

FIG. 2. Turntable and associated parts.

a record) it will rotate slowly toward the right in such a manner that the heel of the pawl will engage the spindle of a micrometer head (Fig. 4). This micrometer head is equipped with a dial gauge, giving an outer dial and an inner dial reading. It is to be noted that one revolution of the indicator of the outer dial is equivalent to the movement of the indicator from one number to the next upon the inner dial. Care must be exercised to see that the pawl is properly engaged with the correct tooth on the tone arm gear.

The colored teeth on this gear provide the main sectors of indexing, with the accurate setting in any one sector shown upon the dial gauge. Thus, both the color of the tooth and the reading of the dial gauge determine the radial position of the arm with relation to the record. Consequently, with the white dot on the record placed opposite one of the numbers on the turntable rim, the proper setting with relation to the gear color and dial gauge reading will insure the accurate placement of the needle upon a predetermined spot on the record.

It is to be noted that as the white dot on the record edge is moved clockwise or counter-clockwise, syllables or notes may be subtracted from or added to the original point of contact of the needle on the record.

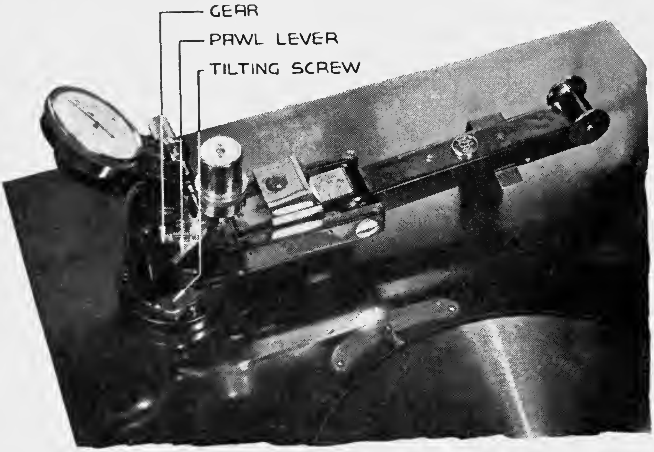

FIG. 3. Pick-up arm adjustments.

Since both motions of the tone arm mechanism are dependent for operation upon gravity alone, and no latches or catches are present, there will be no sticking or jamming of the mechanism.

From the foregoing description of the device, it is evident that the precision with which the mechanism operates makes it possible to index any specific sound in a card file by means of the record number and three separate readings; namely:

(*1*) The color of the gear tooth exposed by the notch in the pawl plate.

(*2*) The inner dial and the outer dial readings of the micrometer dial gauge.

(*3*) The location of the white dot on the record with respect to the engraved numbers on the turntable rim.

In this way, the usual "hunting" for the desired sound is eliminated, and such sounds are made as fully available as the various volumes in a properly indexed library.

OPERATION

To reproduce a desired sound, the procedure should be as follows: The record is placed upon the turntable, and the centering pin is replaced firmly in order to center the record and remove any excess clearance between the record and the pin. The tilting adjustment screw is set so that the arm rotates slowly toward the right when

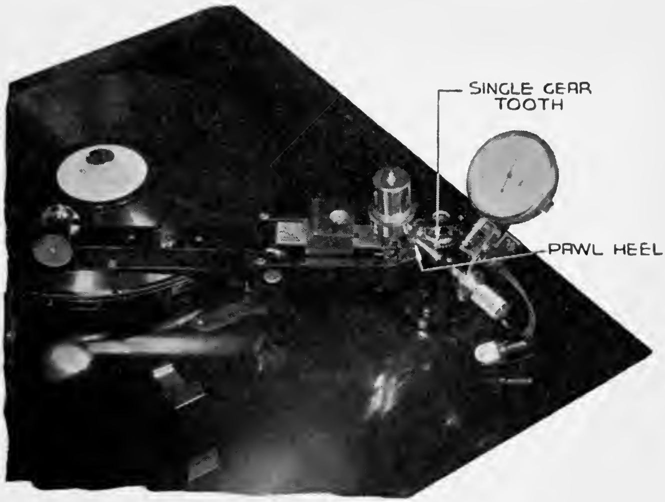

FIG. 4. Pick-up arm with gear light removed.

held poised above the record. The micrometer head is set to indicate approximately zero on its dial indicator. The record is played in the normal manner, and when the desired sound is heard the phonograph motor is immediately shut off. The left forearm is rested lightly on the tone arm in order to prevent dislodging the needle from the record groove. The pawl is then released by drawing the pawl lever away from the axis of the tone arm support with the index finger of the left hand. The pawl plate is rotated until the pawl heel is brought into contact with the spindle of the micrometer head. The pawl lever is then released so that it will engage the nearest gear tooth away from the spindle of the micrometer, and the pawl is locked into mesh with the gear by applying pressure on the pawl lever toward the axis of the tone arm support. The micrometer head is next adjusted until its spindle contacts the pawl heel, and the spindle is backed off approximately thirty units on the outer scale of the dial indicator, to compensate for the coasting of the motor after power has been shut off. The pick-up is raised so that the electromagnet holds it poised above the record. The mechanism is then released by depressing the release button and it is noted whether the needle contacts the record ahead of or behind the desired sound. Then the

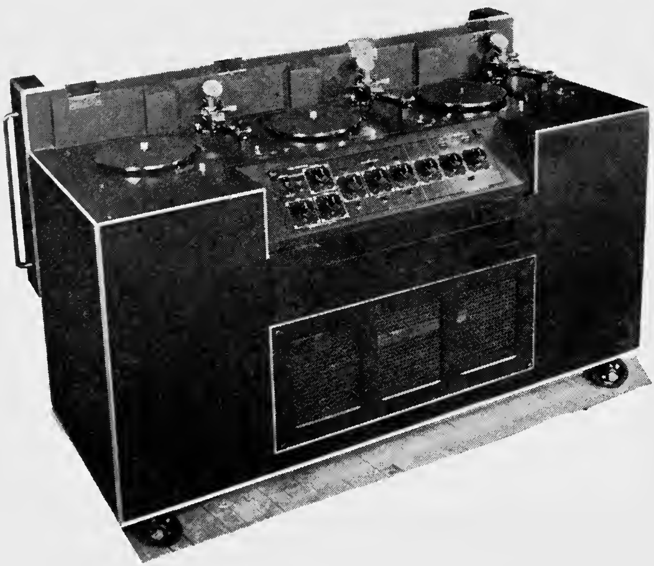

FIG. 5. Sound effects phonograph unit for National Broadcasting Company.

micrometer adjustment is moved in or out, as may be necessary, keeping in mind that approximately ten points upon the outer scale of the dial indicator is equivalent to a movement of one groove at the needle point. Continue in this manner by the trial and error method until the needle consistently engages the proper groove. Precise adjustment is then made by rotating the record with relation to the turntable until the pick-up needle falls upon the exact point of the record for the desired sound. A rotation of the record through approximately ninety degrees will add or subtract (depending upon the direction of rotation) a short word or a syllable.

ADVANTAGES

The device has the following advantages:

(*1*) Simplicity: There are no locking catches or mechanical latches used in either the up and down motion of the pick-up arm or in the rotary motion of the arm. Gravity alone controls both the motions. Consequently, there is no possibility of sticking or jamming, and it is not necessary to make any very accurate adjustments of either of these motions.

(*2*) Once the needle is engaged by the record groove, the arm is as free to move in any direction as a manually operated arm. There are no springs or other constant loads tending to force the needle in any direction.

(*3*) Since the pawl heel is in engagement with the micrometer head until the needle is actually pulled away by the record groove, there is no possibility of inaccurate lateral wavering of the pick-up arm after release or before engagement with the record groove.

(*4*) Since the tapered centering pin accurately centers the record by removing all "play" between the record and the pin, and since the rotary position of the record with relation to the turntable is fixed, it is possible to replace the record upon the turntable and bring the needle down upon the exact word or sound that may be desired by pre-setting the device.

(*5*) Even though recorded grooves may be eccentric with relation to the center hole, the device will still function perfectly satisfactorily.

(*6*) Since the beginning of fall of the pick-up arm is indexed by the record itself, it is possible to spot a fixed sound accurately very much more readily than with a device that is not indexed according to the rotary position of the turntable.

(*7*) Each of the mechanical parts, with the single exception of the cammed turntable switch, is rigidly located upon the single pick-up arm unit. This makes it possible to move the arm and use it in combination with any turntable with satisfactory results, without locating the parts accurately with relation to each other on each new set-up.

POSSIBLE USES

Figs. 5 and 6 show a typical example of a *de luxe* application of the mechanism. Fig. 5 is the phonograph amplifier unit, and Fig. 6 is one of the loud speaker units recently developed and manufactured for the National Broadcasting Company for producing sound effects in their various key studios throughout the country. Although this record word-spotting mechanism was originally developed for the National Broadcasting Company for this purpose, it is evident that the same release mechanism could be used in combination with existing turntable units, amplifiers, and speakers, so that the overall cost of the set-up could be readily controlled, depending upon the specific requirements of each installation.

The overall equipment is extremely flexible in view of the fact that the single fully equipped arm may be set up on any motor board

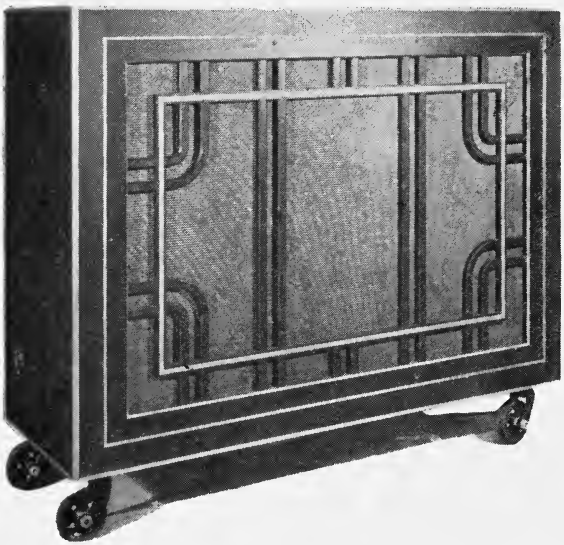

FIG. 6. Sound effects loud speaker unit for National Broadcasting Company.

for use with any turntable as long as the turntable has been equipped with the proper release cam.

Since the release button may be located remotely the device lends itself to stage operation, since the mechanism could be located in the wings and the stage director could personally release the pick-up to provide a realistic scream or other desired sound, which could be properly cued with relation to the rest of the performance. The device is also useful in dubbing sound from already recorded sources on either wax or film. It is satisfactory for use in automatic announcing systems or for any other purposes where certain definite sounds must be reproduced from sources already recorded on records.

A DEVELOPING MACHINE FOR SENSITOMETRIC WORK*

L. A. JONES, M. E. RUSSELL, AND H. R. BEACHAM**

Summary.—*Sensitometric testing of photographic materials requires that the laboratory be able to obtain the same results, with a high degree of precision, for identical samples of material, although the individual tests may necessarily be made at widely different times. All factors tending to influence the results must be held constant over long periods of time.*

A developing machine is described designed for a laboratory in which a relatively large volume of sensitometric work must be done. It accommodates sixty strips positioned vertically on six metal racks, which can be lowered into the developer simultaneously and removed either simultaneously or individually, so that different development times may be given to different parts of the load.

The developer circulation across the face of the exposed material is sufficiently rapid that further increase of agitation produces little if any increase in the rate of conversion of latent image into metallic silver. The circulation is of two sorts: (1) a relatively slow, uniform movement of developer in the vertical direction produced by a propeller that forces the developer down into a well external to the main tank, from the lower end of which it spreads out beneath a perforated false bottom in the tank and rises throughout the body of the tank, flowing back again into the top of the well; (2) a much more violent agitation produced by vertical paddles moving back and forth close to the exposed surfaces. Both agitating elements are driven by a synchronous motor, assuring the same rate of circulation at all times. The entire machine is jacketed by thermostatically controlled water at 65° ± 0.1°F.

Results show that the circulation throughout the body of the tank is so nearly uniform that they are not influenced by (a) whether the heavily exposed end of the sensitometric strip is up or down, (b) the position of the strip within the tank, or (c) whether a complete or partial load of strips is developed at one time. Results indicate also that the agitation is sufficiently violent that the rate of conversion of latent image into metallic silver is at or near the maximum attainable. Uniformity and reproducibility of development is very markedly superior to that attainable with any type of hand- or machine-rocked tray with which the authors have had experience, and the use of the machine marks a very definite advance in the precision with which sensitometric values may be established.

The process of measuring the characteristics of a photographic material by sensitometric methods may be divided, for convenience of discussion, into several distinct steps: (*a*) selecting the sample; (*b*) conditioning the sample prior to exposure; (*c*) exposing the sample

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

in a sensitometer; (*d*) processing the exposed sample; (*e*) measuring the densities in the developed sample; (*f*) plotting the data in graphic form; and (*g*) interpreting the results.

In order to obtain consistent and reproducible values over long periods of time, every step in this process must be controlled to a high degree of precision. In the present communication, we are concerned chiefly with an instrument and a method for obtaining a high degree of reproducibility in processing the material which has been exposed in the sensitometer.

The processing may also be separated for convenience of discussion into several steps, namely: development, fixation, washing, and drying. Of these, development is by far of the greatest importance. While it is true that variations in the washing, fixation, and drying of the developed sensitometric strip may produce some variations in the density of the resultant silver deposits, these variations are relatively small, and it is quite easy to maintain the conditions of washing, fixing, and drying sufficiently constant so that no variations can be attributed to these processes. On the other hand, it is extremely difficult to maintain the constancy of development with sufficient precision to eliminate errors arising from variations in the development process. For instance, the density of the resultant silver image depends upon the constitution, concentration, and temperature of the developing solution, and also upon the time of development, and very profoundly upon the degree of agitation of the developing solution.

The present discussion is confined largely to methods of maintaining constancy of temperature, time, and agitation.

During past years in most sensitometric laboratories the development of the exposed sensitometric strips has been carried out in hand-rocked or possibly machine-rocked trays. Where the number of strips to be processed is not particularly large and the work can be done by one operator, the hand-rocked tray method is fairly satisfactory. An individual apparently can maintain a rocking technic over relatively long periods of time that will give consistent results, but it seems to be very difficult for two or more operators to learn rocking technics that will give results agreeing with each other. Hence, if the volume of work is such that several operators are required, the hand-rocked tray method leaves much to be desired.

Many efforts have been made to develop mechanical means for rocking trays that will not give definite wave patterns and result in local nonuniformity of development action. Some of these have been quite satisfactory but not entirely so. Here, again, a relatively large number of such devices is required to handle a large volume of work, since a single tray can not accommodate a large number of sensitometric strips. On the whole, the mechanically rocked tray has not proved very satisfactory where a large volume of high-precision sensitometric work is to be done.

Many attempts have been made to build developing machines for this purpose, and some very successful results have been obtained. We shall not attempt to discuss the literature at length, but a bibliography covering some of the more important efforts in this direction is appended to this communication. Suffice it to say that in most cases the design has been from a very specialized point of view, and the machine has not been of such a nature as to accommodate a large number of strips at one time; nor have these designs been such as to be susceptible of redesign in order to accommodate larger numbers of strips.

The enormous increase in the volume of sensitometric work done in this laboratory forced us about two years ago to consider the design and construction of a sensitometric developing machine, and in the following pages will be given a description of this instrument, together with a discussion of the quality of the results attained therewith.

In designing a developing machine to meet our requirements, it was considered desirable to obtain as closely as possible the following characteristics:

(*1*) It should be precisely reproducible from physical specifications.

(*2*) It should produce highly uniform development over that area of the material contributing to the results of the test.

(*3*) The degree of agitation of the developer should be such that any variation would produce little or no variation in the resultant densities.

(*4*) The capacity of the machine should be such as to permit processing a relatively large number of strips at each loading.

(*5*) The quantity of developer per strip should be relatively small.

(*6*) It should be possible to remove part of the strips at various times without disturbing the remainder.

(*7*) The machine should be easy to operate in total darkness.

(*8*) Changing the developer and cleaning the machine should require a minimum of time.

(*9*) The design should permit the use of a convenient and accurate automatic temperature regulator to hold the temperature of the solution within the required limits.

(*10*) The machine should be built of materials not affected in any way by the various developing solutions that must be used.

(*11*) The structure should be rugged and simple so as to require a minimum of upkeep.

In Fig. 1 is shown a cross-section through the developing machine installed in the water bath used for maintaining constant temperature. The developing solution is contained in a rectangular stainless steel tank about 20 inches long, 6 inches wide, and 16 inches deep. The sensitometric strips, which are 12 inches long and 25 mm. wide, are

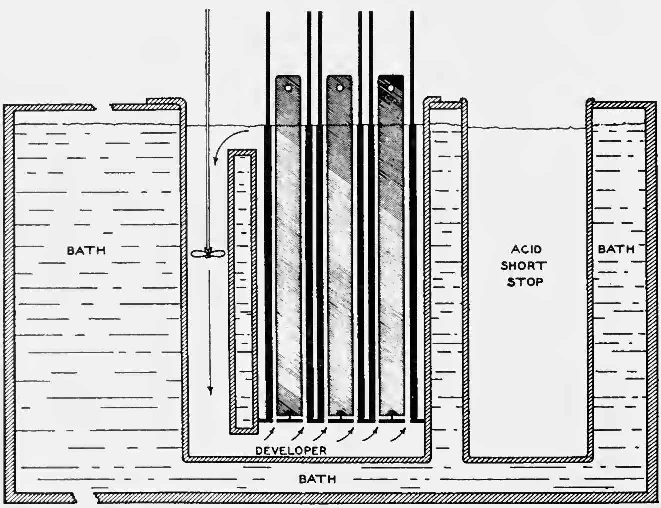


FIG. 1. Cross-section of the developing machine installed in the water bath.

mounted upon racks and positioned vertically in the developing tank. Fig. 3 is a schematic view of the developer tank with the positions of the sixty strips indicated.

At the rear of the rectangular tank in which the strips are developed is a cylindrical well about 3 inches in diameter. This is connected to the bottom and top of the developing tank so that the developer can be forced downward in the well by a propeller type of stirrer driven by a synchronous motor. The structure is such that the developer driven down in this cylindrical well is delivered uniformly to all parts of the bottom of the tank, entering under a perforated false bottom. It spreads out and rises uniformly through the cross-section of the tank, and, as it reaches the top, flows back into the open upper end of the cylinder. The mechanical structure is such that uniform upward velocity of the developer is maintained at every point in the tank in which the strips are being developed. In addition to this circulation of the developer, much more violent agitation is provided by a set of three vertical paddles which are moved back and forth at a fairly high velocity.

As stated previously, the 12-inch sensitometric strips are mounted upon stainless steel racks. When the strips are prepared, two holes

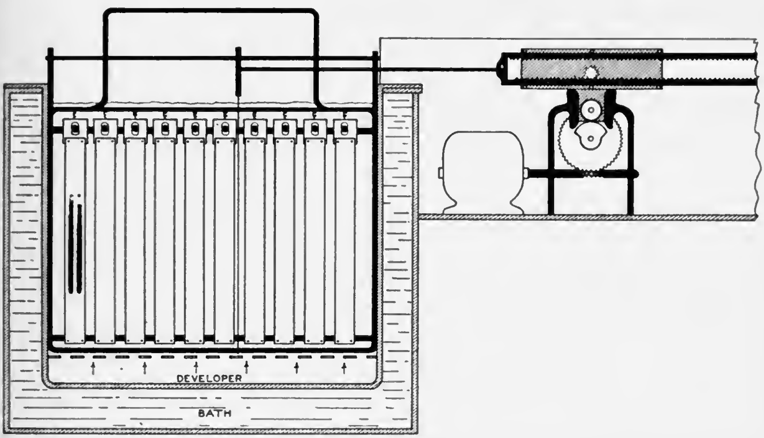


FIG. 2. Schematic view of the driving mechanism, motor, and method of suspending the strips.

are punched at each end. By means of these holes, the strips are mounted upon pins, one pair of which is carried by a coil spring so that the strips are maintained under uniform tension at all times. Ten strips are mounted upon each rack and provision is made for the placement of six racks in the tank at one time.

In Fig. 1, the heavy vertical black lines represent the positions of the racks carrying strips, while the cross-hatched areas represent the paddles. It will be seen that a paddle is positioned between each pair, the emulsion side of the strips facing inward toward the paddle between each pair of racks. These paddles are driven back and forth by a synchronous motor operating through a worm and worm-wheel and a double alternating rack and pinion movement, as indicated in Fig. 2. The velocity of travel of the paddles is such that a complete cycle is made in approximately six seconds.

A superstructure, also of stainless steel, is built onto the tank so that the film holders may be placed in the proper position before being lowered into the solution. Guides are built in the tank to hold the racks in place during development. These guides extend a distance above the surface of the solution so that the operator is able to place the lower end of each rack in its guide while the rack is suspended above the level of the developing solution by means of two arms extending outward from the superstructure. When all is in

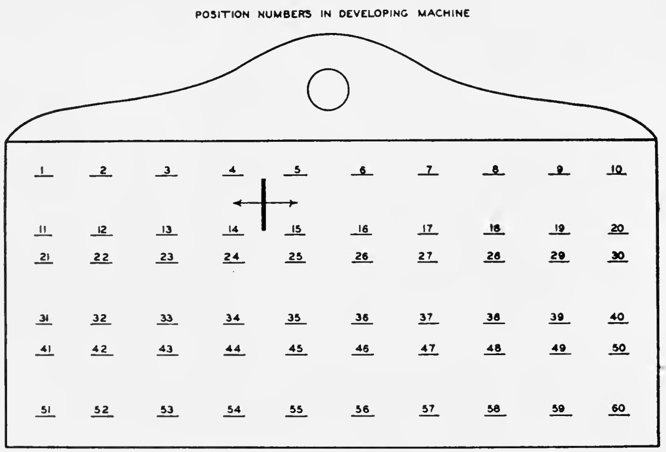


FIG. 3. Schematic diagram indicating the positions of the sixty strips in the developer tank.

readiness, the operator pushes downward on the carriage from which are suspended the film racks. This carriage is counterbalanced by weights so that it stays in its upper position until forced downward by the operator. When the carriage is lowered and the strips are immersed in the solution, the stirring mechanism automatically starts. The two arms supporting the film racks may now be turned back and the carriage returned to its upper position, thus making it possible to remove at any time one or more of the racks without disturbing the others.

When a rack is taken out, it is quickly rinsed in the acid stop-bath mounted immediately in front of the machine (Fig. 1). From there it is transferred directly to the fixing bath which is positioned conveniently to the left of the developing machine. The fixing bath container is also water-jacketed by the constant-temperature bath so that all solutions to the action of which the strips are subjected are at the same temperatures.

It is usually desirable when developing sensitometric strips to use a series of development times in order that the effect of time of development upon the sensitometric characteristics may be determined. It has been necessary, therefore, to remove a part of the strips at a series of different times, and, since most of this work is done in extremely dim illumination or even in total darkness, it is necessary to have

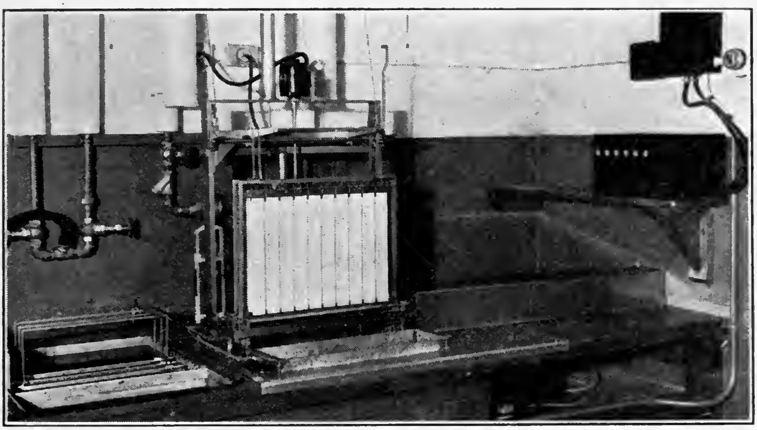


FIG. 4. Photograph of the assembled developing machine. The timing mechanism is shown at the extreme right.

some automatic timing device that will indicate to the operator when a given rack of strips should be removed. For this purpose a special timing device was constructed and mounted conveniently near the machine so that the operator receives both a visual and an audible signal. This timing mechanism is driven by a synchronous motor which is started automatically by the lowering of the carriage that supports the racks carrying the exposed strips. This synchronous motor, operating through a double worm reduction gear, drives a set of six disks so that they make one complete revolution in 20 minutes. Upon the periphery of each of these disks is a lug that may be set at any desired position relative to the starting point. As the group of disks rotates after the starting of the motor, these lugs, by closing electrical circuits, give the desired signal to the operator. The first signal is given by a buzzer which begins to operate a few seconds prior to the completion of the development time for which a particular lug is set; and in addition to this, a small electric lamp located behind a green translucent window, upon which is a number corresponding to the film rack to be removed, is energized. At the instant the buzzer stops, the indicated time has elapsed, and the

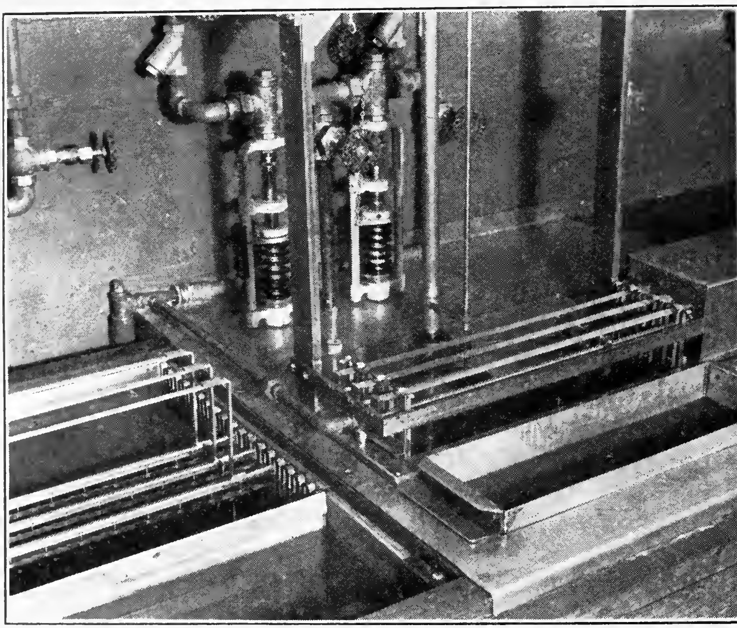


FIG. 5. Assembled machine, looking down into the developing, fixing, and stop-bath tanks.

operator then removes the rack corresponding to the signalled number.

In Fig. 4 is shown a photograph of the assembled developing machine. At the extreme right on the shelf is the automatic timing mechanism. In the central part of the photograph is shown the superstructure of the developing machine, with the carriage upon which are hanging two racks filled with sensitometric strips. Immediately in front and at the center may be seen the top of the acid stop-bath tank, and at the extreme lower left-hand corner may be seen a few film racks in the fixing tank.

In Fig. 5 is shown another view of the assembled machine, taken looking down into the developing, fixing, and stop-bath tanks. At the rear may be seen a part of the double control mechanism which will be mentioned in the next paragraph.

The temperature of the developing solution is held constant to within approximately ±0.10°F by means of a controlled water bath that surrounds the developing and stop-bath tanks. Warm and cold water lines (the former at about 90°F and the latter at about 45°F) furnish water to the bath for maintaining a constant temperature. The flow of water from these lines is controlled by two Sylphon water-mixing valves, actuated by means of the vapor pressure of highly volatile liquids contained in a copper bellows. The bellows is placed in the water bath to be controlled. Small variations in temperature of the bath cause large changes in the action of the valve as a result of the change in the vapor pressure of the liquid within the bellows. Two such valves are used, one on the warm water supply, the other on the cold. The settings of these valves are made to overlap in such a way that both of them are always allowing water to enter the tank when the bath is at the normal temperature. The incoming water is circulated about the tank by means of baffle plates. The overflow passes through an outlet pipe to the washing tank and thence into the rinsing tank, and from there to the drain. The flow of water through the washing tank is sufficient to keep the hypo content low, but since the cross-section of the tank is rather large, the agitation produced by the incoming water from the water bath is not sufficient. Additional agitation in the washing tank is obtained by the injection of air at the bottom of the tank through a series of fine holes.

Before starting to use this machine for our routine sensitometric testing, it was, of course, necessary to make an elaborate series of tests to establish its suitability for the work. It is essential that the same sensitometric characteristics shall be obtained for identical samples of photographic materials when processed in any one of the sixty positions in the machine, and also that the results shall be identical, irrespective of whether the maximum exposure end of the strip be placed at the top or at the bottom of the tank. Moreover, we must be sure that identical samples of a photographic material processed at widely different times shall give identical results.

In order to make a thorough study of the effects of agitation upon the results, five different agitation conditions were studied, as follows:

(*a*) No agitation.
(*b*) Propeller only.
(*c*) Paddles only.
(*d*) Propeller and paddles (low speed).
(*e*) Propeller and paddles (high speed).

For this series of tests a quantity of motion picture positive film was used, carefully selected from a relatively old coating that had been seasoned for a long time in an atmosphere having a temperature of 70°F and a relative humidity of 50 per cent. Great care was

TABLE I

Typical Data Obtained for Development with No Agitation

Step	Position 6	12	24	38	44	50	56	For 30 Strips Average	Spread
1	. .	. .	. .	. .	. .	. .	. .		
2	2.66	2.63	2.67	2.64	2.66	2.65	2.66	2.66	0.04
3	2.48	2.48	2.51	2.47	2.49	2.48	2.48	2.48	0.04
4	2.34	2.32	2.34	2.32	2.34	2.35	2.30	2.30	0.05
5	2.16	2.18	2.20	2.17	2.17	2.20	2.18	2.18	0.04
6	1.97	1.98	2.01	1.96	1.98	2.01	1.97	1.98	0.06
7	1.79	1.80	1.82	1.78	1.80	1.80	1.79	1.79	0.04
8	1.59	1.60	1.62	1.59	1.62	1.64	1.61	1.61	0.05
9	1.41	1.41	1.41	1.40	1.41	1.44	1.42	1.42	0.04
10	1.21	1.21	1.21	1.18	1.21	1.25	1.21	1.21	0.07
11	1.00	0.98	1.00	0.98	1.00	1.03	1.00	1.00	0.05
12	0.79	0.80	0.82	0.80	0.82	0.82	0.81	0.81	0.03
13	0.63	0.62	0.63	0.62	0.62	0.64	0.63	0.63	0.02
14	0.45	0.44	0.45	0.45	0.47	0.47	0.45	0.45	0.03
15	0.32	0.31	0.32	0.31	0.32	0.31	0.31	0.31	0.02
16	0.20	0.19	0.21	0.19	0.21	0.21	0.21	0.20	0.02
17	0.12	0.12	0.12	0.11	0.12	0.11	0.12	0.12	0.01
18	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.00

Maximum exposure end down.

exercised to be sure that the material represented a maximum of uniformity throughout. Exposing the test strips was done on a Type II*b* sensitometer maintained under the usual invariant conditions. In loading the racks, each alternate strip was placed with the heavy exposure end downward, and the remainder with the heavy exposure end upward. In the first test, no agitation, the machine was filled with a carefully standardized mix of *D-16* developer brought to a temperature of 65°F ±0.10°, and allowed to stand for some time so as to come to a perfectly quiescent state. The carriage was then lowered very carefully so as to create a minimum of disturbance within the body of the developer, and the entire sixty strips were allowed to develop for a period of five minutes. No agitation whatsoever was given either to the developer or to the strips.

After fixing, washing, and drying the strips, the densities were read visually on one of our standard densitometers. Some typical data obtained in this manner are shown in Table I. Here are given the readings made on seven selected strips which were developed with the maximum exposure end down. In the next to the last column will be found the average values for the entire thirty strips that were developed with the maximum exposure end down. The values in the last column are those of total spread within the entire group of thirty strips. It will be noted that these total spread values are exceedingly low, indicating that development has proceeded with great uniformity for all thirty positions occupied by these strips in the tank. The data for the thirty strips developed with maximum exposure end up were treated in exactly the same way and the values for total spread were found to be of the same order as those shown in Table I.

In Fig. 6 are plotted the density values obtained for the two groups of strips developed, one with maximum exposure upward and the other with maximum exposure downward. This shows very clearly the effect of the reaction products formed during development as they stream downward along the face of the exposed materials. This is ample demonstration that the condition of no agitation is one which can not be tolerated in sensitometric work.

This procedure was then repeated exactly, with the exception that the solution was agitated by the operation of the propeller in the cylinder at the rear of the developing tank; and exactly similar runs were made for the three other conditions of agitation indicated previously, that is, with the paddles only, with the propeller and paddles, and with the propeller and paddles at accelerated speed.

It does not seem necessary or desirable to attempt to present in detail all these data. The results can be satisfactorily analyzed for each of the conditions of agitation by a consideration of the data corresponding to those presented in the last two columns of Table I.

In Table II are shown the average density values for the thirty strips developed with the maximum exposure end downward under each of the agitation conditions. It is quite evident from a consideration of these values that there has been a progressive increase in the rate at which development proceeds. This rate of increase is very marked for the first three steps of increasing agitation, while running the paddles at accelerated speeds produces only slight increases in the density values obtained, and these increases are confined almost entirely to the higher densities. It will be noted that in the low-

TABLE II

Average Density Values for the Thirty Strips Developed under Each of the Agitation Conditions

Step	No Agitation	Propeller	Paddles	Propeller & Paddles (Low Speed)	Propeller & Paddles (High Speed)
2	2.66	..	..	..	..
3	2.48	..	..	..	..
4	2.30	..	..	..	..
5	2.18	2.89	3.01	..	..
6	1.98	2.69	2.84	2.94	3.02
7	1.79	2.49	2.63	2.73	2.79
8	1.61	2.27	2.39	2.49	2.55
9	1.42	2.04	2.13	2.24	2.28
10	1.21	1.76	1.84	1.95	1.98
11	1.00	1.48	1.55	1.65	1.67
12	0.81	1.19	1.25	1.33	1.33
13	0.63	0.90	0.95	1.01	1.01
14	0.45	0.63	0.68	0.72	0.72
15	0.31	0.43	0.45	0.49	0.50
16	0.21	0.26	0.28	0.30	0.30
17	0.12	0.15	0.16	0.16	0.16
18	0.06	0.08	0.09	0.10	0.10
Speed	12.9	14.6	15.1	16.6	16.6
Gamma	1.48	1.86	1.94	2.01	2.05

Values in above taken from the average of all strips developed with maximum exposure end down.

density range, the agreement between low-speed and high-speed paddle operation is excellent. At the bottom of the table are found the values of speed and gamma computed from the curves plotted from average densities, and, as would be expected, both these values increase as agitation is increased, representing, however, practical equilibrium for the last two conditions.

In Table III are tabulated the total spread values for the five conditions of agitation. These values show some very interesting facts. As mentioned previously, the total spread values obtained with no agitation are remarkably low, indicating excellent uniformity of development from position to position in the tank. With the propeller operating, these total spread values rise to an astonishing extent, indicating that with this amount of agitation, the lack of

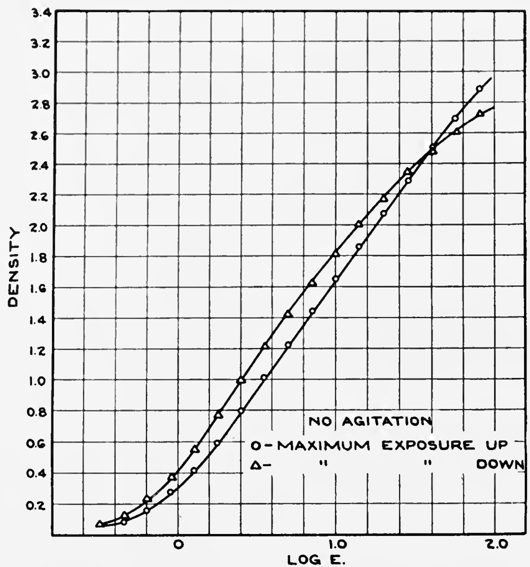
TABLE III

Total Density Spread Values Obtained for the Five Conditions of Agitation

Step	No Agitation	Propeller	Paddles	Propeller & Paddles (Low Speed)	Propeller & Paddles (High Speed)
2	0.04	..	..	..	..
3	0.04	..	..	..	..
4	0.05	..	..	..	..
5	0.04	0.41	0.10	..	..
6	0.06	0.42	0.10	0.08	0.04
7	0.04	0.34	0.10	0.09	0.05
8	0.05	0.39	0.07	0.07	0.04
9	0.04	0.36	0.06	0.05	0.03
10	0.07	0.28	0.05	0.05	0.04
11	0.05	0.29	0.04	0.04	0.03
12	0.03	0.27	0.07	0.02	0.02
13	0.02	0.15	0.03	0.03	0.04
14	0.03	0.15	0.04	0.04	0.02
15	0.02	0.12	0.05	0.03	0.02
16	0.02	0.05	0.04	0.02	0.02
17	0.01	0.03	0.02	0.02	0.02
18	0.00	0.02	0.01	0.02	0.02

Values in above table taken from average of all strips developed with maximum exposure end down.

uniformity from point to point in the tank has increased enormously. This is quite readily understood, however, when we consider that the agitation is in a single direction and that the currents may move in fairly fixed paths which may be far from straight lines, thus producing a more or less definite pattern of developer replacement over the surfaces of the exposed strips. It is obvious that with this amount and this kind of agitation the uniformity of development from point to point in the tank is extremely poor. With the paddles



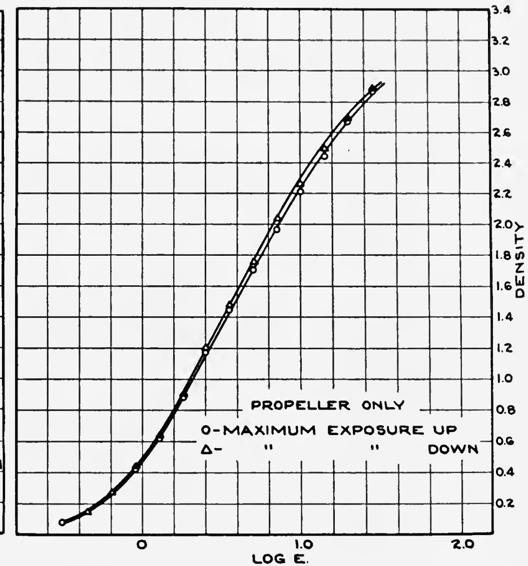


FIG. 6. (*Left*) Characteristic curves plotted from the averages of two groups of strips developed with no agitation.

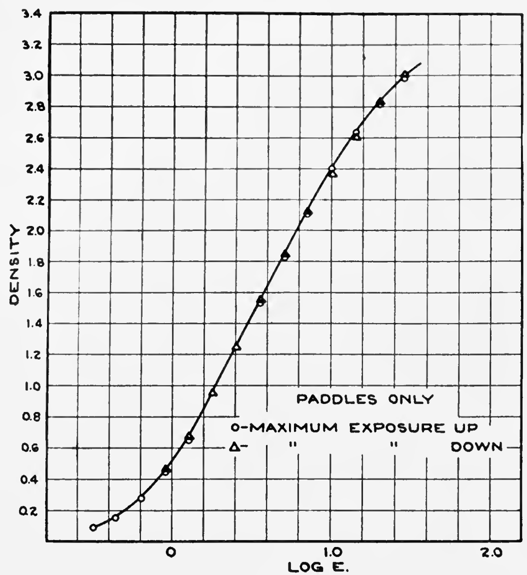
FIG. 7. (*Right*) Characteristic curves plotted from the averages of two groups of strips developed with agitation by propeller only.

operating alone the condition is greatly improved, but still the total spread and therefore the nonuniformity is much greater than that obtained with no agitation.

With the propeller running and the paddles operating at the lower speed, further improvement is obtained, but the uniformity is still not as good as that obtained with no agitation. By increasing the speed of the paddles, further improvement occurs, and now the total spread is of the same order as, or perhaps slightly better than, that obtained with no agitation. These total spread values are so low that we feel quite confident in saying that a satisfactory state of uniformity in the developing tank has been reached. In other words, the developer is moved so rapidly and so thoroughly that every point of the surface of the exposed strips is subjected to the action of a developer that is uniform in power, and the reaction products are being swept away from these surfaces at such high velocities and so completely that there is no nonuniformity of development due to localized high concentrations of reaction products.

We wish now to turn to a further consideration of the results obtained from the groups of strips developed in part with maximum exposure upward and in part with maximum exposure downward. These results for the condition of no agitation have already been shown in Fig. 6. In Fig. 7 are shown the two characteristic curves plotted from averages of the two groups of thirty strips developed by agitation with propeller only. It will be seen that there is a slight but definite difference. In Fig. 8 it will be seen that the two curves representing the two groups of thirty strips have now become coincident, and the same is true for the other two conditions of agitation, as illustrated in Figs. 9 and 10.

An inspection of the data in Table II has already revealed that as the agitation is increased in violence the rate of development has increased appreciably. In order to show this more graphically, the curves in Fig. 11 are presented. It will be seen here that for the two conditions of maximum agitation there is still a slight difference, especially in the region of high densities (D greater than 1.8). The change, however, is so slight that we felt justified in assuming that further increase in agitation did not produce appreciable increase in the magnitude of density resulting from a given exposure; and we have concluded that, for the work to be done with this equipment, using the agitation produced by the paddles at the accelerated velocity supplemented by the propeller, a sufficiently high rate of development



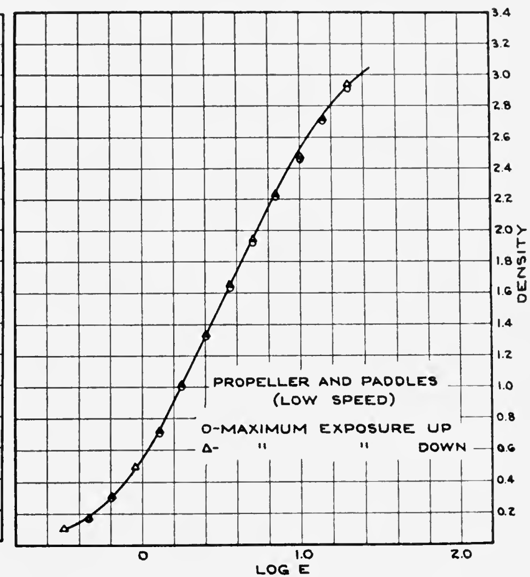


FIG. 8. (*Left*) Characteristic curves plotted from the averages of two groups of strips developed with agitation by paddles only.

FIG. 9. (*Right*) Characteristic curves plotted from the averages of two groups of strips developed with agitation by propeller and paddles operating at low speed.

has been attained so that the limit of density obtainable from a given exposure has been closely approximated.

In practical work the characteristics of a given emulsion are generally determined by developing a relatively few strips. Thus, it is of utmost importance to know, with a high degree of certainty, whether there is any difference in the extent of development of strips developed in one position in the machine as compared with those in any other position. To establish this definitely, five complete runs were made under the condition of maximum developer agitation. The density values from each of the five strips for a single position in the machine were then averaged, and these averages for the sixty positions compared with each other. Again, we shall not present

TABLE IV

Average Density Values and Total Density Spread of Strips Developed in Different Positions in Developing Machine

Step	Average	Spread
6	3.03	0.03
7	2.79	0.04
8	2.55	0.03
9	2.29	0.02
10	1.99	0.03
11	1.67	0.02
12	1.34	0.02
13	1.03	0.03
14	0.72	0.02
15	0.49	0.02
16	0.30	0.02
17	0.16	0.01

the data in detail, but shall illustrate the results by giving the average density values together with the total spread. These are shown in Table IV. It will be seen that the values of total spread are extremely small when it is considered that even these can not necessarily be ascribed entirely to nonuniformity of processing, since that may include certain errors due to reading and other factors.

Since in the past, hand-rocked and mechanically rocked trays have been used for the work that is now being done with this developing machine, it is of interest to compare the rate of development attained by the two methods. This information is of interest in drawing conclusions as to the development times that must be used with the machine method to give extents of development comparable with the

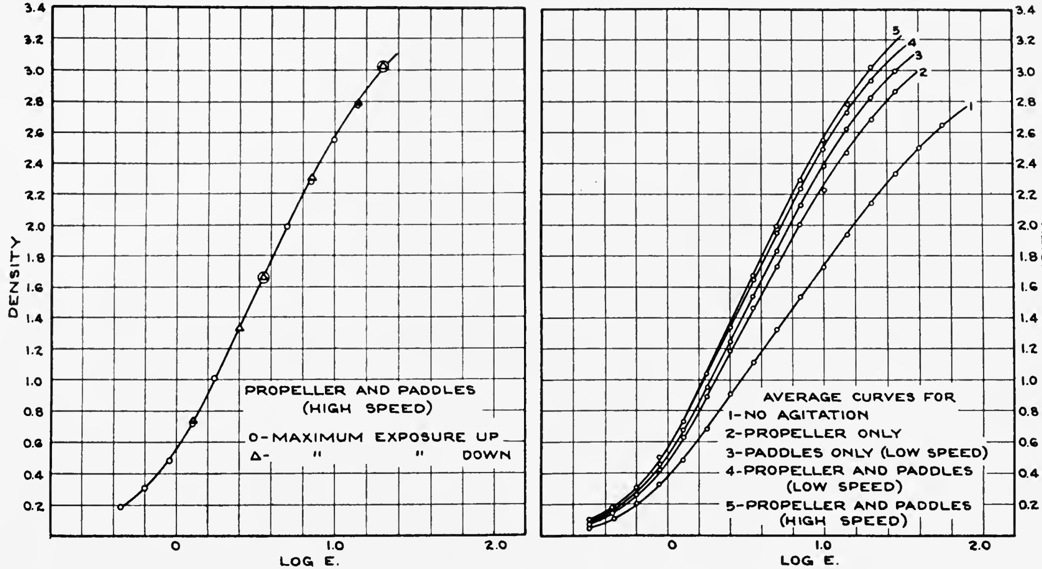


FIG. 10. (*Left*) Characteristic curves plotted from the averages of two groups of strips developed with agitation by propeller and paddles operating at high speed.

FIG. 11. (*Right*) Curves showing the increase in extent of development with increase in agitation.

older technic. For this purpose one of our machine-rocked tray equipments was used. In Fig. 12 the results obtained are shown graphically. Curves for the density of five selected steps are plotted, density being shown as a function of frequency of rocking. It will be seen that the density obtained by this method rises rapidly in the region

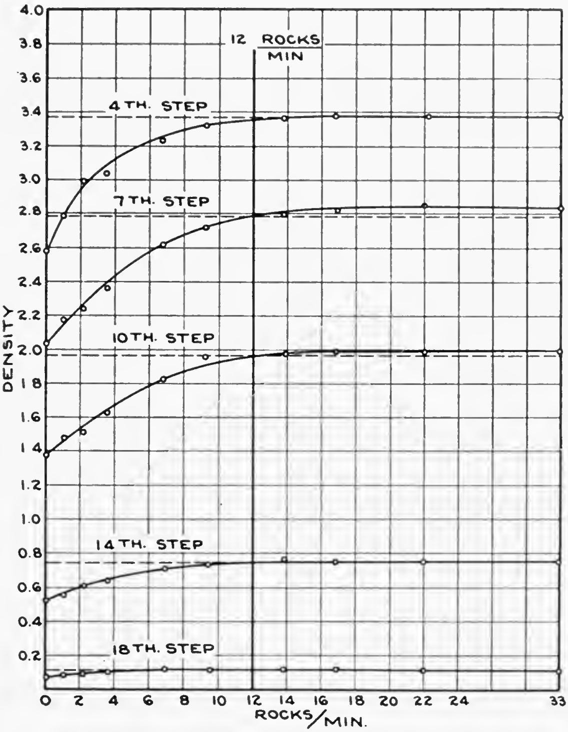


FIG. 12. Results obtained with mechanically rocked tray equipment. Density plotted as a function of frequency of rocking.

of low frequency of rocking to a limiting value which becomes constant in the region of higher frequency. The dotted horizontal lines represent the densities obtained with the developing machine for the same time of development, using developers of identical composition and temperature. It will be seen from this that the developing machine is giving an extent of agitation corresponding to the maximum obtainable in the mechanically rocked, and, by inference, in the hand-rocked technics.

One other method of developing for sensitometric purposes has been recommended and used to some extent. This is the so-called "brush method" of development originated by Clark[1] and later used and elaborated to some extent by other workers in this field. In this method, agitation is produced by using a soft, camel's hair brush which is swept by hand continuously back and forth across the emulsion surface. It has been stated that this results in a maximum

TABLE V

Results Obtained by Brush Development Compared with Those Obtained by Machine Development

Step	Brush					Machine	
	C.M.K.	H.R.B.	W.A.S.	Average	Spread	Average	Spread
2	3.36	3.34	3.40	3.37	0.06	3.35	0.04
3	3.30	3.28	3.35	3.31	0.07	3.30	0.05
4	3.24	3.21	3.31	3.25	0.10	3.25	0.03
5	3.11	3.10	3.18	3.13	0.08	3.10	0.04
6	2.97	2.94	3.05	2.99	0.11	2.93	0.03
7	2.79	2.75	2.90	2.81	0.15	2.73	0.04
8	2.56	2.54	2.60	2.57	0.06	2.49	0.03
9	2.31	2.28	2.41	2.33	0.13	2.24	0.02
10	2.04	2.02	2.12	2.06	0.10	1.97	0.03
11	1.74	1.71	1.81	1.75	0.10	1.67	0.02
12	1.43	1.40	1.49	1.44	0.09	1.36	0.02
13	1.15	1.10	1.19	1.15	0.09	1.07	0.03
14	0.86	0.78	0.87	0.83	0.09	0.77	0.02
15	0.60	0.55	0.61	0.59	0.06	0.55	0.02
16	0.39	0.36	0.38	0.38	0.03	0.35	0.02
17	0.23	0.22	0.21	0.22	0.02	0.20	0.01
18	0.14	0.13	0.14	0.14	0.01	0.13	0.00
19	0.08	0.07	0.07	0.07	0.01	0.07	0.00

possible rate of development and in maximum uniformity of development over the surface of the materials being treated. Our experience with this method has indicated that it does give excellent uniformity over a given portion of material, but that different operators may differ appreciably from each other in the amount of development obtained in a given time. It seemed desirable to compare the development produced by this machine with that produced by the brush technic; and for this purpose a test was run in which three different operators applied the brush method to a group of strips, and a similar group of strips was run in the machine. The results are shown in Table V. In the first three columns are the values obtained by the individual operators using the brush technic. In the next columns are the averages of these developments, together with the spreads in density obtained among the various developments. In the last columns are the values obtained by the machine processing together with the spreads normally found for this method of development. It will be seen that the spread in results obtained among the opera-

TABLE VI

Values of Speed and Gamma Obtained from Developments Made on Different Days over a Period of Approximately One Month

Tested	Speed	Deviation	Gamma
April 20	20.0	−0.27	2.05
24	20.4	+0.13	2.07
28	20.6	+0.33	2.06
30	20.4	+0.13	2.05
May 2	20.0	−0.27	2.04
3	20.2	−0.07	2.03
3	20.6	+0.33	2.09
4	20.4	+0.13	2.08
5	20.0	−0.27	2.05
7	20.2	−0.07	2.03
8	20.0	−0.27	2.02
9	20.0	−0.27	2.02
12	20.6	+0.33	2.08
13	20.4	+0.13	2.02
Average	20.27 ± 1.05%	±0.21	2.05 ± 1.0%
Spread	0.60		0.07
Spread	3%		3.4%

tors using the brush method is much greater than that found by machine processing. The density values in the "average" column for the three brush developments are slightly higher than those obtained by the machine, indicating that the brush technic probably does give somewhat more perfect removal of the reaction products from the surface of the materials being developed than does the machine. The difference, however, is not great and in view of the spread between different operators it appears that the machine technic is definitely superior when the volume of work is such as to require several different operators.

Finally, as an indication of the time uniformity of the work that can be done with this developing machine, the values shown in Table VI are presented. These show the values of speed and gamma obtained from runs made on different days over a period of approximately one month, and are derived from the average of strips all cut from a single roll of motion picture positive film carefully aged and seasoned to represent a maximum of uniformity throughout its length. It will be seen that the mean deviation from the average speed is only ±1 per cent, while the mean deviation from the average gamma is also ±1 per cent. The maximum spread in the case of speed is 3 per cent, while that for gamma is 3.4 per cent. It must be remembered that these deviations may be attributable to several factors other than the lack of reproducibility and uniformity of agitation and temperature control within the developing machine. They certainly include possible variations in the concentration and constitution of the developer and possible errors in the determination of density.

We feel confident in stating that the performance of the developing machine is all that can be desired, and that the errors that formerly might have been attributable to lack of uniform and reproducible agitation in the processing of sensitometric strips have now been reduced to a point far below the errors attributable to other causes.

REFERENCE

[1] CLARK, W.: "Standard Development," *Phot. J.*, **49** (Feb., 1925), No. 2, p. 76.

BIBLIOGRAPHY

SHEPPARD, S. E., AND MEES, C. E. K.: "Investigations on the Theory of the Photographic Process," *Longmans Green & Co.* (London), 1907.

TADAROKU, O.: "On a Developing Apparatus with a Rotary Plate Holder," *Bull. Kiryu Tech. College,* 1921.

SHEPPARD, S. E., AND ELLIOTT, F. A.: "The Influence of Stirring on the Rate and Course of Development," *J. Franklin Institute,* **195** (Feb., 1923), No. 2, p. 211.

SHEPPARD, S. E., AND ELLIOTT, F. A.: "The Influence of Stirring on the Rate and Course of Development—Part II," *Ibid.*, **198** (Sept., 1924), No. 3, p. 333.

HEPWORTH, C. M.: "A Developing Machine," *Brit. J. Phot.*, **74** (May, 1927), No. 5, p. 260.

BLOCH, O., AND HORTON, H.: "A Mechanical Developing Appliance for Sensitometric Work," *Phot. J.*, **52** (Aug., 1928), p. 352.

SHEPPARD, S. E., LAMBERT, R. H., AND AKINS, G. M.: "Semi-Automatic Development of Plates in Sensitometry," *IX Internat. Congress Sci. and Applied Phot.; Revue d'Optique Theorique et Instrumentale.*

DISCUSSION

MR. TOWNSLEY: You spoke of reaching a flat part of the speed curve. In what terms is the speed expressed?

MR. JONES: I meant the flat part of the agitation curve. The curves represent growth of density with the cycles per minute of rocking the tray. The speed values were obtained for five different conditions of agitation. For the first one, with no agitation, the speed value was relatively low. Then it increased and became 16.6, in the next to the last one. The last one was 16.6, which means that increasing the agitation of the next to the last did not produce any increase in speed. We therefore assumed that we had reached the flat part of the speed curve, speed being plotted as a function of the agitation.

MR. TOWNSLEY: Has that been carried far enough to show whether the curve dropped off again with very, very high agitation?

MR. JONES: I believe that Dr. Sheppard has made some experiments at extremely high agitations. I am not sure what the results were.

MR. SHEPPARD: I do not know how the speed would compare with the agitation in your case, and in rotations I would not say what it was. With the developers that we used, the density over the whole of the curve, as a function of agitation, was a function of the number of revolutions of a propeller. This density went through a rather flat maximum. I do not know to what to attribute that. I do not see exactly why it should not stay perfectly flat, but it seemed to be a perfectly evident phenomenon.

MR. JONES: Might we assume that you had the developer moving so fast that it did not have time to stop and do its work?

MR. SHEPPARD: It might be possible. There is another possibility; we found in certain cases that the effect of bromide was altered by the velocity of agitation.

MR. OSWALD: In obtaining these data, have you worked out the smallest permissible amount of developer in relation to the emulsion surfaces being developed?

MR. JONES: We have not carried that to an ultimate conclusion. This tank holds about $7^1/_2$ gallons of developer and accommodates 60 strips. After having used it for one development, if we reload and develop another 60 strips in that same developer there is perceptible change. For work of highest precision we can not use a developer more than once. In certain work in which the requirements are not quite as exacting we do use it twice. But for routine testing in which we want the maximum of precision, we always discard the developer after having developed 60 strips.

MR. FARNHAM: For a person doing sensitometric work without such equipment, your data indicates that 12 rockings per minute, or even a little faster might be satisfactory. Also, is the rocking of the tray continuous motion?

MR. JONES: I have no sufficiently precise specification of the gear mechanism that was used to rock the tray to say exactly what the motion would be. I assume it is something approximating a simple harmonic. It is probably produced by a rotating wheel and a lever.

You ask whether one can rely upon that particular number of rocks per minute to be satisfactory. No, because the agitation is produced at the surface of the film and might be very different with a different mechanical structure. If you built yourself a mechanically rocked tray, you would have to run just such a series as we did, increasing the cycles per minute, plot the growth of density with frequency, and then find out where the curve flattens.

MR. MILI: Can you define the speed as used in these various tables accurately?

MR. RUSSELL: The values in the table were determined from the exposure required to produce a certain density. The density was 0.30 in this case.

MR. JONES: In the early part of the paper I mentioned brush development. That technic has been recommended by a good many workers. It does produce very uniform development over the area of a single sample of film, and in the hands of a single operator it affords very satisfactory reproducibility from time to time. But, as I stated, in the hands of different workers we have found considerable variation. We used three operators, who were given instructions and told to brush at the rate of so many cycles per minute. They tried to follow the instructions. The results of the different operators showed about two to three times as much spread as the machine.

The explanation is, of course, that perhaps even if they do carry out the proper technic, one man will press a little harder on the brush than another, and it just seems impossible with any human manipulation to make eight or ten different observers produce the same results; by which I mean results of the same uniformity as we can get with mechanically driven agitating systems.

MR. FAMULENER: You showed very little deviation between strips. Would you say that by using no agitation it would be possible to develop strips that, while they would not reach their full development, would, if the same technic were followed as regards heavy end down or heavy end up, be entirely comparable throughout a series of tests?

MR. JONES: The evidence indicates that. It is extremely bad practice, however, for the reason that you have impressed upon the photographic material a series of exposures, and are going to plot the results in density as a function of the exposure. Of course, you will want to know later how the material is rendering different amounts of exposure.

If you mount the strip, we shall say, with the heavy exposure end up, reaction products will be produced that will stream down over the other areas of the sensitometric strip, giving a distorted value. Thus, processing with no agitation will show you the characteristics of the material when developed only under the particular conditions. I do not see how you can apply it to other work where that same condition of complete quiescence does not exist. I think it is very bad practice to do it.

MR. SCHMIDT: What is the minimum development time necessary to achieve uniform results? In other words, can a short working development be applied safely, or do you prefer to develop for at least five or ten minutes?

MR. JONES: The minimum development time will depend upon the developer, upon the photographic material, and upon the degree of agitation. If we should substitute for the developer that we were using, which, by the way, was *D-16*, a very active developer such, let us say, as a caustic type, we should get completion of development in a very much shorter time with the same agitation.

MR. POTTER: What are some of the precautions necessary to determine the identity of composition of the developer being used from time to time during a series of experiments?

MR. JONES: We purchase the ingredients in relatively large quantities and of the maximum obtainable purity. I think that Mr. Crabtree can tell you what tests he applies for raw materials. Then, of course, the raw materials are mixed by one of Mr. Crabtree's assistants, the greatest of care being given to weighing, mixing, and all that sort of thing. Then we blend. We have a system in which we use several different mixes: assuming that we have ten available mixes, we take one gallon out of each mix. That is the general scheme, although the numbers quoted may not be exact.

After having the final developer, we give it a sensitometric test, using a sample film that is carefully conditioned, aged, and laid aside for the purpose. If we get a batch that shows variation in contrast or in speed greater than a certain tolerance that has been established by experience, it is rejected.

MR. CRABTREE: We take as large quantities of each ingredient as possible, and treat them as standards for the sensitometric work. When the stocks are almost exhausted we make a careful photographic check of the new stock against the old stock.

Answering Mr. Schmidt, the disadvantage of rapid development is, of course, the possibility of errors involved in transferring the film from the developer to the stop bath. As the time of development is extended the error diminishes proportionately.

MR. MATTHEWS: In precision work have you any minimum number of strips that you average for best results?

MR. JONES: It is impossible to generalize. The number of strips desirable for averaging will depend, to some extent at least, upon the type of photographic material. It is desirable, of course, to have a development technic so uniform, so reproducible, that the number of strips to be averaged can be reduced to a minimum.

A study of the data in the paper will show that the total spread in the values derived from a large number of strips developed by the machine technic is much lower than the total spread within an equal number of strips developed by the hand-rocked tray technic. That, of course, means that to obtain a result subject to some specified probable error, the number of strips that must be averaged in the case of the machine technic will be definitely less than in the case of the hand-rocked tray technic. I do not have data at hand showing exactly the relationship between the number of strips to be averaged in the two cases to give the same probable error.

MR. MARCUS: Do you intend to use a mechanical device for dipping the film into the developer and lifting it out, so as to eliminate the human factors?

MR. JONES: No, we think that is unnecessary. The operation is so simple and the time consumed in doing it is so small compared to the time of development that we feel sure the variation due to this operation is quite negligible.

It is possible that it might be necessary if one were using development times and conditions such that at the time of removal of the strip development was proceeding at a high rate; but if we are up pretty well to the equilibrium point then, of course, errors due to that variation in time would be very small.

MR. SCHMIDT: Have the sensitometer strips used to prepare the slides that have been shown, all been dried under definite conditions?

MR. JONES: Yes, the drying conditions throughout were constant.

MR. TOWNSLEY: The curves show that less time is required to obtain a given gamma with greater agitation. Have you carried the work far enough to reach the peak?

MR. JONES: No. I tried to make clear the fact that with lower degrees of agitation the gamma was growing quite rapidly. Then, for the maximum agitation and the step just next to the maximum of those shown there was a change of only 0.04 in gamma. The time rate of change in gamma became very low.

MR. TOWNSLEY: You find the whole time-gamma curve shifting upward?

MR. JONES: Yes.

NOTE ON THE USE OF AN AUTOMATIC RECORDING DENSITOMETER*

C. M. TUTTLE AND M. E. RUSSELL**

Summary.—*A recording physical densitometer designed to read strips from the type IIb sensitometer has been previously described.*[1] *This instrument has been in service in the sensitometric department of the Kodak Research Laboratories for about one year, during which time it has been operated steadily. Approximately 100,000 sensitometric strips have been read thus far. The instrument is capable of an output of about 700 strips per day.*

Experience has shown that more repeatable results are attained with this instrument than by routine, visual methods. Comparative data accumulated in an experiment lasting several weeks are presented, together with a time study of the two methods of densitometry. Certain features to be changed in the design of a new instrument will be discussed. The new instrument will be improved in both ruggedness and speed.

The advisability of using devices of this nature in a release print laboratory will depend upon a number of factors, such as initial cost, quantity and quality of output, and ease of maintenance.

A recording physical densitometer designed to handle routine work for the sensitometry department of these Laboratories has been in continuous service for about a year. During this time a considerable amount of data concerning its speed, accuracy, and durability has been obtained. It is the purpose of this paper to compare these factors with corresponding data for routine visual methods.

DESCRIPTION OF THE INSTRUMENT

Since the principles of design and operation of this instrument were discussed at some length in a previous paper[1] an abbreviated description taken from that paper will suffice for the present purpose.

The instrument operates on the two-cell null method, with controlled intensity of the measuring beam. The schematic drawing, Fig. 1, shows the essential features of the apparatus. The lower

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

light-beam illuminates the comparison cell, and the intensity of this illumination may be manually regulated within a small range to set the instrument zero. Light in the second beam traverses an aperture variable as to area over a maximum to minimum ratio of 1000 to 1.0. In the drawing, the two beams are shown as if they originated from different sides of the lamp. The actual optical system makes use of a beam-splitter. After passing through the variable aperture, the light is incident upon one of the areas of the sensitometric strip. Nearly in contact with the photographic material is placed the sur-

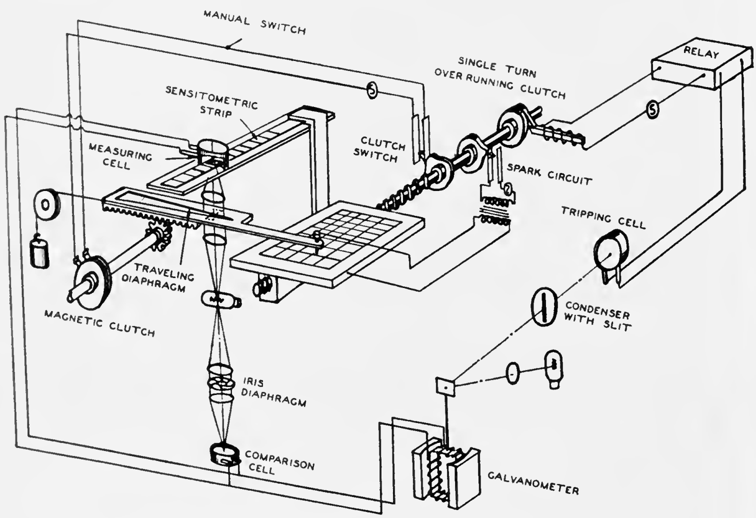

FIG. 1. Schematic diagram of automatic densitometer.

face of the measuring photocell. This part of the optical system follows the suggestion of a previous paper.[2] The two photocells, the one in the comparison beam and the other in the measuring beam, are connected in opposed potential to a galvanometer.

Light from a second source collimated by a second optical system is reflected by the galvanometer mirror upon a large condenser lens. The lens, except for an open slit at the zero position of the galvanometer, is covered by an opaque mask. At zero galvanometer deflection, the light is concentrated upon a third photocell. The output of this cell is used to close a relay which initiates the operation of recording and shifting the coördinate paper and the sensitometric strip.

In operation, the first step of the sensitometric strip is registered over the window of the measuring photocell, thereby decreasing the light intensity upon the cell and throwing the photocell-galvanometer circuit out of balance. A hand-operated switch closes the circuit of a magnetic clutch, which drives the diaphragm-changing mechanism in the direction for increasing the light in the measuring beam.

When the light intensity upon the measuring cell has become equal to that upon the comparison cell, the relay is tripped. The relay circuit energizes a solenoid pulling a plunger, which releases an over-running clutch and allows it to make one revolution. The over-running clutch drives a shaft upon which are cams operating two switches. The first small fraction of the turn of the shaft through the medium of these switches de-energizes the diaphragm-driving clutch and discharges a spark through the graph paper from a metal pointer. The pointer is attached to the end of the traveling diaphragm; thus, its position at all times is a positive indication of the disclosed area of the variable aperture. At the time of the spark discharge, the sum of the effective density of the diaphragm in its optical system and the density of the material being measured is constant.

Upon the shaft that is rotated by the over-running clutch is cut a screw, the lead of which is equal to the 0.15-increment upon the abscissa scale of the graph paper. As the shaft completes its single revolution, a stainless steel carriage table, upon which the graph paper is first manually registered and then held by suction, is moved forward the proper amount. Attached to the table is an arm which pulls the sensitometric strip the distance of one step.

At the termination of the operations just described, the instrument has set itself for recording the second point. The diaphragm has been pulled backward enough to unbalance the photoelectric circuit even if the second step should be no greater in density than the first. The magnetic clutch that drives the diaphragm is energized as soon as the shaft completes its revolution, and the upward travel of the diaphragm continues until a match of the two cell intensities is again achieved. Upon the completion of the point-by-point record of all twenty-one steps, the driving circuit is automatically broken and the paper may be removed.

SPEED OF OPERATION

The densitometer has been designed to carry a maximal load of about seven hundred II*b* sensitometric strips per day with a single operator. The bulk of the work that it handles consists in plotting families of curves of varying times of development for positive film. Eight sets of points for eight strips are customarily plotted upon a single sheet. For this type of work, the average time per strip is fifty seconds. Since, in routine visual densitometry of the same kind of work, the average reading rate is one strip in two minutes, with one person reading while a second person records, the machine method may be said to be nearly five times as fast as the visual method. The machine has the additional advantage that by being operated for two shifts instead of one, it can take care of peak loads without having to employ additional skilled photometricians.

ACCURACY AND REPEATABILITY

The results of a series of tests that show the accuracy and repeatability of measurements made by the physical densitometer in comparison with measurements made by visual instruments will now be discussed. Typical sensitometric strips were chosen for a number of materials, including both negative and positive motion picture films with clear, gray, and colored bases. Each strip was read on ten occasions, covering a period of about 6 weeks. In order to obtain visual readings typical of those normally made in routine sensitometry, the strips were mixed in with daily test-strips, and readings made by the regular operators in the normal manner. The visual measurements were made on an instrument using a Martens polarization photometer of which the optical characteristics are such that the results agree with those obtained by a Jones high-intensity densitometer.[3]

In Table I are typical results obtained for a gray-base motion picture negative material. Each of the ten readings is tabulated together with the averages for each step. Comparing the average values obtained by the two methods, it will be noticed that the results for the physical instrument are in practically perfect agreement with those obtained visually. For no step is the difference in density more than 0.01.

When the individual values themselves are examined, it is at once apparent that the physical instrument gives noticeably more consistent results than those attained by the visual method. For example, on the twelfth step all the values obtained by the physical instrument are either 0.63 or 0.64. When read visually, the values range from 0.61 to 0.65. In some cases the range of visual values is somewhat less than that and in a few cases somewhat larger.

TABLE I

Results Obtained for a Gray-Base Motion Picture Negative Material

Step	Aug. 4	Aug. 11	Aug. 18	Aug. 23	Aug. 28	Sept. 2	Sept. 7	Sept. 11	Sept. 15	Sept. 18	Average
Physical											
2	1.33	1.34	1.34	1.35	1.34	1.34	1.34	1.35	1.33	1.34	1.34
4	1.21	1.21	1.21	1.21	1.22	1.21	1.21	1.21	1.22	1.21	1.21
6	1.07	1.09	1.08	1.08	1.08	1.08	1.08	1.07	1.07	1.09	1.08
8	0.93	0.95	0.94	0.94	0.94	0.94	0.94	0.93	0.94	0.94	0.94
10	0.79	0.79	0.79	0.80	0.80	0.79	0.79	0.80	0.79	0.79	0.79
12	0.63	0.63	0.63	0.64	0.64	0.63	0.64	0.63	0.63	0.64	0.63
14	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
16	0.37	0.37	0.37	0.37	0.36	0.36	0.37	0.37	0.37	0.37	0.37
18	0.27	0.27	0.28	0.27	0.28	0.27	0.28	0.27	0.28	0.28	0.28
Visual											
2	1.32	1.33	1.33	1.32	1.33	1.33	1.35	1.34	1.34	1.32	1.33
4	1.20	1.19	1.19	1.20	1.20	1.19	1.22	1.21	1.22	1.20	1.20
6	1.07	1.07	1.07	1.07	1.08	1.06	1.08	1.10	1.09	1.08	1.08
8	0.94	0.94	0.95	0.95	0.93	0.94	0.93	0.94	0.95	0.96	0.94
10	0.77	0.79	0.80	0.79	0.79	0.78	0.81	0.80	0.79	0.78	0.79
12	0.61	0.63	0.64	0.63	0.63	0.61	0.64	0.63	0.65	0.64	0.63
14	0.49	0.48	0.50	0.50	0.50	0.51	0.51	0.48	0.52	0.51	0.50
16	0.37	0.37	0.37	0.36	0.37	0.38	0.37	0.36	0.38	0.37	0.37
18	0.30	0.28	0.30	0.29	0.30	0.31	0.29	0.30	0.28	0.30	0.30

Table II, which is an analysis of the values given in Table I, gives the average values obtained by the two methods, the spread in values (that is, the differences between the highest and lowest individual readings), and the average deviation for a single reading by each method. The results for spread in density show that in no case did the values of density obtained during the course of the test differ by more than 0.02, when read physically. The readings for about half the steps differed by only 0.01, and for one step no variation at

TABLE II

Motion Picture Negative Material—Clear Support

Step	Average		Spread		Average Deviation	
	Physical	Visual	Physical	Visual	Physical	Visual
2	1.34	1.33	0.02	0.03	±0.004	±0.009
3	1.26	1.26	0.02	0.03	0.006	0.009
4	1.21	1.20	0.01	0.03	0.003	0.010
5	1.15	1.14	0.02	0.04	0.006	0.008
6	1.08	1.08	0.02	0.04	0.005	0.009
7	1.01	1.01	0.02	0.03	0.008	0.007
8	0.94	0.94	0.02	0.03	0.002	0.008
9	0.87	0.87	0.01	0.03	0.005	0.008
10	0.79	0.79	0.01	0.03	0.004	0.008
11	0.70	0.70	0.01	0.03	0.003	0.012
12	0.63	0.63	0.01	0.04	0.005	0.009
13	0.55	0.56	0.01	0.03	0.003	0.011
14	0.50	0.50	0.00	0.04	0.000	0.010
15	0.42	0.42	0.01	0.04	0.004	0.007
16	0.37	0.37	0.01	0.02	0.003	0.004
17	0.32	0.32	0.02	0.02	0.006	0.008
18	0.28	0.30	0.01	0.03	0.005	0.008
19	0.27	0.27	0.01	0.02	0.005	0.008
Average			0.013	0.031	±0.004	±0.009

all was found. The same strip, when read by the visual method, however, showed a small but definitely larger spread in values for the ten readings than that obtained by the physical instrument. Of the eighteen steps read, five had a spread of 0.04, ten had a spread of 0.03, and three had a spread of 0.02. In no case was the spread less than 0.02.

When the results obtained for the average deviation for a single reading are examined it will be noted that the results for the physical instrument vary from 0.00 to ±0.008, with an average for all steps of ±0.004. When read by the visual method, the average deviation for a single reading varies from ±0.004 to ±0.011 with an average of ±0.009; *i. e.*, the uncertainty of a single reading made by the visual method is at least twice that of a reading made by the physical method.

Since the sensitometric characteristic is usually determined by drawing the smooth curve that best represents the composite result for fifteen or more points, it will be realized that the uncertainty of making an individual visual reading is of no very great importance. To illustrate the point, the curves in Figs. 2 and 3 were plotted from

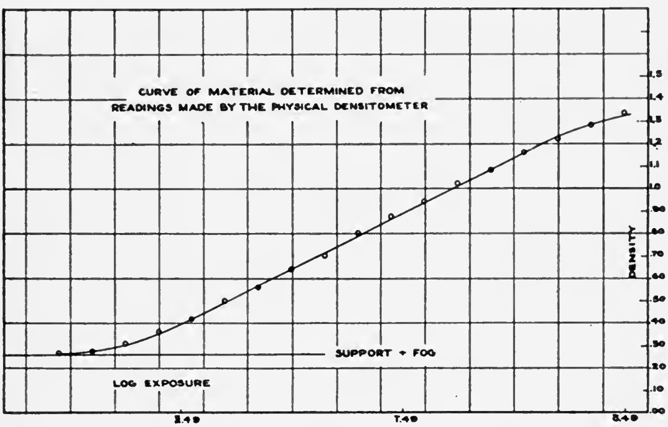

FIG. 2. Curve of material determined from readings made by the physical densitometer.

physical and visual density readings of the same strip. The curves are practically identical, although the scattering of the visual points about the line is appreciably greater than the scattering of the physical density values.

Thus, for routine sensitometry it is doubtful whether the increase of accuracy of the physical method over the visual method is of great importance. It may be mentioned, however, that the physical instrument has a distinct advantage over the visual method in that it is not subject to the likelihood of mistakes in readings or settings or to the possible skipping of steps. Moreover, its accuracy is unimpaired by the fatigue that affects the quality of results obtained by the visual methods.

There is one case for which the additional accuracy of the physical instrument is very important. For some types of sensitometric work it is necessary to determine with high precision a point on the characteristic curve having a certain slope or gradient. If the gradient is very low, it usually lies on the toe of the curve, and if the exact slope of the curve in that region is not known with high precision, it becomes extremely difficult to determine definitely the exposure required to produce the gradient in question.

Table III gives results for a motion picture positive material on a clear base similar to those given in Table II for a motion picture negative material. It will be noticed that the average results obtained by both methods for this material are practically identical,

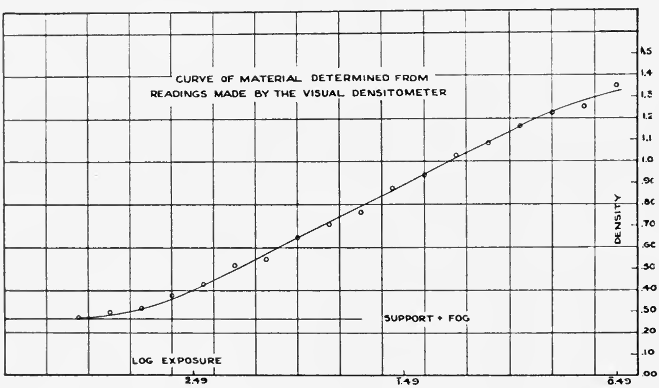

FIG. 3. Curve of material determined from readings made by the visual densitometer.

showing that the difference in diffusion characteristics between fine-grained positive and course-grained negative materials has no effect upon the results produced by the physical instrument. The spreads in density values obtained by both methods are again about the same as those obtained for the negative material. Likewise, the average deviation for a single reading is the same for both methods, as was true in the former case.

The results discussed so far were from measurements made on clear- or gray-base film. Similar measurements were made also on motion picture positive material coated on green and red supports. A summary of the results obtained for the green-base material is given in Table IV. Because of the difficulty of making a visual match for a highly colored strip, it is common practice in visual densitometry to place a piece of the fixed-out support in the comparison beam so that the color of the two sides of the photometric field is the same. With the physical instrument measurements were made including the density of the colored strip. It will be noted, therefore, that the values obtained by the physical method are somewhat higher than those made by the visual method. The density of the colored support measured by the physical instrument was found to be 0.20. When this density is subtracted from the total density for each strip measured by the physical instrument, the agreement of results with those obtained by the visual method is as good as those obtained for materials coated on clear or gray supports.

TABLE III

Motion Picture Positive Material—Clear Support

Step	Average Physical	Average Visual	Spread Physical	Spread Visual	Average Deviation Physical	Average Deviation Visual
8	2.59	2.60	0.03	0.03	±0.007	±0.011
9	2.41	2.40	0.01	0.04	0.005	0.012
10	2.14	2.13	0.02	0.04	0.007	0.011
11	1.86	1.86	0.02	0.03	0.005	0.009
12	1.54	1.54	0.01	0.04	0.004	0.010
13	1.23	1.24	0.01	0.03	0.004	0.009
14	0.93	0.94	0.01	0.02	0.004	0.005
15	0.68	0.69	0.01	0.04	0.002	0.016
16	0.47	0.47	0.01	0.04	0.004	0.007
17	0.29	0.30	0.01	0.03	0.005	0.012
18	0.18	0.19	0.01	0.04	0.005	0.010
19	0.12	0.13	0.00	0.03	0.000	0.008
20	0.09	0.09	0.00	0.03	0.000	0.005
Average			0.012	0.034	±0.004	±0.009

While the spread in density values for the green support obtained by the automatic instrument is the same as was noted for the other materials, the spread in visually measured values, is noticeably larger. The average deviation for a single reading by the physical method is exactly the same as for the clear-base materials, but the average deviation for readings made visually is distinctly greater (especially for the higher densities) than was noted for other materials, in spite of the fact that color differences in the field were eliminated. The loss of visual accuracy in the reading of colored materials is probably the result of the decrease in contrast sensitivity of the eye to small differences in brightness for light of certain colors as compared with white light. A similar effect may be noted in Table V. The average deviation for a single reading made by the visual method for a red-base material is much greater than for a clear-base material.

The values in Table V for a motion picture positive material coated on a red base are given in the same manner as those in Table IV for a green-base material. When allowance is made for the density as measured by the physical instrument, the densities obtained by the visual and physical methods are nearly identical for every step. The spread in density and the average deviation ob-

TABLE IV

Motion Picture Positive Material—Green Support

Step	Average Physical With Base	Average Physical Minus Base	Visual Minus Base	Spread Physical	Spread Visual	Average Deviation Physical	Average Deviation Visual
8	2.61	2.41	2.44	0.02	0.06	±0.006	±0.013
9	2.42	2.22	2.21	0.02	0.04	0.006	0.013
10	2.18	1.98	1.97	0.02	0.04	0.005	0.012
11	1.88	1.68	1.67	0.01	0.05	0.005	0.015
12	1.63	1.43	1.41	0.01	0.03	0.004	0.008
13	1.32	1.12	1.11	0.01	0.05	0.005	0.010
14	1.04	0.84	0.84	0.01	0.05	0.005	0.014
15	0.80	0.60	0.61	0.01	0.07	0.002	0.011
16	0.62	0.42	0.43	0.00	0.02	0.000	0.012
17	0.45	0.25	0.26	0.01	0.03	0.003	0.007
18	0.34	0.14	0.15	0.02	0.02	0.005	0.005
19	0.25	0.05	0.09	0.01	0.03	0.002	0.009
20	0.21	0.01	0.04	0.01	0.03	0.004	0.004
Average				0.012	0.040	±0.004	±0.010

tained by the physical method are exactly the same for the red-base material as for the other materials. Both the spread and the average deviation for values obtained by the visual method are much greater for the red-base material than for any of the others studied.

To summarize the results of this comparison it may be said that there is no inherent difference in the average results obtained by the two methods; the accuracy of the physical instrument is greater in making a single reading on any kind of material and very markedly greater with colored supports; and the instrument is essentially free from mistakes that may be made by operators of visual instruments.

DURABILITY AND RUGGEDNESS

Although the instrument requires remarkably little attention, some improvements and changes in the original model are desirable. Most frequent difficulties encountered during the first six months of operation were: (*1*) wear in high-speed parts, such as the drive shafts and bearings of the motors and speed reducers; (*2*) sticking in the dash-pot of the piston that draws the diaphragm back; (*3*) pitting and burning of the sparking point and its insulator; (*4*) dust in the optical system.

The mechanical defects were largely overcome by making spare elements for all high-speed parts and modifying the design so that these parts may be readily replaced.

TABLE V

Motion Picture Positive Material—Red Support

Step	Average Physical With Base	Average Physical Minus Base	Visual Minus Base	Spread Physical	Spread Visual	Average Deviation Physical	Average Deviation Visual
9	2.76	2.28	2.31	0.04	0.06	±0.011	±0.030
10	2.54	2.06	2.07	0.02	0.04	0.007	0.012
11	2.29	1.81	1.78	0.03	0.05	0.009	0.011
12	1.96	1.48	1.48	0.02	0.06	0.005	0.017
13	1.70	1.22	1.20	0.01	0.07	0.004	0.016
14	1.42	0.94	0.93	0.01	0.04	0.003	0.010
15	1.17	0.69	0.68	0.01	0.04	0.005	0.011
16	0.95	0.47	0.48	0.00	0.04	0.000	0.015
17	0.78	0.30	0.31	0.02	0.02	0.005	0.007
18	0.66	0.18	0.17	0.01	0.03	0.003	0.010
19	0.58	0.10	0.10	0.01	0.04	0.002	0.009
20	0.54	0.06	0.05	0.00	0.03	0.000	0.008
Average				0.015	0.043	±0.004	±0.013

The piston that falls into the dash pot has been made loose-fitting to prevent sticking. It now acts merely as a counterweight, and the distance to which the diaphragm is moved back now depends solely upon the time during which the circuit of the magnetic clutch that drives the diaphragm is open. The timing is controlled by the switch-operating cam or the shaft driven by the over-running clutch.

A small point—not more than ten mils in diameter—must be used for the spark discharge, as otherwise the position of the spark will vary too much. All wires of this diameter will either oxidize or melt unless they are protected by an insulator making sufficiently close contact with the metal to cool it. Porcelain and plastic molded materials are unsatisfactory because they pit. Carbon deposits from the burned paper gather about the metallic point and materially increase the sparking area. Frequent cleaning or replacement of such points and insulators was necessary. An insulator made from a diamond bored with a 10-mil hole with a platinum wire drawn through the hole has proved entirely satisfactory.

The difficulty of dust in the optical system, particularly on the small end of the diaphragm opening, has not yet been entirely avoided. Efforts have been made to seal the system more thoroughly, but occasional cleaning is still necessary. Fortunately, errors arising from this cause are quickly discovered by periodically reading a check strip.

The photoelectric control system, including the relays, has given no trouble. If any appreciable change in cell sensitivity has taken place, both comparison and measuring cell must have changed in the same manner. It is believed that the opposed potential circuit with barrier layer cells used at the null output point is exceedingly reliable. The mechanical relay in well over two million operations has never caused any trouble.

Both lamps are run below their rated voltage, and replacements are infrequent. Three weeks is the average life of the measuring lamp and that of the galvanometer lamp, two months.

REFERENCES

[1] TUTTLE, C.: "A Recording Physical Densitometer," *J. Opt. Soc. Amer.*, **26** (July, 1936), No. 7, p. 282.

[2] TUTTLE, C., AND HIATT, B. C.: "A Note on the Measurement of Photographic Densities with a Barrier Type of Photocell," *J. Soc. Mot. Pict. Eng.*, **XXVI** (Feb., 1936), No. 2, p. 195.

[3] JONES, L. A.: "An Instrument (Densitometer) for the Measurement of High Photographic Densities," *J. Opt. Soc. Amer.*, **7** (March, 1923), No. 3, p. 231.

DISCUSSION

MR. KELLOGG: Does the physical densitometer read the identical spot on the step tablet each time? If so, how big is the spot?

MR. RUSSELL: One of the limitations, of course, of any sort of physical densitometer is that of getting plenty of light through the sample. Consequently, the instrument is designed for just about all of a type II*b* sensitometer step, which is about 8-mm. square. Our visual instruments are of the Martin's polarization type, which read areas not quite that large, but very nearly so.

MR. KELLOGG: I wonder, when using the type that measures smaller areas, how much variation occurs due to lack of perfect uniformity of the sample area. For example, the Capstaff densitometer, I believe, used a hole only about $^1/_2$ mm. across. How much variation to expect would depend upon the density and type of the photographic material, but could you give us a general idea what the variation is for a spot of that size?

MR. RUSSELL: The answer to that would depend somewhat, of course, upon the character of the strip being read. For motion picture film that has been carefully exposed, processed, and read, the results obtained by the two methods are very similar. For strips handled somewhat more carelessly, dust specks and things of that sort may be quite serious in the small field of the Capstaff instrument, causing the results to vary quite noticeably.

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SOCIETY ANNOUNCEMENTS

HOLLYWOOD CONVENTION

HOTEL ROOSEVELT
MAY 24–27, 1937

As announced in previous issues of the JOURNAL, the next Convention of the Society will be held at Hollywood, Calif., May 24th–27th, inclusive. Headquarters of the Convention will be the Hotel Roosevelt, where excellent accommodations are assured. A reception suite will be provided for the Ladies' Committee, and an excellent program of entertainment will be arranged for the ladies who attend the Convention.

Special hotel rates, guaranteed to SMPE delegates, European plan, will be as follows:

One person, room and bath	$3.50
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	6.00
Parlor suite and bath, 1 person	9.00
Parlor suite and bath, 2 persons	12.00

Room reservation cards will be mailed to the membership of the Society in the near future, and everyone who plans to attend the Convention should return his card to the hotel promptly in order to be assured of satisfactory accommodations.

Special garage rates will be provided for SMPE delegates who will motor to the Convention, and arrangements for golfing and other diversions will be announced by the Local Arrangements Committee in the near future.

The dates of the Convention have been chosen in order that delegates may avail themselves of the summer tourists' rates, which go into effect May 15th. The following table lists the railroad fares and Pullman charges:

City	Railroad Fare (round trip)	Pullman (one way)
Washington	$120.75	$20.50
Chicago	86.00	15.75
Boston	132.80	22.25
Detroit	98.30	18.00
New York	126.90	21.75
Rochester	112.50	19.25
Cleveland	101.35	18.00
Philadelphia	122.85	21.00
Pittsburgh	107.10	18.75

The railroad fares given above are for round trips, forty-five day limits. Arrangements can be made with the railroads to take different routes going and coming, if so desired, but once the choice is made it must be adhered to, as changes in the itinerary may be effected only with considerable difficulty and formality.

New streamlined trains will be operating from Chicago to Los Angeles and San Francisco, making the trip to Los Angeles in 39 hours. A special fare is levied on these trains.

Plans for the Convention are already under way. The Papers Committee, under the Chairmanship of Mr. G. E. Matthews, and directed by Mr. J. I. Crabtree, *Editorial Vice-President*, are already engaged in soliciting an outstanding group of technical papers and presentations. The Officers and Board of Managers of the West Coast Section, Mr. K. F. Morgan, *Chairman*, are collaborating with Mr. W. C. Kunzmann, *Convention Vice-President*, in arranging the various facilities of the Convention.

The usual Semi-Annual Banquet will be held, and arrangements will be made for visits to studios and to other points of interest in and about Hollywood. Details of the program will be announced later, but in the meantime members are urged to make their plans early for attending the Convention, and it is suggested that they may perhaps combine their vacation periods with the trip.

ATLANTIC COAST SECTION

At a meeting held on December 3rd in the auditorium of the Electrical Association of New York, several reels of film were projected, through the courtesy of Mr. E. A. Williford, of National Carbon Company, illustrating the various processes applied in making carbons for motion pictures and other purposes. The pictures were accompanied by running comments describing the processes and their functions in producing the finished carbons.

Following this presentation, two reels of motion pictures, made at the M-G-M Studios of Hollywood, illustrating various cinematographic applications of the new polarizing material, Polaroid, were shown. These reels had previously been projected at the Rochester Convention.

As a result of the recent elections, the Officers and Board of Managers of the Atlantic Coast Section for the year 1937 will be as follows:

G. FRIEDL, JR., *Chairman*
L. W. DAVEE, *Past-Chairman*
D. E. HYNDMAN, *Sec.-Treas.*
M. C. BATSEL, *Manager*
H. GRIFFIN, *Manager*

The Chairman, Past-Chairman, and Secretary-Treasurer are elected for one-year terms; of the Managers, the term of Mr. Batsel has yet one year to run; that of Mr. Griffin, two years.

MID-WEST SECTION

At a meeting held on December 10th, at the manufacturing plant of Motiograph, Inc., Chicago, a paper was presented by Mr. E. J. Wienke on "The Adaptability of the Motiograph Projector to Sound." Following the paper, several reels of film were projected showing third-dimensional effects achieved by the Fleischer Studios in producing animated cartoons. These films had previously been projected at the Rochester Convention in conjunction with a paper on the subject appearing elsewhere in this issue of the JOURNAL.

As a result of the recent elections, the Officers and Board of Managers of the Mid-West Section for the year 1937 will be as follows:

C. H. STONE, *Chairman*
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SOCIETY SUPPLIES

The following are available from the General Office of the Society, at the prices noted. Orders should be accompanied by remittances.

Aims and Accomplishments.—An index of the *Transactions* from October, 1916, to December, 1929, containing summaries of all articles, and author and classified indexes. One dollar each.

Journal Index.—An index of the JOURNAL from January, 1930, to December, 1935, containing author and classified indexes. One dollar each.

SMPE Standards.—Reprints of *SMPE Standards and Recommended Practice.* Twenty-five cents each.

Membership Certificates.—Engrossed, for framing, containing member's name, grade of membership, and date of admission. One dollar each.

Lapel Buttons.—The insignia of the Society, gold filled, with safety screw back. One dollar each.

Journal Binders.—Black fabrikoid binders, lettered in gold, holding a year's issue of the JOURNAL. One dollar each. Member's name and the volume number lettered in gold upon the backbone at an additional charge of fifty cents each.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

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JOURNAL
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See p. 218 for Technical Committees

THE PROJECTION OF LENTICULAR COLOR-FILMS*

J. G. CAPSTAFF, O. E. MILLER, AND L. S. WILDER**

Summary.—*In the projection of lenticular color-films a large portion of the incident light is lost by absorption in the tricolor filters. To determine the feasibility of satisfactorily showing these films in large theaters, an experimental projector was set up embodying the few simple changes in standard theater equipment that were necessary to obtain the required large increase in screen illumination.*

Successful demonstrations with the apparatus at Loew's Rochester Theater at Rochester and the Center Theater at New York have proved that it is quite possible to secure enough screen brightness to give a satisfactory showing of the lenticular films in the majority of theaters.

The principal changes made in the standard projection apparatus in order to obtain the greatly increased illumination were as follows:

(1) Increased Relative Aperture.—By substituting an f/1.6 projection lens for the f/2.4 lens commonly used, and by increasing the working relative aperture of the 65-ampere high-intensity reflector arc so as to take full advantage of the increased aperture of the projection lens, it was possible to get 2.25 times the screen illumination obtained with the regular equipment.

(2) Reduction of Shutter Loss.—A further increase was obtained by the use of a quicker pull-down and a corresponding reduction in the angle of the shutter blades; this may not, however, be feasible in practice.

(3) Increased Filter Transmission.—As a result of numerous practical tests it was found to be possible to increase the transmission of the tricolor projection filters by 33 per cent, without undue loss of color values.

(4) Lower Print Density.—The excellent tone reproduction obtained in the process, together with a modification of the optics of the lenticular film, makes possible a substantial lowering of the print density. The resultant increase in the brightness of the projected image amounts to some 25 per cent.

The large increase in the radiant energy directed upon the film has made it necessary to employ a heat filter in the condenser system.

Refinements in the present system are expected to produce additional small increases in illumination, and it is believed to be possible to develop other special equipment to take adequate care of the few (special) cases where it is necessary to project upon an unusually large screen.

The lenticular film color process, in common with other additive color processes, involves a large loss of light by absorption in the color filters necessarily used in the projection system. Therefore,

* Received October 12, 1936; presented at the Fall, 1936, Meeting at Rochester, N. Y. Communication No. 605 from the Kodak Research Laboratories.

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

it requires so much more illumination than is needed for projecting black-and-white pictures that it was believed until recently by many persons in the industry that it was impossible to show these pictures properly even in the average theater, not to mention the *de luxe* houses having screens from 25 to 35 feet in width. To illustrate the seriousness of the problem, it was estimated that about ten times the normal amount of light would be needed. The color filters used for projection during the earlier experimental work had a transmission of only 12 or 13 per cent, and the intensity was further reduced by the lenticular surface of the film support. The Kodak Research Laboratories recently undertook to make a systematic

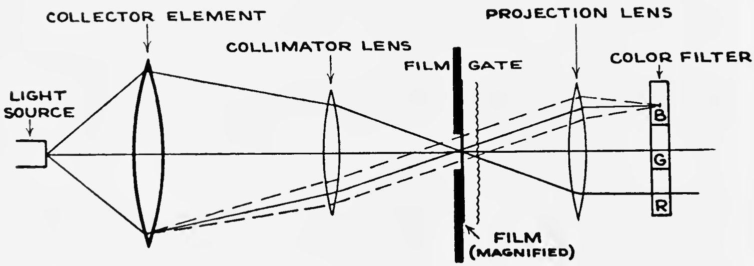


FIG. 1. Diagram of projection optical system for lenticular color-film.

investigation of the possibilities of lenticular film projection and to give an actual demonstration in a *de luxe* theater.

A preliminary survey of the problem indicated quite a number of possible ways in which the screen illumination could be increased. Some of these, which were temporarily laid aside for practical reasons, will not be mentioned except in the concluding remarks. With a desire to limit the investigation to the use of already existing projection equipment with only minor alterations, the work was pursued along the following lines:

(*1*) Reduction of the absorption loss in the color filters.
(*2*) Modification of the optical system to increase its relative aperture.
(*3*) Recovery of part of the light lost because of the shutter.
(*4*) Reduction of the density of the prints.
(*5*) Improvement in the operating conditions of the illuminating system.

EXPERIMENTAL

Filters

Since the greater part of the light is lost due to absorption in the color filters, the problem of screen brightness becomes progressively easier as the filter transmission is increased. After a certain point, however, the colors of the projected picture begin to lose saturation, and appear "washed out." The color reproduced upon the screen can be of no higher degree of purity than that of the projection filters. As the red filter is made lighter, it soon begins to transmit yellow, and becomes an orange-red. With such a filter a good red can not be represented properly upon the screen. After considerable experimental work with dyes, and a number of observations with filters of different densities, a standard filter was finally adopted that was thought to have the highest transmission it was possible to get without too noticeable loss in color saturation. The transmission of this filter, when used with the high-intensity arc system to be described later, was 22 per cent. This multiplied by the 80 per cent transmission of the lenticular film support gives an overall transmission of 17.6 per cent. Therefore, the factor by which the normal illumination needs to be increased is 5.8 times.

Optical System

Fundamental Conditions.—As shown in Fig. 1, the essential elements of a projection system suitable for lenticular color-films are: light-source, collective element, collimator lens, film-gate, projection lens, and color filter. A detailed discussion of the optical relations involved in the use of lenticular films is not within the scope of this paper, and therefore a mere statement is made of the necessary conditions to be observed in practice:

(*1*) The light-source must be imaged at the film-gate.
(*2*) The collecting element must be imaged at the color filter.
(*3*) It is essential that all elements be centered upon the optical axis.
(*4*) The color filter must be located at the front focus of the projection lens.

It will be obvious that the first three of these are the identical conditions for optimal screen brightness and uniformity, even in black-and-white projection. The fourth condition comes about as a result of a particular optical property of the lenticular color-film itself, and is dependent upon the optical arrangement used in printing.

Projection Lenses.—The greatest single gain in illumination promised to come from increasing the relative aperture beyond the $f/2.5$ systems commonly used. In view of the successful use, in the 16-mm. field, of lenses having relative apertures of $f/1.6$ or better, it was thought that it should be possible to set up a 35-mm. system that would be equally efficient. Two $f/1.6$ lenses were obtained having focal lengths of 120 and 160 millimeters. Except for the somewhat inferior definition of one of them, these lenses were entirely satisfactory for the purpose. On account of the much larger diameter of the lens barrel, it was necessary to make a new lens mount for the Simplex projector.

Illuminating Systems.—Before the increased relative aperture could be fully realized, it was necessary to modify the existing illuminating system so as to fill an angle of $f/1.6$ and at the same time to fulfill the

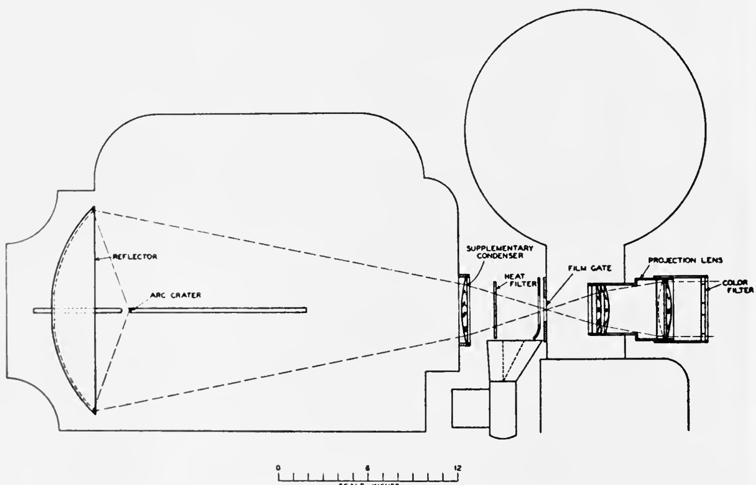


FIG. 2. Scale drawing of experimental projection system.

conditions necessary for use with lenticular films. The lamp selected for the first experiments was the Peerless "Magnarc,"* which appeared to be a good example of a high-efficiency reflector system. After a number of optical arrangements had been tried, using reflectors of various focal lengths, it was apparent that the only change necessary was the addition of an inexpensive condenser lens at the front of the lamp house. To avoid breakage due to the extreme heat, this lens was made of Pyrex. The complete optical arrangement as it was finally used is shown in Fig. 2, which is drawn approximately to scale. The regular "Magnarc" reflector is 14 inches in diameter, and

* Other lamps on the market similar to this one should be equally suitable.

$5^1/_4$ inches from the arc crater. The plano surface of the auxiliary condenser is 28 inches from the center of the reflector, and $5^1/_4$ inches from the film-gate. This condenser is $4^7/_{16}$ inches in diameter and 15 inches in focal length. The addition of this condenser to the "Magnarc" brings the image of the reflector into the plane of the three-color projection filter. The filter is located near the front focal plane of the projection lens, a necessary condition for lenticular film projection. In order to allow the larger cone of illumination from the modified illuminating system clear access to the film-gate, it became necessary to enlarge the apertures in the shutter housing and in the masks back of the aperture plate on the Simplex projector. When the full $f/1.6$ relative aperture is filled, there should be 2.31 times the screen brightness that is obtained with a corresponding system of relative aperture $f/2.5$. The actual screen brightness obtained with this system was slightly less due to mild imperfections in the quality of the reflector. Certain dark zones appear upon the reflector surface when viewed from the film-gate. This modified "Magnarc" system was used for a great part of the experimental work and for the demonstrations that are to be mentioned presently.

Magnification of the Arc Crater.—It will perhaps be contended that the increase in the relative aperture attained in this way is at the expense of the crater magnification at the film-gate, and that the uniformity in screen brightness will be unsatisfactory. Of course, the crater of the high-intensity arc is not uniform in brightness, being brighter at the center than at the border. For this reason, and also in order to provide some tolerance in the position of the arc, present illuminating systems are made to have a higher magnification than would be necessary just to fill the aperture. However, when the lenticular color-films are projected with the above-described system, the corners of the picture do not appear to be more poorly illuminated than is the case with the average black-and-white system. The reason for this lies in a particular requirement of the camera and projector lenses used in the lenticular film process. The lenses used in black-and-white work, both in the camera and, to a somewhat less extent, in the projector, cause a falling off in the marginal illumination due to the fact that the lens aperture can not be completely filled for oblique angles.[1] With some of the camera lenses ordinarily used in black-and-white work, this becomes so bad that the corner illumination falls nearly to zero, and results in a print having higher density at the corners than at the center of the picture. When this print is projected, the additional density at the corners adds considerably to the deficiency of corner illumination already present in the projection system.

This property of the lenses becomes objectionable in the lenticular color-film process, but for a different reason, as seen in Fig. 3, which shows different views of the lens and color filters as they would appear when viewed from different points of the screen. Disproportionate areas of the color segments are illuminated for different

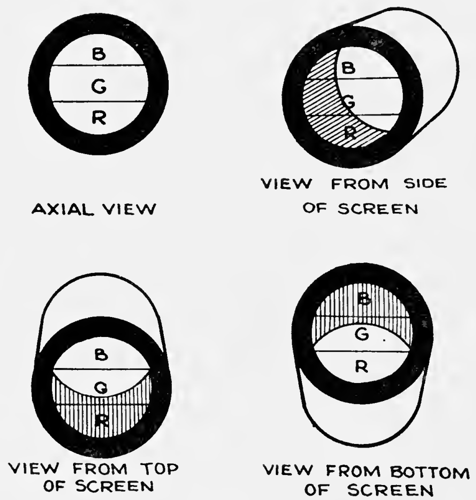


FIG. 3. Projection lens and color filters seen from different points of the screen showing cut-off of the filter zones.

positions around the margin of the screen, a condition that leads to an uneven distribution of color on the screen and can not be tolerated. Thus, because of the choice of lenses that this makes necessary, one can afford to use a lower magnification of the crater. However, it may be desirable to have a slightly larger crater image than that used in the present system, which could be accomplished by substituting a 9- or 10-mm. carbon for the 8-mm. one now used.

The Heat Problem.—Considering that there are already reports from theaters when using improved black-and-white equipment of too much heat at the picture aperture, it was not surprising to find in the preliminary trials with this more efficient optical system that the film was badly damaged by the terrific heat. Attempts to cool the film by a jet of compressed air were insufficient. Clearly some sort of heat filter had to be used. Previous experience with water cells did not favor their use in the theater projection booth, so heat-absorbing glass was tried. Used in a single sheet, it broke repeatedly even though it was of the heat-resisting type. Cutting the glass into $^3/_4$-inch strips and mounting the strips side by side prevented breakage, but it was found that the glass would soon melt unless subjected to a current of air. Since too much color in the glass would have been objectionable, it was necessary to use a density only just sufficient to reduce the heat to a safe value. The filter finally adopted was in the form of several $^3/_4$-inch strips of Corning *Extra-Light Aklo*, 2 millimeters thick, held loosely side by side in a rectangular metal frame, and cooled by a gentle current of air from a small furnace blower. The location of the filter in the optical system must be such that the edges of the glass strips are not visible upon the screen. In the present instance, the glass was mounted upon the front of the shutter housing at a distance of approximately $3^3/_8$ inches from the film-gate. No trace of the edges of the strips has ever been noticed upon the screen. The air was directed upon both sides of the glass by appropriate baffles With this filter, which transmits only 25 or 30 per cent of the total heat energy, the heat at the aperture is actually less than that occurring with some of the better projection lamps now in use. The familiar "biscuit" appearance of projected prints is entirely lacking. Part of the air from the blower is directed upon the film-gate, which gives slight additional cooling to the film and to the metal parts around the aperture.

A Relay Condenser System.—To see what could be done with the 120-ampere, high-intensity arc used with a condenser system, a Hall & Connelly lamp was set up with a set of 7-inch condensers and a relay system. In a relay system full advantage can be taken of the entire crater surface because it is not imaged at the aperture. Furthermore, advantage can be taken of the fact that the entire crater area emits red light of practically uniform intensity. Since in color work, the limiting color seems to be red, use can be made of the entire crater surface. The measurements of screen brightness made with this set-up show that it is possible to get equally as bright a screen with the "Magnarc" system, and it becomes somewhat easier to maintain the screen uniformity. Therefore, where there is sufficient space in the projection room to accommodate the increased length of a relay system, this type of lamp would serve very well. The remarks about to be made about adjustment and operation of the optical system apply equally well to condenser systems and reflector systems.

Adjustment and Operation.—A great number of observations were made with the best types of black-and-white illuminating systems at present in use, in order to determine, if possible, what effect the operating conditions and the adjustment and alignment of the optical system had upon screen brightness. Based upon these observations, it is believed probable that the average theater projection machine often does not deliver much more than half the screen illumination it is capable of delivering. Losses occur in many ways: accumulation of dirt upon the screen lowers the reflecting power; the reflector or condenser surface facing the arc becomes clouded with smoke, pitted by flying particles, and has to be cleaned constantly in order to preserve the light transmission. Because of the imperfections in the commercial mirrors and condensers, the screen uniformity is not at its best when the system is adjusted to provide the maximum of screen brightness.[1] The projectionist, therefore, has to sacrifice a considerable amount of screen brightness in order to improve the uniformity. Errors in centering condenser systems can be responsible for appreciable losses of illumination. Some projection lenses are in use that have a lower transmission than is desirable. Carbon arcs are somewhat erratic in behavior. The crater sometimes burns unevenly, and the crater brightness varies from time to time. Substantial improvement could be made in all these operating conditions. Possibly new equipment would have to be designed in order to free the projectionist from the necessity of constantly attending to the adjustments of the various manual controls found upon the present lamps. If the arc operation could be sufficiently stabilized, and the arc crater accurately held to the optical axis, the entire system could be set up and adjusted once for all, and the projectionist would then be required to make only the single adjustment of keeping the arc crater in the correct position along the optical axis. There is no reason, furthermore, why an arrangement using photoelectric cells could not be devised that would make even this adjustment automatically.

Reduction of the Shutter Loss

Since 50 per cent or more of the incident light is lost at the shutter, it seemed worth while to attempt to recover some of this loss by speeding up the pull-down movement, and using shutter blades of the narrowest possible angle. No originality is claimed for the method used. Inside the housing of the Geneva pull-down mechanism used on all Simplex machines there is a pair of small spur gears, through which the intermittent assembly is driven. By substituting a pair of elliptical gears, the intermittent movement was accelerated so that the pull-down period occurred in 52 degrees of the cycle instead of the usual 90 degrees. Using this in combination with a 45-degree covering blade and a 30-degree flicker blade, a gain of 59 per cent was made in screen illumination. However, it was thought that this was too severe for the film, and a second pair of elliptical gears was prepared that gave a more moderate acceleration to the pull-down mechanism, and accomplished the movement of the film in a 68-degree interval. Using with this a covering blade of 60 degrees and a flicker blade of 40 degrees, a gain of 44 per cent was realized. However, unless there are certain changes made in projector design that will compensate by reducing the stresses occurring during the pull-down operation, it is doubtful whether application of even this mild degree of acceleration to the Geneva movement is practicable. The Powers movement, however, because of the smooth acceleration, offers possibilities for a quicker pull-down.

The proper size for the shutter blades was arrived at empirically by progressively increasing the width until there was no noticeable flicker or travel-ghost upon the screen at the ordinary brightness level. Advantage was taken in these experiments of the fact that the perceptibility of both flicker and travel is less as one proceeds to lower levels of illumination. If it should later be found necessary to increase the shutter blade slightly, it would represent a loss of only a few per cent. A further discussion of the subject of projector mechanisms is believed outside the scope of the present paper. Although the work done so far must be regarded as merely preliminary, there seems to be ample ground for believing that more can be done in a practical way to recover a considerable part of the light lost at the shutter. In this connection, moving the shutter to a position very near the film plane so as to effect quicker cut-off of the light-beam would be a worth while step. However, in the small neighborhood theaters, probably no change in projector mechanism would be needed in order to get sufficient light.

Print Density.—Another loss of light occurring in the ordinary projector is caused by the minimum photographic density allowable in making the print. Because of the excellent tone reproduction attained with the lenticular process, it is possible to make the print density lower than that of a corresponding black-and-white print by approximately 0.10. This gives a 25 per cent increase in picture brightness.

Summary of the Gains Made.—It was pointed out above in connection with the filters that the maximum filter transmission, combined with that of the lenticular support, was in the neighborhood of 17.6 per cent, which corresponds to a factor of 5.8. This is the factor by which the screen brightness must be increased in order to equal that of corresponding black-and-white projection. The gains made and discussed above may be summarized as in Table I:

TABLE I

		Factor
(*1*)	Increased relative aperture (*f*/2.5 to *f*/1.6)	2.31*x*
(*2*)	Reduction of shutter loss 60° to 40° shutter, 68° pull-down	1.44*x*
(*3*)	Lower print density by 0.10	1.25*x*
	Product of all the above gains	4.32*x*

This is somewhat short of the required 5.8, which is necessary to balance the filter loss. In addition to these gains, the authors are of the opinion that the screen illumination can be doubled if sufficient improvement can be made in the operating conditions of the arc and the optical system. The product of this and all the gain factors given above leaves ample margin for the projectionist in operating the projector when compared to the loss factor of 5.8 mentioned above.

DEMONSTRATIONS

The complete experimental projector was used to give two demonstrations in the Loew's Rochester Theater in April, 1936. On both occasions the 52-degree accelerated pull-down was used. After the 68-degree pull-down was substituted, the machine was used to give a demonstration in the Center Theater in Radio City on July 9, 1936, before some 200 guests. Many of the audience commented upon the show, but no one expressed any feeling that there was a lack of screen brightness. Some said they actually believed the screen brightness was greater than necessary.

Although many measurements of the screen illumination were made throughout all these experiments, a simple statement of the values in foot-candles attained would have little meaning in view of the conflicting reports already published both as to the screen brightness actually prevailing in theaters and as to the actual level of screen brightness that is to be desired. To give some indication, however, of the amount of light obtained on the screen of the Center Theater, the value measured with a Weston illumination meter, model *603*, without the color filters or lenticular film, but with the shutter running, was 33 foot-candles at the center of the screen. The screen picture was 22 feet wide, and the projection angle was approximately 28 degrees. If the heat-absorbing glass filter had been removed, the value would have been more than 40 foot-candles.

FURTHER POSSIBILITIES

Of course, every precaution was taken in both the demonstrations to assure optimal operating conditions. It is probably too much to hope that optimal conditions could be thus maintained at all times. With this in mind, other possibilities will now be discussed, by means of which still more light might be obtained. If the regular high-intensity carbons were used, instead of the Suprex carbons, in connection with a reflection type of lamp of most efficient design, there would be an increase due to the higher intrinsic brightness attained with the regular high-intensity carbons. The possibilities that a new type of arc source will be developed having still higher intrinsic brightness can not be excluded. In this connection, carbon manufacturers express the belief that developmental work now in progress will produce a carbon that, with the proper optical system and lamp mechanism, will give the desired intensity, color, and uniformity of light, and, at the same time, keep the energy input into the arc within reasonable limits. There are some improvements yet to be made in the present experimental optical system that will make it possible to eliminate some of the glass-air reflection losses. A desirable further improvement in the optical quality of commercial reflectors would reduce losses arising from the imperfect formation of the crater image at the film-gate. The belief has already been expressed that improvement in projector design could be made that would further reduce the shutter loss. Another consideration is the possibility of a slight reduction of the screen size. Even for black-and-white projection, a reduction of screen size is being advocated by some in the industry. It is difficult to find any objection to doing this, since, with the present sizes of screens there is always a large block of seats near the front of the theater that the patrons avoid because of the discomforts of so large a viewing angle. There would seem to be no loss of desirable seating space by making conditions more comfortable for those in the front even at the expense of some loss in the rear of the house. Since the screen brightness would vary inversely as the square of the screen width, a considerable gain in illumination ought to be made possible by only a moderate reduction of screen size. The use of the ordinary specular screens would, of course, be limited to the long narrow houses, in which the seats are distributed within an angle of some 20 degrees. The design of equipment to take care of the few large houses having exceptionally large screens must be considered as a separate problem.

CONCLUSION

Although not all possibilities have been utilized in this preliminary investigation of the problem, it is seen from the foregoing experiments that lenticular color-films can be projected satisfactorily in the average theater without the necessity of making major alterations in the present equipment.

REFERENCE

[1] COOK, A. A.: "A Review of Projector and Screen Characteristics and Their Effects upon Screen Brightness," *J. Soc. Mot. Pict. Eng.*, **XXVI** (May, 1936), No. 5, p. 522.

DISCUSSION

MR. RICHARDSON: Is it not possible, by means of the additional lens, to parallel the light-beam between the aperture and the projection lens, and thus have more uniform screen illumination?

MR. MILLER: Arc lights do not radiate with equal intensity in all directions. Something could probably be done by using a shorter focal length reflector. Unfortunately none were available at the time, and we wanted to incorporate a minimum number of changes in the lamp.

MR. TASKER: The review room screens at Universal Studio are measured daily, in view of the fact that they vary considerably. We find that it is possible by daily readjustment of the arc to get such results as 16 foot-lamberts at the center, $14^1/_2$ to 15 at the edges, measured horizontally across top and bottom. Within a day's time the lamp is out of adjustment, and may be off as much as 15 at the center, 15 on one side, and 11 on the other.

MR. KURLANDER: A ratio of $1^1/_2$ to 1 from the center to the corners is considered excellent. That is about the limit one can get and still maintain good efficiency. It is comparatively easy to get evenness if one wants to sacrifice intensity.

For 16 years or more we have been trying to get even a 10 per cent increase in screen illumination. Mr. Miller has just told us how he obtained a 400 per cent increase. In view of some of the methods used to attain this 400 per cent increase, I should like to see it analyzed a bit more. The mechanical efficiency of the projector, over a period of 16 years, has been increased from about 4 per cent to 8 per cent—a 100 per cent increase over a period of 16 years. Here, over night, we have another 400 per cent.

MR. MILLER: We got 2.3 times as much light by increasing the relative aperture. It was a few per cent less than that when the aperture was increased from $f/2.5$, which is about what is used on the average now, to $f/1.6$. I purposely omitted discussing the optical principles, particularly because they were so well treated by A. A. Cook in the JOURNAL of last May.

MR. MCAULEY: What is the distance from the vertex of the mirror to the aperture? How much did you move up the projector?

MR. MILLER: The projector was moved up only very slightly. The distance from the vertex of the reflector to the lens was 28 inches; from there to the aperture was $5^1/_4$ inches, making a total of $33^1/_4$. I believe a distance of 34 inches is recommended by the lamp manufacturers.

MR. MCAULEY: Was it necessary to change the reflector?

MR. MILLER: No.

MR. MCAULEY: In order to get the increase of speed? It would seem that you would hardly fill the lens at a distance of 33 inches.

MR. MILLER: If the light-rays are drawn backward after passing through the auxiliary condenser, it seems from the aperture as if the mirror were bigger.

MR. BRENKERT: Did you say that with the same mirror that was furnished with the lamp, and by adding the collimating lens, you filled an $f/1.6$ lens?

MR. MILLER: Yes.

MR. BRENKERT: And obtained more light upon the screen than by using an $f/2.3$?

MR. MILLER: Yes.

MR. BRENKERT: How did you get more light out of the arc, through the aperture and from the mirror, without changing any mirror specifications?

MR. MILLER: The fact is that the spot upon the aperture plate in the regular machine is much larger than the aperture itself, due to imperfections in the optical system, and also to the fact that the lamp manufacturer is desirous of giving a broad tolerance to the projectionist for keeping his arc focused properly. The magnification of the lamp without the condenser was six times.

MR. BRENKERT: You reduced the size of the spot by means of the auxiliary condenser, and that is your sole mention of greater angle and more light.

MR. MILLER: Yes, but we could use a larger carbon and a little more current, and thus increase the size of the spot. We use an 8-mm. carbon; but I think a 10-mm. would be better.

MR. BRENKERT: What became of the illumination at the corners?

MR. MILLER: If a black-and-white film was projected, the corner illumination was not good; if a lenticular film, the corners were no worse than for the black-and-white, with normal projection as occurring in theaters.

TRICK AND PROCESS CINEMATOGRAPHY*

J. A. NORLING**

Summary.—*Process photography, which is the broad classification given to all branches of special and trick cinematography, plays an important part in making today's motion picture. Many articles have appeared relating to this subject, but, unfortunately, most of them have been devoted only to a discussion of the importance of this branch of photography, and very few writers have divulged any of the details of the methods employed. This paper sets forth in general the underlying procedure in the various branches of the art, and treats many phases thereof in sufficient detail to be fully informative.*

The branches of process photography disclosed include: transitional effects, such as dissolves and wipes; matte shots; simple and intricate multiple exposures; composites and montages; animated titles and presentation effects; combined drawing and actual photography; optical trick printers and cameras; miniature projection background process; problems in making dupe negatives by projection, dodging, etc. Important steps are described and illustrated, and special devices are shown and their essential functions and operation described.

Trick cinematography, as exemplified by double exposures, miniature settings, and so-called "glass" shots, have been employed to a considerable extent since the early days of the motion picture. The pioneer workers created some excellent effects, considering their facilities. They were handicapped in several ways. Early cameras did not provide sufficiently accurate registration to avoid movement between individual exposures comprising a composite scene. In addition, the photographic emulsions then available were unsuitable for duplicating. The first limitation, that of accurate registration, has been overcome almost entirely by refinements in camera and printer design; the second handicap, that of inadequate photographic materials, has also become a matter of minor importance.

The early cameras were rather flimsy contraptions, and the film pull-down mechanisms were anything but accurate. Claws of vari-

* Received October 10, 1936; presented at the Fall, 1936, Meeting at Rochester, N. Y.

** Loucks and Norling Studios, New York, N. Y.

ous types and spring-operated pawls engaged the sprocket holes. Attempts were made to keep the film in registration by the use of pressure pads and side shoes, but these were expedients that only partly performed that function. It was not until pilot-pin registration made its appearance that the problem of accurately positioning the film was on its way to a satisfactory solution.

With the appearance of well-designed cameras, and the introduction of dissolving shutters, masking devices, *etc.*, it became easier to produce trick effects at the time of shooting, whether in the studio or on location. Due to the length of time often required for these operations when made on the set, the production of transitional effects, such as fades and dissolves, ultimately became a matter for after-treatment. Fades were made in the negative by bleaching; dissolves by duping on a printer. Neither method was very convenient, nor were the results, especially with dissolves, very satisfactory. Intricate work, such as matte shots, still had to be made on an original negative, which was kept in the camera magazine, often for days, until all the exposures comprising the composite could be completed. Extreme care had to be exercised to overcome variations in exposure and contrast.

With the appearance of suitable duplicating emulsions, it became possible to use methods of after-treatment for nearly all the special effects required in making the modern motion picture.

Contrary to the prevailing notion, most trick photography does not demand a completely equipped laboratory containing expensive and complicated equipment. Most, if not all, the effects used in production can be made in the modern camera. The prime requirement is skill and ingenuity on the part of the operator. A few minutes of work with simple tools and odds and ends will often be all that is required to make special apparatus for the production of an effect. Some time ago a kaleidoscope was needed to produce a multiple effect shot of some advertising material. Now such a device is quite expensive, and the demand for a kaleidoscope is very limited. It took a short time to assemble one out of three pieces of mirror held together with film tape.

Of course, special equipment is essential if speed of production is to be attained, and for the more elaborate types of work. Hence, in the modern plant will be found optical printers, trick title and animation stands, and other devices. The important features of these devices will be described later.

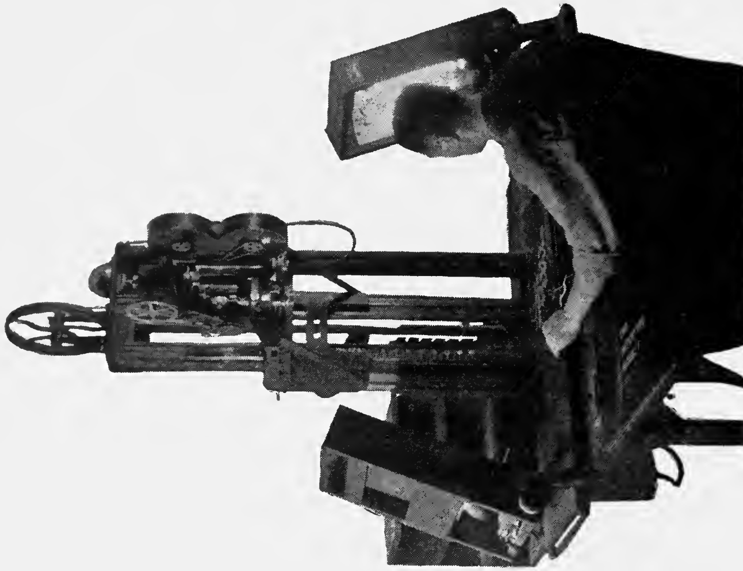
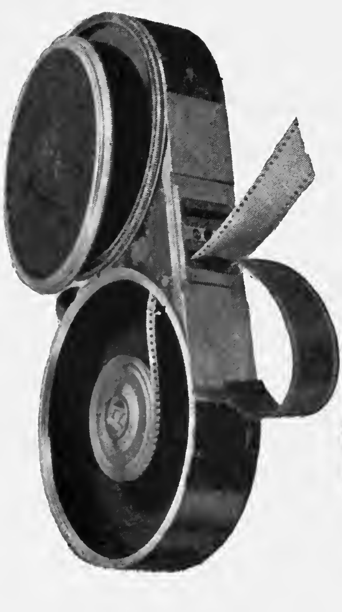


FIG. 3. Animation stand.



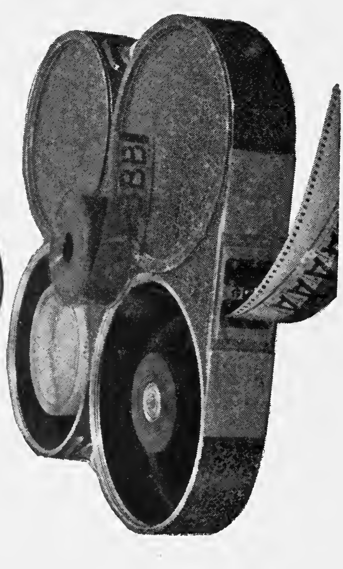


FIG. 1. (*Upper*) Print rolled face to face with negative film for producing fade-ins or fade-outs in the camera.
FIG. 2. (*Lower*) Bipack magazines for making fades and dissolves in the camera.

TRANSITIONAL EFFECTS

There are many routine steps in process work that can be simplified so that operations can be carried on by anyone after brief instruction and practice. Transitional effects, such as fades and dissolves, formerly made at the time of shooting the original scene on the movie stage, are at present usually made in an optical printer. This apparatus affords a wide range in achieving effective results. Before describing special apparatus, such as the optical printer, it may be of benefit to describe how some of these effects can quickly and easily be produced using any motion picture camera. Suppose a fade-in (or fade-out) is required. A print (usually made on special stock and in accordance with the specifications laid down by the film manufacturer for duplicating positives) is rolled up in the magazine face-to-face with the required length of negative film (usually a special duplicating negative stock, but not necessarily, as any negative film can be used provided it is *properly* developed) (Fig 1).

It is extremely important to use negative film that has been rewound some days previously so that the emulsion is on the outside instead of the inside, as it comes from the manufacturer. In addition, it is necessary to keep the positive for a few hours also wound emulsion side outward. This procedure imparts a natural curvature to the film with the emulsion face on the outside of the curve, and assures good contact between the print and the negative in the camera gate. (Those who have had experience in making bipack color-films will appreciate thoroughly the necessity for preparing the films in this way.) A framed leader at the beginning of the roll facilitates operations.

The film is threaded through the camera gate with the print toward the lens. Light coming through the lens will expose the negative through the print. In threading the positive through the gate the print must be framed in relation to the camera aperture. To expose the negative, the best light, as well as the most convenient, is the reflection from a white card that is evenly illuminated by any kind of lamp. Exposure is controlled by setting the lens diaphragm.

For a fade-in, the camera shutter first is closed, and the camera crank turned to the point where the beginning of the fade is to take place. Using the single-frame crank facilitates operations, as it enables counting by frames. When the desired frame is reached, the shutter is opened gradually and at a rate determined by the desired length of the fade.

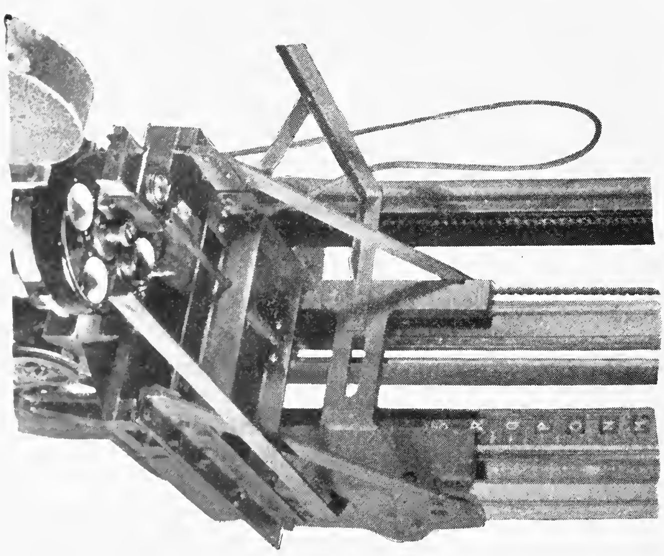


Fig. 4. Automatic focusing device on animation stand.

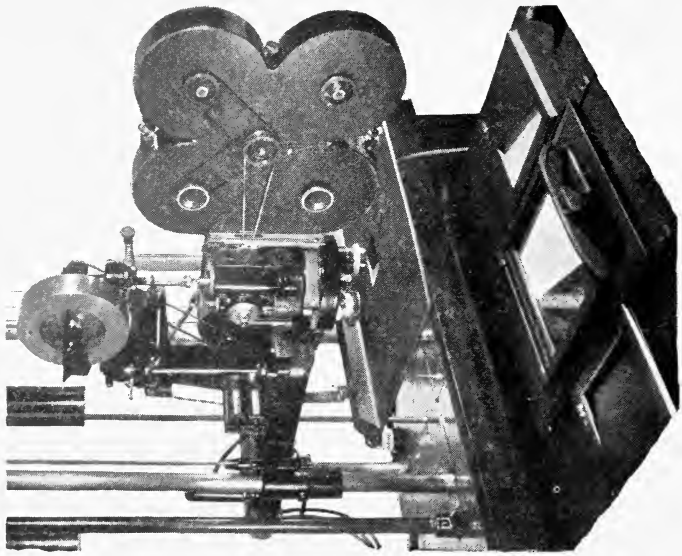


Fig. 5. Animation camera, set up for making "wipes."

For making fades and dissolves in the camera, bipack magazines are a great convenience. The best way is to set up the prints in separate matched rolls which should have framed leaders spliced on at the beginning. Fig. 2 shows two rolls made up; the one in the lower compartment of the magazine *A*, the other *B*. The marked unexposed negative is placed in the upper compartment of the magazine. After the first exposure through print *A* has been completed, roll *B* is put into the magazine and the operations are carried out as before, except that the shutter must be closed at the point where it was opened for the first run. This method of making dissolves is well known to most cameramen. The purpose of reviewing it is to simplify the description of other, more complicated, methods and to make them easily understood.

SPECIAL EQUIPMENT

(*1*) *The Animation Stand*

One of the most useful pieces of apparatus in a process or trick photography department is an animation or vertical title stand. Fig. 3 shows such a stand with a mobile camera carriage which can be raised and lowered to accommodate fields of various sizes. This particular stand is provided with an automatic focusing device. (Fig. 4).

The long, flat cam is cut to a curve calculated for the focal length of the lens. A roller on a push rod follows the curve of the cam, which transmits movement to a sliding member, which in turn effects movement of the lens. Pins on the lens barrel are engaged by slanting slots in the sliding member.

A mercury vapor *M*-tube below a window in the table top affords a brilliant and even illumination. It is covered with an opal glass screen for diffusing the light. The camera, a standard Bell & Howell, is driven by a mechanism connected to the single-frame drive shaft. This mechanism is designed to allow single-frame exposures to be made either continuously or intermittently. The camera speed can be varied from 24 to 240 exposures per minute. The average camera speed is 160 exposures per minute, but lower speeds are necessary in certain kinds of work and when working with extremely slow emulsions such as the *1505* and the newer duplicating negative materials.

Exposure settings can be made either by varying the lens aperture or by changing the shutter opening. For making exposures at a low speed, or intermittently by one frame at a time, it is extremely important to provide some means of maintaining the speed uniform; otherwise a variation in exposure between frames may occur. Such variations are very slight, but they affect seriously those portions of a picture the densities of which are in or close to the underexposure region of the H & D curve. A heavy flywheel upon the driving shaft of the mechanism assures uniformity of speed.

The advantage of using the animation camera in making dissolves and special dupes lies in the flexibility of control that is possible. For split-screen composites, cut-out masks can be used over the window. Special screens, lightly shaded in selected areas, can be used to hold down exposure in certain portions of the scene. This operation, called "dodging," can be used to overcome excessive light values that tend to subordinate the central point in a scene. The advantages of "dodging" have long been realized in still picture work, but have found little application in motion pictures. "Animated dodging" can be employed to achieve certain effects; for instance, it is relatively simple to apply this stunt to show a character surrounded by a ghostly glow moving about the scene. To produce such an effect in the studio would be extremely difficult. The actor would have to be wired like an electric sign, and that would probably interfere with his work. It would be extremely difficult, if not impossible, to light the set properly.

A great variety of effects can be done on the animation stand, among which are the transitional effects known as "wipe-outs." *Wipe-out* is a word that was added to studio parlance several years ago to describe the effect obtained when one scene blends into another by movement rather than by cross-fading as in a dissolve. Fig. 5 shows an animation camera set up for making "wipes." Cut-out masks consisting of a series of matched pairs are used, numbered for convenience. They are laid down over the window one after the other, and a single exposure is made in the camera for each mask. The masks shown at the left of Fig. 6 contain an opaque section moving in from the the left. The mating set, shown at the right, has an open space that exactly matches the opaque area in the other. One pair of masks is required for each frame of the effect. If the wipe-out is two feet long (the most commonly used), thirty-two pairs are required, or a total of sixty-four. In making wipes by this method, the film is run through the camera twice, the first exposure being made through set *A*, the second through set *B*. Prints of the component scenes are loaded in contact with negative stock in bi-pack magazines, as described before.

The method permits many variations of procedure. For instance, the effect may start slowly, and be speeded up at the end by eliminating some of the masks of the series. An effect can be stopped at any point and recontinued. By arranging the masks in different ways, either a black space or a lighter area can be used as the dividing line between scenes. However, this is a slow and tedious method of making wipes, but in special cases its advantages often outweigh this handicap. Other methods of making wipes are more widely used. A favorite device is a mechanical attachment on an optical printer, usually a moving shutter geared to the camera drive so as to move as the film runs through. The essential principles are the same as with the cut-out masks, but, naturally, the variety of effects is limited.

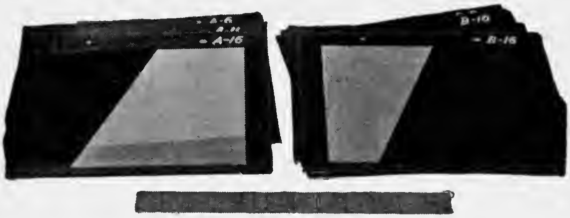


FIG. 6. Cut-out masks used for making "wipes" with the animation camera.

A great number of mask patterns is required to meet the increasing demands for variety. Fig. 7 shows one page of a catalog listing more than 250 different patterns.

(2) *The Optical Printer*

Fig. 8 shows a typical optical printer. Its essential features are: (*a*) a projecting mechanism (which can be a camera rebuilt for the purpose); (*b*) a light-source; (*c*) a photographing camera; (*d*) a lens designed for unit magnification; and (*e*) a driving mechanism.

The projecting camera, in this case, is a Bell & Howell camera, rebuilt to allow a beam of light to pass through the aperture. The major change required is in the intermittent mechanism. Fig. 9 shows how the pull-down bar has been changed to an open yoke. The pressure pad has been cut away to full-aperture clearance. A prism is mounted behind the shuttle and looks out through a window in the camera door. For convenience in mounting upon the optical bench, another right-angled prism is attached to the camera door

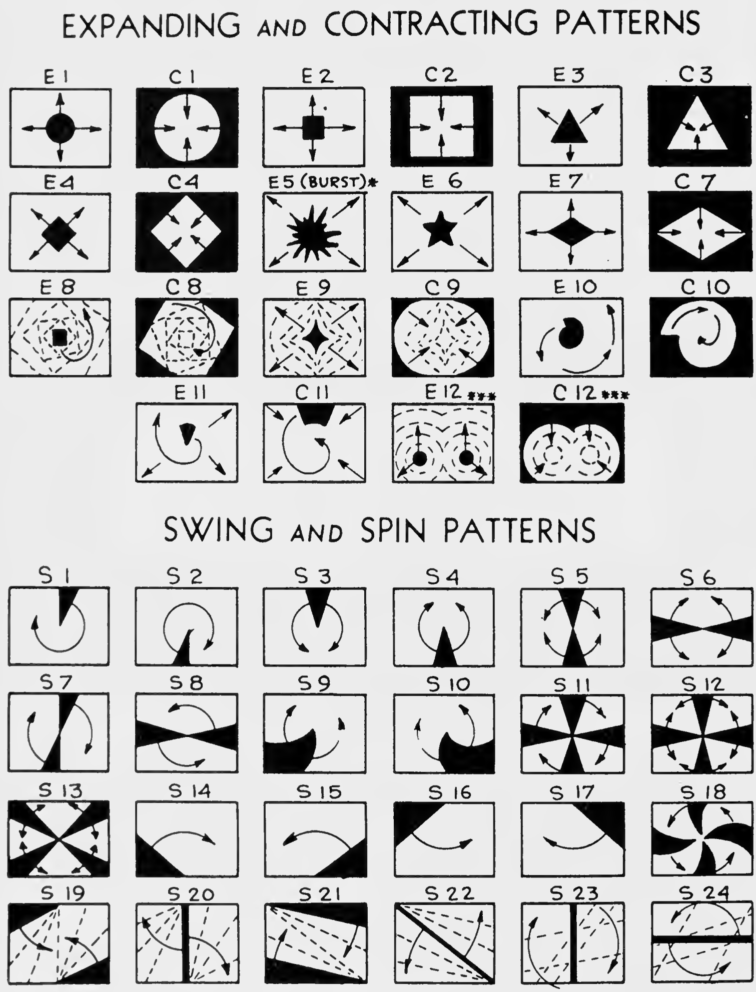


FIG. 7. A few mask patterns.

allowing the lamp house to be mounted to the rear of the camera. The lamp house is an Eastman medical spotlight using a 500-watt lamp. One of its most important features is the cooling cell with which it is provided. Heat at the projector gate is a serious problem, as the film must remain perfectly flat. In this printer there is no appreciable rise of temperature at the aperture. It is necessary that the field of illumination be uniformly flat. To achieve this, a thin flashed opal glass screen is placed at the front face of the inner prism (Fig. 9). The flatness of illumination resulting from this arrangement is entirely satisfactory.

The lens mount (Fig. 10) is built to accommodate lenses of various focal lengths, and is provided with vertical and horizontal adjustments and can be rotated. By shifting its horizontal adjustment the lens may be rotated eccentrically. The lens shown in Fig. 10 is

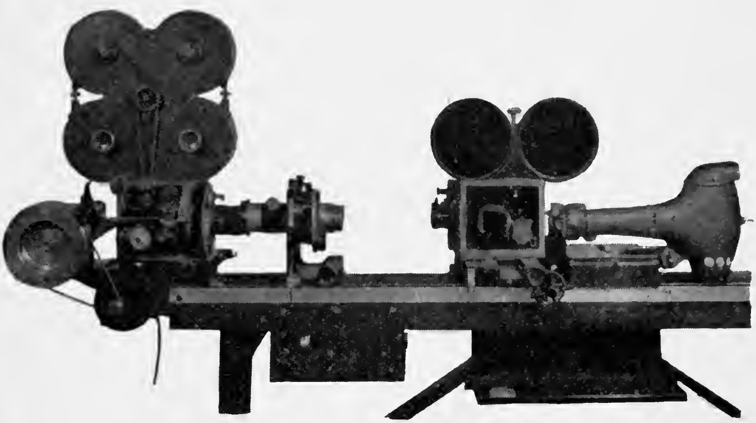


FIG. 8. A typical optical printer.

designed for unit magnification. Its equivalent focal length is $6^1/_2$ inches and its working aperture is $f/33$ (the aperture is fixed and can not be adjusted). Such a small aperture is required for special work to be described later. For work requiring more light, lenses of larger working aperture may be inserted in the mount.

The camera and projector drive mechanism is variable-speed, and can be run either forward or reverse (Fig. 8). It is provided with a heavy flywheel to assure uniformity of exposure. The drive is geared to the projector through a splined countershaft and a train of gears connected to the single-frame driving shaft in the projector camera (Fig. 11). This gear train contains a clutch which can be adjusted to drive the projector either forward or reverse, independently of

FIG. 9. Showing alteration of intermittent mechanism of Bell & Howell camera for optical printer.

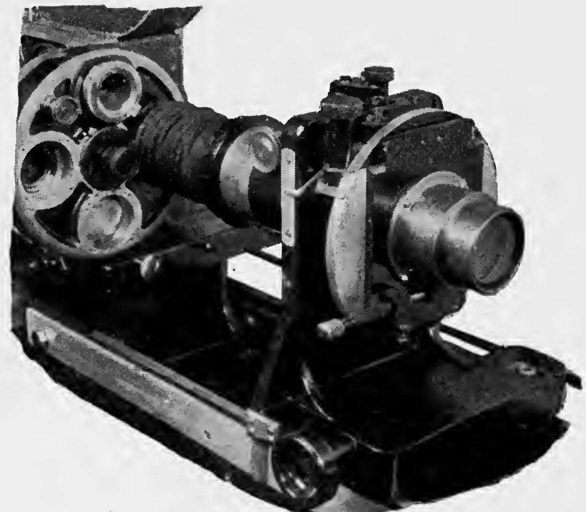


FIG. 10. Lens mount for optical printer, having vertical, horizontal, and rotational adustments.

the direction of film travel in the camera. Declutching the projector drive allows the projector to be operated by hand.

The projector camera and the lens are mounted upon separate sliding carriages which are adjusted by hand according to the enlargement or reduction required (Fig. 8). Calibrated scales indicate the size of the picture for each lens and projector setting.

This optical printer differs from most others in that neither the camera nor the projector is adjustable vertically or transversely. All horizontal and vertical adjustments of the picture are accomplished

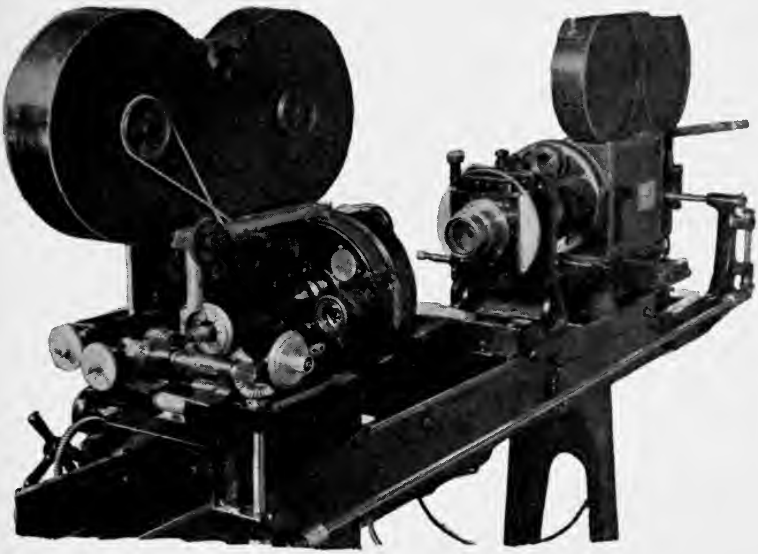


FIG. 11. Projector camera drive.

by moving the lens. This method is just as satisfactory in operation as the more complicated means required for moving the camera or projector.

Matched and accurate registration of the films in the optical printer is of the utmost importance. Lining up for *exact* registration is difficult if one depends entirely upon a scale, no matter how fine the mechanical adjustment may be. A very satisfactory and convenient method is to line up with target films. The target film consists of a pattern of ruled lines and symbols, similar to the pattern upon a lens-testing target. A negative of this target chart is placed in the projector, and an image thereof projected to a print placed in an auxiliary aperture plate in the camera. The setting at which registration occurs becomes instantly apparent when the image of the negative exactly fits the print in the aperture plate. At this point the image cancels out the clear spaces in the print, and what the operator sees is a gray patch with no trace of the target pattern.

The production of fades and dissolves by means of the optical printer is relatively simple. A print is placed into the projector and copied off in the camera and the shutter manipulated to effect fading.

For making wipes on the optical printer, several methods can be used, including the mechanical arrangement previously mentioned. This mechanical shutter device is rather limited as to pattern variety, for which reason film masks are more frequently employed (Fig. 12). Mask print *A* carries one side of the matching masks, and mask print *B* the other. These are placed into and advanced through the projector according to the data prepared on an exposure key sheet. The duplicating prints that are to be copied are loaded in contact with the negative in bipack magazines.

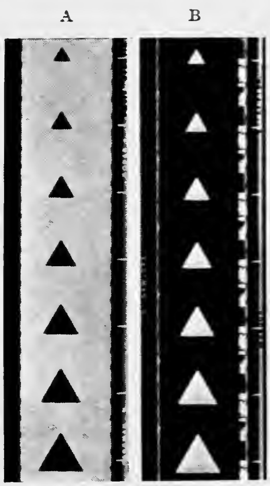


FIG. 12. Film masks for making "wipes" on the optical printer.

For sharply defined wipes the lens is focused sharply upon the film mask. For diffused, or blended-edge, wipes, the focus is adjusted to the desired degree of fuzziness. This will not affect the picture definition in the slightest degree, since the dupe negative is made by contact as described previously, and not by projection. The mask pattern is, of course, reproduced by projection.

A unique attachment for the optical printer is what is called "the spinner." Fig. 13 shows a view of this useful mechanism, by means of which are produced swinging or turning-field effects. The film-advancing mechanism is designed to be rotated upon a vertical axis. The device is hand-manipulated, frame by frame, and turned through the desired angle as each frame is advanced. The lens, having an aperture of $f/_{33}$, has sufficient depth of focus to keep the image reasonably sharp throughout at least 45 degrees of the 90-degree turn. The projection head can be adjustable horizontally so that the axis of rotation may be centered at any point. Thus it

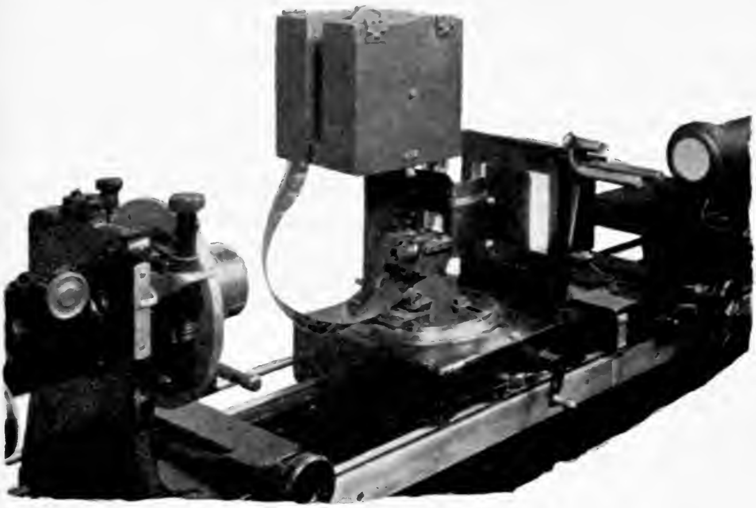


FIG. 13. The "spinner," an attachment for producing swinging or turning-field effects.

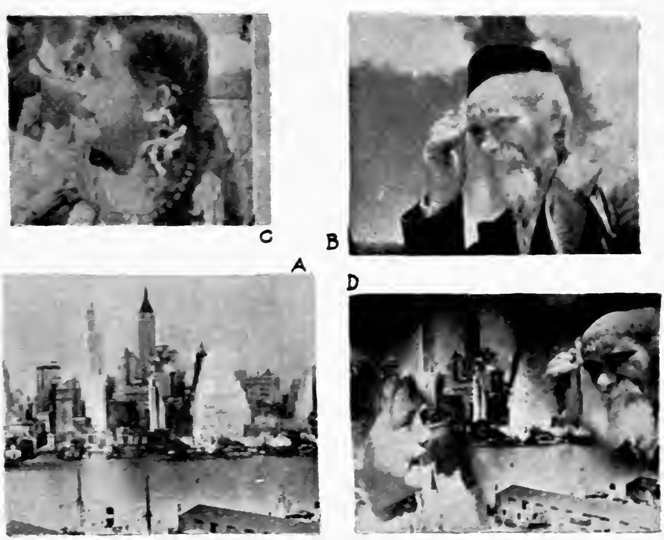


FIG. 14. A typical montage.

becomes possible to cause the image to swing in or out at the extreme right or left, or to spin about its center. This mechanism is used to make "book-page" transitions and other effects that require motion to continue as the angle of the scene is changed.

There are many possibilities for the optical printer in making montage and composite-action strips. There are several ways in which such make-ups can be arranged. One method will be described that was employed in a typical montage containing three different scenes combined as shown at *D* in Fig. 14. Note that the three

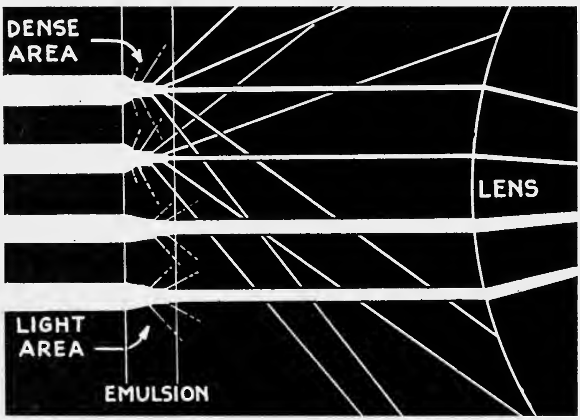


FIG. 15. Dispersion of light by silver particles in the emulsion, causing change of contrast in optical projection.

scenes, *A*, *B*, and *C*, are combined in a single frame, *D*. Note that *C* has been reversed left for right in the composite.

Masks are made for the areas assigned to the various component scenes. The mask for *A* is inserted into the camera in front of the unexposed negative, either as a cut mask placed into the mask slot, or as a travelling film mask loaded in contact with the negative. The print is put into the projector and the lens moved so that the required portion of the original scene shall fall within the open area of the mask. Scenes *B* and *C* are handled in the same manner, using the masks prepared for each. The print of scene *C* is turned around in the projector to reverse the direction of the action as required in this particular montage.

Many special effects are made on the studio stage during the filming of the primary scene. For instance, ghosts or visions can be made to appear in the scene by photographing the primary scene through a partially silvered mirror. The ghost image is picked up by reflection in the mirror from a set placed at right angles to the optical axis of the camera lens. The same effect can be achieved by after-treatment in the optical printer, and with greater ease.

Glass shots are seldom used at the present time although they were quite the vogue several years ago. The background and sometimes part of the foreground are painted upon glass in such a manner as to match adjoining parts of the scene. Better results can be attained in a simpler manner with the optical printer.

Matte shots often give the cameraman considerable trouble. Such work can easily be done with the optical printer. In fact, the optical printer is among the most versatile tools at the command of the film technician.

Print quality is an important matter in many types of trick photography. It is unnecessary to point out that prints must be clean and free from blemishes of any kind; but the degree of contrast and the density of the duplicating print must receive special consideration, depending upon whether the prints are to be copied by projection or by contact. If dupes are to be made by projection, the prints should be much less contrasty than for contact duping. The reasons for this are well known, but it will do not harm to give a short review of them.

A change in contrast takes place in optical projection. Fig. 15 shows diagrammatically what ocurs to light passing through the print emulsion. The light is dispersed by the silver particles in the emulsion. The dispersion is greater where the deposit of silver is heaviest, as in the shadows of a picture, and less in the clearer portions of the picture, as in the highlights and bright objects.

In contact duping this dispersion has little effect upon the contrast; but in projection, this scattering of light will result in a considerable increase of contrast. The aperture of the lens gathers very little of the dispersed light, even when using large-aperture lenses of short focal length. When stopping down, still more contrast is obtained, because less of the dispersed light is gathered by the aperture. In optical printing, if the density of the shadows in the print is great in relation to the lighter portions, too much dispersion takes place to retain much shadow detail. Little dispersion occurring in the lighter portions will result in full exposure at those points as against underexposure in the shadows. Any change of aperture setting will affect the contrast to some degree, and if the range in setting is large, as from $f/4$ to $f/32$, a marked increase of contrast will occur. With this consideration in mind, exposure adjustments should be made by varying the intensity of the light or the duration of exposure, and *not* by changing the lens aperture, as is done in many optical set-ups.

There is no better way to insert a background in composite photography than by background projection or by the Dunning process, but some composite scenes requiring background insertion can be made on the optical printer at less expense, if the picture action is suitable: for instance, a mass of clouds, or the sun rising over a distant mountain, or any silhouette background across which there is no action. Some background insertions can be made without preparing any travelling masks, but in most cases travelling masks are found necessary

While comparatively little footage is now being made with travelling masks, the use of travelling mattes affords an opportunity for achieving some striking results and is peculiarly adaptable to certain kinds of composite work. Travelling masks are often difficult to make, especially when they have to be animated or drawn frame by frame to fit the action or other elements of a scene

Among the interesting possibilities of travelling masks is the production of combined cartoon and actual photography. To produce such animated composites it is necessary to have some means of accurately confining the cartoon figure action in relation to actual objects in the scene. Each frame of the primary or background scene is traced off to furnish a guide for the drawing of the cartoon creature.

There may be several ways of doing this, but the most convenient method is to use a projection camera in the animation stand (Fig. 16). Each frame of the original scene is projected down upon a sheet of paper accurately registered on standard animation pins. The artist can easily trace the outline of the figure upon the projected image.

The tracings are used as guides for the animator, who draws the cartoon character directly upon the same sheet. The pencil drawings are then traced in India ink upon transparent sheets of celluloid, which are opaqued on their reverse sides in various shades of opaque paints. Travelling masks are prepared by photographing these drawings and multiple-exposing over the primary scene by several runs through the optical printer.

Fig. 17 shows an animation stand set up to produce cartoons by

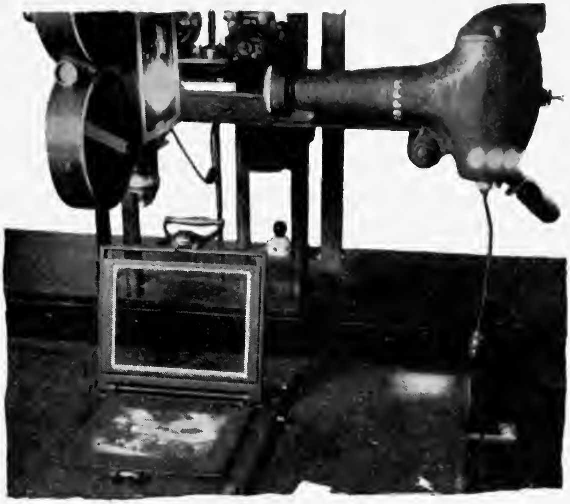


FIG. 16. Projection camera used with animation stand, for producing combined cartoon and actual photography.

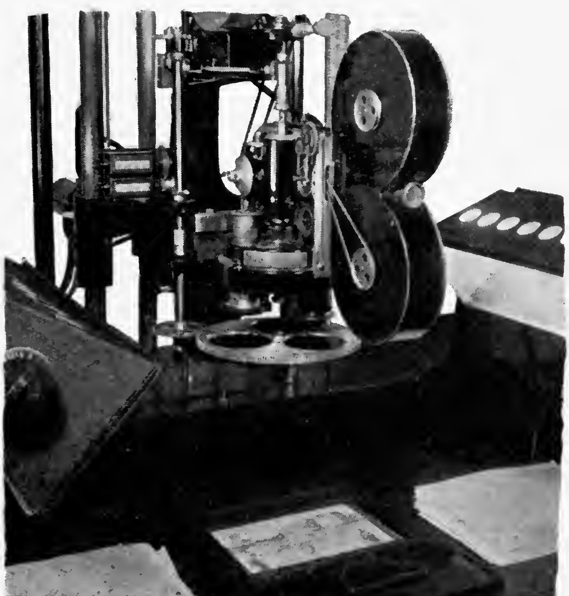


FIG. 17. Animation stand set up for producing cartoons by the Technicolor process.

the Technicolor three-color process. The wheel located directl below the lens contains the color-separation filters: red, green, and blue. Exposures are made of each drawing successively through the three filters, which are balanced for the negative emulsion used and for the characteristics of the lamps employed. This provides a single negative instead of three separate negatives, but three times as long as a negative for black-and-white. Three matrices, one for

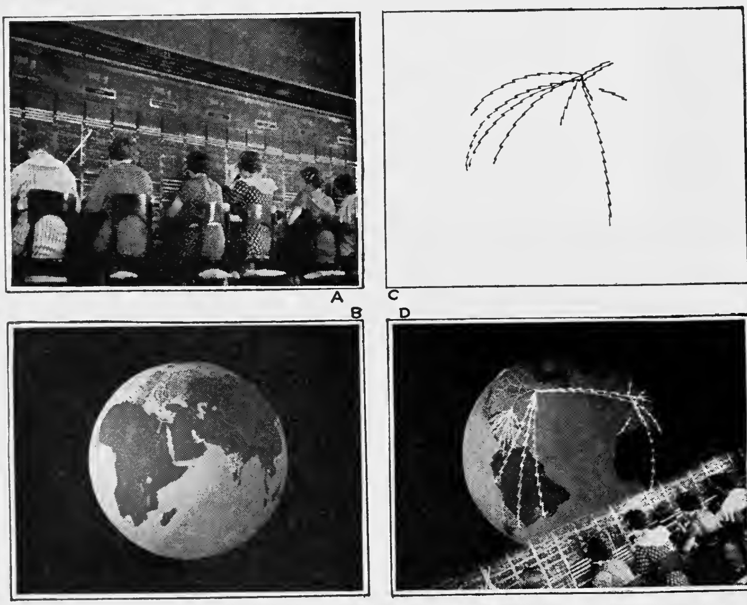


FIG. 18. A trick scene containing an animated drawing combined with actual scenes.

each color, are made from this negative on an optical "skip printer. Prints are made from the matrices by the Technicolor imbibitio process. Wipes, dissolves, and multiple exposures for color work ar easily produced on either the cartoon camera or the optical printe from duplicating prints as described for black-and-white worl Both the animation camera and the optical printer are provided wit switching arrangements that can be pre-set so that three exposure are made every time the exposing button is pressed. This mechanism is designed so that, no matter what the operator does or fails to d it is impossible to get out of synchronism by exposing more than three or less than three frames for each impulse.

The animation stand is particularly advantageous in photographing special titles. Some of the effects seen in the elaborate titles in modern films require considerable work of many different kinds. Special lighting, such as by spots, *etc.*, is often employed. A very effective stunt used for the main title of an industrial film required that a shallow tank of water be used above the title cards and that the transitions between the titles be effected by a disturbance on the surface of the water. Clay models, small sets, *etc.*, often required as backgrounds, can be photographed on this type of animation stand. Panoramic boards that can be adjusted to move in varying steps, either horizontally or vertically, are provided for special trick title manipulation.

Probably the most difficult, and certainly the most tedious and painstaking to make, of all trick scenes, are those containing animated drawings combined with one or more actual scenes. An illustration of the steps involved in a typical composite of this kind is shown in Fig. 18. It was desired to combine the following elements: *A*, a view of a telephone switchboard; *B*, a view of a revolving globe; *C*, animated drawings of transoceanic and transcontinental radio telephone circuits. The final composite is shown in *D*.

The scene starts with a full view of the switchboard. The camera then tilts upward and swings to place the switchboard down in the lower right-hand corner of the frame. As this swing takes place, the revolving globe containing the animated circuits is disclosed as if it were behind the board. The following steps were required in producing this composite:

(*1*) *Scene A*, that of the switchboard, was photographed, and a duplicating print made thereof.

(*2*) This print was projected down upon the field in the animation stand, and using this projected image as a guide, a series of masks was made to cover up the portion of the frame to be occupied by the globe. Since the footage consumed by the downward movement of the switchboard amounted to fifteen feet, this meant that 240 matched pairs had to be made.

(*3*) The globe was mounted upon a turntable and photographed as it rotated. It was necessary to provide guide lines upon the globe to be followed by the animator when drawing the animated radio circuits. These lines were not to show in the finished composite, and this presented what seemed at first quite a problem. It was solved by drawing the lines upon the globe in red, and loading a bipack camera with clear-base panchromatic negative film in front and orthochromatic film in back. Lighting and photographic tests were made until a balance was reached such that the front negative showed no trace of the lines. The lines were, of course, reproduced as nearly clear lines upon the back negative. A print from each of these negatives was made in the optical printer.

(4) The print from the ortho negative of the globe was placed in the animation stand projector and the guide lines traced off upon white paper sheets registered upon pins in the animation field.

(5) The pencil tracings were then used as guides for the animation, which was done in India ink upon sheets of celluloid. Notice that the animation lines upon the composite are white, but that the drawings are black.

(6) These black line-drawings were placed over a white background, and a negative made thereof upon positive stock exposed for extreme contrast and developed to a high contrast.

(7) This negative was loaded in the animation camera in contact with duplicating negative stock, which was exposed by the light from the window in the field as one set of the masks obtained in a previous operation was laid down over the light-source. This gave the first exposure on the final composite negative.

(8) The next operation required a similar treatment, using the same masks with the print of the globe (this is where the print obtained from the panchromatic negative of the globe was used). This operation gave the second exposure on the composite negative.

(9) In the next operation, the duplicating print of the switchboard was set up in contact with the negative, and exposures were made as for operations 7 and 8 except that the mates of the masks were used.

From the above-given very abbreviated résumé of a typical complex scene it can be appreciated that accurate registration plays a leading role in process photography. Accurate registration requires placing and holding the film exactly during exposure, but it is equally important that there be no movement of the cameras when taking any of the component scenes. All takes must be made with the cameras rigidly mounted. Hand-driven cameras are likely to move slightly at each turn of the crank, and even the slight movements produced through this cause result in unsatisfactory registration.

It is always advisable to have some means of checking the accuracy of registration. For this purpose a very simple procedure is used. A target chart is prepared containing ruled lines. The camera is placed in the animation stand and the chart is photographed in the following manner: First an exposure is made of the right half of the chart, covering up the left half with a black screen. Then the film is turned back to the starting point, and a second exposure is made while covering the right half and exposing the left half. Exposures are made in this way of the top and bottom parts. Exposures are made also by running forward while one-half is exposed, and making the second exposure while running the camera in reverse. The lines join up perfectly, and when projected, exhibit no movement apart, if the mechanism is in good working order. If there is any movement visible upon the screen at the juncture of the lines it is an indication that the pilot pins have become worn and should be replaced.

Film shrinkage is a real handicap, and all prints made for composite work should have exactly the same dimensions in the perforations. If old and shrunken films have to be used in special cases, provision must be made accordingly. All prints should be made on machines that will not introduce new errors in registration. It is sometimes advantageous to make one's own prints in the camera to assure accuracy of registration. This is unnecessary where first-class laboratory service is available.

Process photography long has been and continues to be a valuable element of film production. Several volumes would be needed to review the subject completely. This paper has been limited to certain basic processes and brief descriptions of special equipment and typical production procedure. The processes described will, it is hoped, be of some value in suggesting other methods and improvements in technic.

SLIDE-RULE SKETCHES OF HOLLYWOOD*

H. G. TASKER**

Summary.—*A brief review of some of the current improvements in production methods and production tools used in the motion picture industry.*

The subjects mentioned include processing laboratories, cameras, synchronizing methods, and various items of sound equipment and methods, including a review of the present status of push-pull recording.

The paragraphs that follow comprise brief and informal glimpses of some of the technical changes that have come over Hollywood and its production methods principally within the last year. The broad subject of technical advances in Hollywood production methods is by no means fully covered, the individual "sketches" are by no means complete, and even their accuracy may be doubted; but it is hoped that they will afford to many motion picture engineers residing in other parts of the world a measure of familiarity with what is going on in Hollywood.

Double-Track Recording.—Push-pull recording has at last become an actuality in a number of Hollywood studios. The Society is already familiar with the remarkable results obtained by RCA Manufacturing Company with its push-pull recording of the Class *B* type first demonstrated at the Atlantic City Convention of the Society (April, 1934), and since shown in improved forms at several later Conventions and described in the Journal. Perhaps we are less familiar with the push-pull system of Electrical Research Products, Inc., which was developed out of early work of Douglas Shearer (Metro-Goldwyn-Mayer) and was shown at the Hollywood Convention in May, 1935. It comprises two variable-density tracks, of the Class *A* type but arranged in phase opposition. The method does not have the inherent noiselessness of the RCA method, but owing to a secondary effect it nonetheless accomplishes a very substantial noise reduction.

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* Received December 1, 1936; presented at the Fall, 1936, Meeting at Rochester, N. Y.

** Universal Pictures Corp., Universal City, Calif.

This secondary effect is the fact that when noise reduction is applied to a push-pull track, noise reduction "thumps," being in phase on the tracks, are cancelled out by the push-pull connection of the system. Consequently, higher-speed, lower-margin noise reduction may be successfully applied to this push-pull system than was possible in the former single track. Furthermore, the push-pull arrangement cancels out much of the second harmonic arising from photographic distortions, making possible the use of much greater noise reduction on the one hand, and considerably higher maximum modulation on the other. As a result of these considerations the ERPI push-pull method obtains about the same extension in volume range as does the RCA method.

First releases of sound originally made by the variable-density push-pull system and dubbed to single track were made by Metro-Goldwyn-Mayer and include *The Great Ziegfeld*. First release of sound-track made with the ERPI push-pull system is the musical score for *Magnificent Brute* by Universal. The latter company has also the first ERPI all push-pull picture in production: *Top of the Town*, a musical, to be released in January. No releases have yet occurred containing sound originally made by the RCA push-pull system.

Novel and Economical Editing Theaters.—The average major studio in Hollywood has from fourteen to twenty projection rooms, or review rooms. The bulk of these are used by the film editors, who do their detail work with Moviolas but must have something more like the theater to get the "feel" of complete sequences as they are made ready. There must also be such places for the chief editors, directors, and others to see the progress of the cutting. Universal has devised an exceptionally economical and effective editorial projection room by installing projection type Moviolas with filtered incandescent lamps and blower gates. This makes it possible for the film editor to be his own operator, saving several hundred dollars in salaries each week. He first threads the machine, which is located in a fire-proof booth, and then walks into the review room proper, from which the machine may be operated by remote control. The fact that these Moviola projectors can be started, stopped, or reversed at the touch of a button saves a tremendous amount of time in studying difficult cuts.

Synchronizing Methods.—Studios employing interlock motor drives for camera and sound recorder have found that the old method of applying synchronizing marks to the two films before rotating the machinery loses much valuable time. Several studios have abandoned these synchronizing marks, and use, instead, a method that consists in clapping a pair of sticks together in front of the camera after the motors are up to speed. These sticks are usually combined with the camera slate. The result is by no means wholly satisfactory, as time is still lost while the assistant cameraman gets out of the scene with his slate. Furthermore, the sound of the clap-sticks is often annoying to the actors, making it difficult for them to get into the mood of the scene. Severe trouble of this sort is encountered when working with animals, which are often frightened by the sound of the sticks. As a result of these difficulties, and through the efforts of the Sound Committee of the Academy of Motion Picture Arts and Sciences, a standard synchronizing method is evolving out of early work of Metro-Goldwyn-Mayer and others. In this system a portion of the picture negative is fogged by a neon light, and at the same instant the exposure of a portion of the sound-track is varied so as to print upon each film synchronizing marks anywhere from 6 to 12 inches long. This act will be unaccompanied by any sound other than a buzzer of moderate tone, to indicate to the director and cast that the equipment is up to speed and that action may begin. Metro-Goldwyn-Mayer and United Artists have made provision also for slating between scenes by providing a cameraman with a button for starting the cameras instantaneously at any time without communicating with the sound recording room. Other companies are following suit. While all this may seem comparatively unimportant, it must be remembered that the slating and synchronizing operation occurs at the moment when everything is in readiness for a take, and consequently any delay at this moment delays the entire company and is very costly. It is estimated that if used by all studios, the new slating and synchronizing methods will save approximately $250,000 per year.

New Microphones.—Two new microphones have made their appearance in production: a small non-directional, or "cue ball" microphone, by ERPI, and the unidirectional ribbon microphone by RCA. The former is used for all current productions by General Service Studios, Paramount, and Universal. Those who use it feel that its characteristics are smoother than those of the former dynamic microphones, but all apply some corrections to its characteristics. Its non-directional characteristic is, in part, a benefit and a detriment. Ideally, a microphone should be absolutely non-directional over the angle from which wanted sound may be received and absolutely non-responsive from all other directions. No such microphone is available, although the unidirectional ribbon of RCA is an approach to the solution of this problem. Columbia has employed it in recording *Pennies from Heaven*, the new Bing Crosby picture. If reduced in size and increased in sensitivity it would lend itself to still greater usefulness.

Millions in New Sound Equipment.—By far the most exciting change that is taking place in Hollywood just now is a complete remodelling and modernizing of the sound equipment in every studio. This major upheaval is caused in part by the advent of push-pull recording and of improved sound apparatus, all the way from the microphone in the studio to the loud speaker in the theater; and also in part by the tremendous increase in studio activity and the very hopeful outlook for the future. A still greater contributing factor is a new and very liberal merchandizing policy on the part of the two major licensing companies in the sound recording field, each of whom has offered to its licensees an arrangement whereby new equipment and the modernization of old equipment may be paid for out of royalties. The result is a tremendous program of modernization and expansion in sound apparatus averaging more than $200,000 per studio.

New Cameras.—The bulk of Hollywood productions have, over a period of years, been photographed with Mitchell cameras, and the manufacturer of this product has introduced a comparatively quiet camera known as *N C*, which has enjoyed considerable favor during the past two years. More recently Twentieth Century-Fox Film Corp. designed their own silent camera, used for all productions of that company but not elsewhere. Its interesting features were described in the Report of the Progress Committee of the Society, in the July, 1936, JOURNAL. Within the past two months the same company has sponsored the first appearance in Hollywood productions of the DeBrie camera, manufactured in Paris, which has a number of very unusual features and promises to become quite popular as a result. In contrast with former cameras, which were enclosed within blimps so as to reduce camera noise, or in which the mechanism was built to operate as quietly as possible in the hope of avoiding the use of the blimp, the DeBrie camera is so designed that its outer case is, in fact, a blimp, within which the mechanism is relatively exposed. As a result of this design, the camera produces less noise than a regular Mitchell camera in a blimp, and still less noise than the *N C* Mitchell camera without a blimp. At the same time its overall size and weight are less than that of the average camera in a blimp and its mobility and controllability are considerably extended. A feature of great interest to cameramen is the ability to view the action continuously through the film itself during a take.

Head-Turning Equalizer.—Since the microphone is inherently a device that should be placed close to the source of sound, the present technic is to support it on a microphone boom provided with many mechanical gadgets to enable rapid shifts of position of the microphone—in and out, up and down, left and right, and rotational. The microphone boy must be a wizard of dexterity, equipped with a sixth sense of anticipating unrehearsed movements of the actors. Despite his skill there are often situations with which he can not cope; as, for example, when an actor's head is turned from the camera for so short an instant that the microphone boy is unable to follow him, or when the actor stoops down so low that he can not be followed for fear that the microphone will appear in the picture. The result is a loss of high frequencies and, consequently, of intelligibility. To cope with these situations Universal has developed what they call a "head-turning" equalizer, which at a simple twist of the mixer's wrist restores the high frequencies to their normal balance and makes it possible for him to follow instantaneous movements of the actors.

New Processing Laboratories.—There has been considerable activity in constructing new laboratories and modernizing old ones. Consolidated Film Industries has just opened a fine new plant, efficiently arranged and thoroughly equipped. Solution tanks are unusually large and there is adequate provision for agitation of the solution during development. The plant is so arranged that raw stock enters one end of the building, passes successively through the printing, processing, and projection rooms, and is delivered to the shipping room at the other end of the building. This laboratory will include a complement of non-slip sound printers.

Warner Bros. Pictures, Inc., are building a new processing laboratory on the Burbank lot. Abandonment of the Sunset Laboratory is contemplated.

International Cinema, Ltd., has opened a fine new plant, of which an important feature is the photoelectric control of various steps of printing and processing.

Pre-Selection vs. the Split-Film Method.—At least one studio that had been using $17^1/_2$- mm. film for sound recording has found it more economical to return to 35-mm. film and employ, instead, the pre-selection method, with the result that less processing is done but much more film is used. The $17^1/_2$-mm. method consisted in recording along one edge of the 35-mm. film, then reversing the film in the magazines, and recording along the opposite edge. The film was processed in the 35-mm width, and then split before printing. The sound dailies were also on $17^1/_2$-mm. and the resulting savings for an average large studio amounted to around $4000 a month. In practicing this method all sound negative must be processed.

In the pre-selection method the director designates *OK* takes and *Hold* takes, all others being marked *NG*. All but the *OK* takes are broken out of the roll before processing. Since only one edge of the film has been recorded upon, the *NG* takes (and later the *Hold* takes) may be spliced together and the *opposite* edge used for printing sound dailies; thus effecting two economies, in that the *NG* negative is not processed and the daily print stock is obtained without cost. These economies alone amount to around $3500 a month for an average studio, and nearly offset the economies obtained by the $17^1/_2$-mm. method. There remains, however, a reserve of 1 to 2 millions of feet of *NG* stock per year per studio. New ways of using this stock, including leaders, effects negatives, effects positives, and even action dailies, have made the pre-selection method definitely more economical than the split-film method

EFFECT OF LIGHT-SOURCE SIZE WITH 16-MM. OPTICAL SYSTEMS*

G. MILI**

Summary.—*An investigation of two spherical and aspheric condensers, with an f/1.65 projection lens and a test series of high-intensity biplane filament lamps ranging from 200 to 2000 watts, has been conducted to determine the levels of illumination attainable in 16-mm. projection by varying the light-source size.*

An analysis of spherical and aspheric condensers of various designs to show the best possible combination with an $f/1.65$ lens for 16-mm. projection has already been presented.[1] This study was made with the biplane filament light-source now most widely used in the field, namely, a 500-watt, 100-volt lamp, the light-source dimensions of which, when backed with a spherical mirror, are about 9 by 9 millimeters. Since the light-source requirements vary with the spacing between the condenser and the film-gate, it was considered advisable to continue the study, employing light-sources of various dimensions.

PROCEDURE

A series of tests was run with spherical and aspheric condensers 65 mm. in diameter and having a magnification of 2.08. A sketch of the optical elements involved is shown in Fig. 1, while the dimensions

TABLE I

Condenser Data

Curvature	Diameter (*mm.*)	E.F. (*mm.*)	Magnification X	A (*mm.*)	B (*mm.*)
Aspheric	65	33.2	2.08	34.5	87.5
Spherical	65	33.4	2.08	32.3	85.7

for various spacings are given in Table I. The dimensions and the electrical ratings of the filaments, which, when used in conjunction

* Received October 9, 1936; presented at the Fall, 1936, Meeting at Rochester, N. Y.

** Westinghouse Lamp Division, Westinghouse Elec. & Mfg. Co., Bloomfield, N. J.

with a spherical mirror, formed the four light-sources used for test, are given in Table II. Fig. 2 shows the appearance of the sources when lighted.

TABLE II

Light-Source Data

Watts	Volts	Filament Construction	Source *Dimensions (*mm.*)
200	100	*CC*-13*D*	5 × 5
500	100	*C*-13*D*	9 × 9
1000	100	*C*-13*D*	12 × 12
2000	100	*C*-13*D*	15 × 15

*Approximate.

The total light output and the brightness at the center and the four corners of the screen were measured, varying the position of the film-gate from the theoretical plane of the light-source image to the

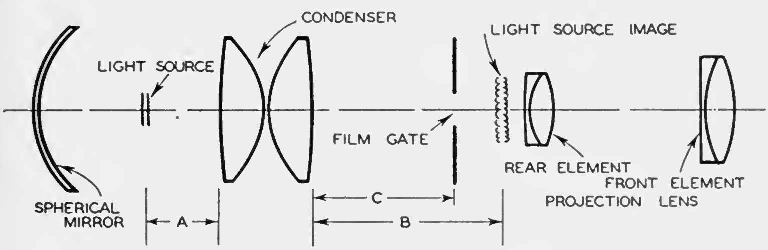
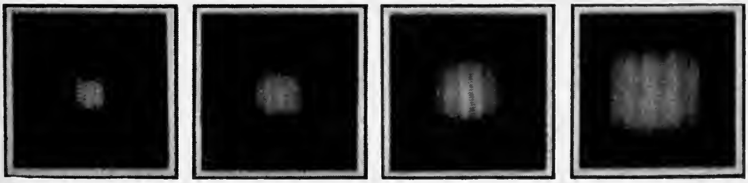


FIG. 1. Optical elements of 16-mm. film projection system.

point where the gate was located against the condenser surface. This procedure was followed with both condensers. The details of the method of taking the readings and photographs of the instruments involved have already been published.[1]

Through back-testing, the effective light-source size to fill com-



200-W 500-W 1000-W 2000-W

FIG. 2. The test light-sources.

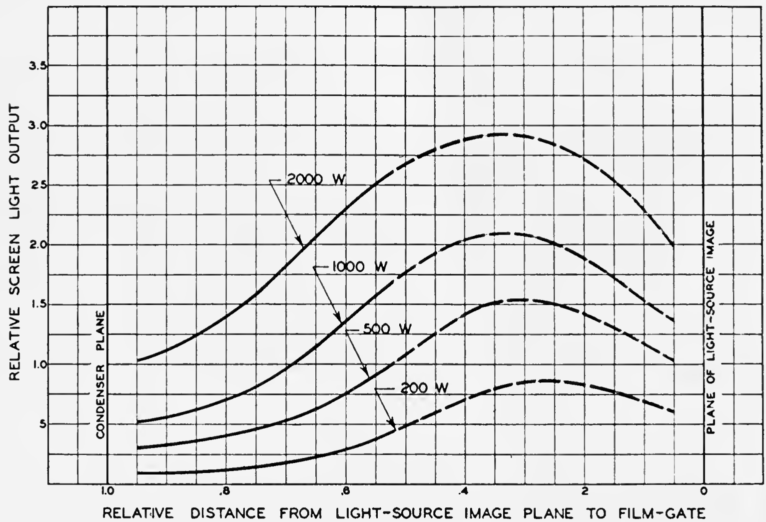


FIG. 3. Screen light output data for various light-sources with spherical condensers (65 mm. in diameter, 2.08× magnification).

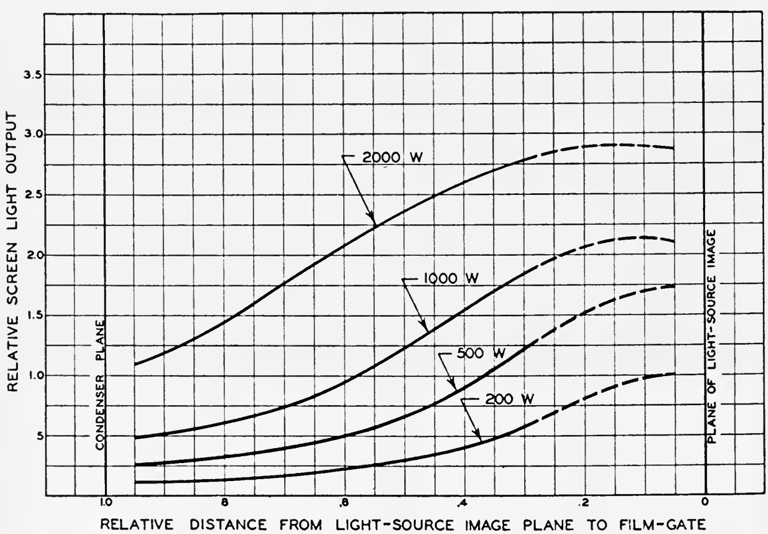


FIG. 4. Screen light output data for various light-sources with aspheric condensers (65 mm. in diameter, 2.08× magnification).

pletely the exit pupil of the system, for various spacings between the film-gate and the condensers, was determined.

RESULTS

The curves in Figs. 3 and 4 show the variation in screen light output for the spherical and aspheric condensers, respectively, with the gate position varied from the plane of the filament image to the condenser surface. The full-line portion of the curves represents the region in which the screen appearance is free from light-source images and striations. It may readily be seen that the increase in the light on the screen is less than the increase in lamp wattage when the gate position is near the plane of the light-source image. On the other

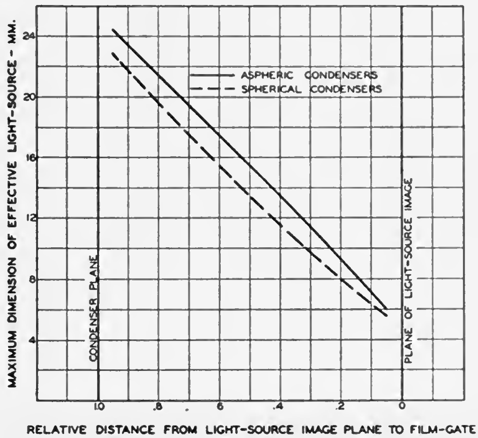


FIG. 5. Variation in light-source requirements for various positions of the film-gate.

hand, the increase becomes more nearly proportional to the wattage the closer the film-gate is brought to the condenser. This is explained by the fact that the light-source requirements of the optical system differ with the position of the film-gate.

As may be noted from Fig. 5, the maximum dimension of the effective light-source is larger, the closer the film-gate is placed to the condenser. Now, with the film-gate near the plane of the filament image, the maximum dimension of the effective light-source is about 6 millimeters; and it is evident from Table II that, with the exception of the 200-watt lamp, all the test lamps more than fill the exit pupil of the system. The increase in screen light output is therefore caused by the fact that with the larger sources, only the central portion of the filament is effective, and this is brighter than the outer regions. This may be seen in Fig. 6, which shows an image of the type of light-source used for test. Upon this image are superimposed

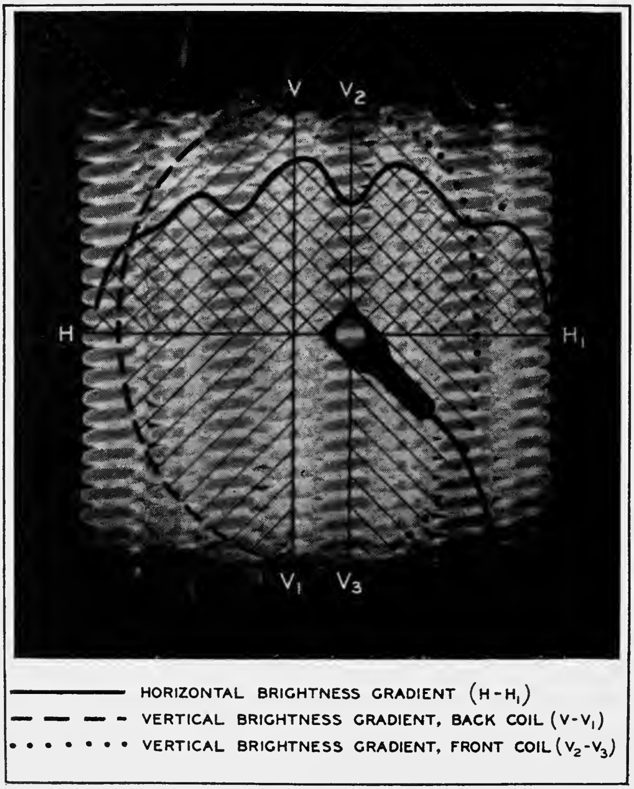


FIG. 6. Curves of the periodic variation, or brightness gradient, across and throughout the length of a front and rear coil of a biplane filament with a spherical mirror, are superimposed upon an image of the light-source. A scale drawing of the light-sensitive cell used for the measurements correlates the size of the test spot with the coil diameter.

the curves of the brightness gradient across the filament and throughout the length of a front and rear coil.

As the film-gate is moved closer to the condenser, and, therefore, farther from the plane of the light-source image, the size of the effective light-source becomes greater than sufficient to accommodate the sources involved. At and beyond this point, except for the secondary effect of aberration and slight test errors, the screen light output should increase in the same ratio as the lamp wattage.

In order to bring out the effect of source size and brightness gradient, the screen light output curves are plotted on the basis of equal efficiency for all lamps. In practice, however, a comparison on the basis of equal-life performance would be more important. For a given filament construction and equal life, lamp efficiency increases with wattage because of the increase in wire size. This is indicated in the curve plotted in Fig. 7. Accordingly, a somewhat greater increase

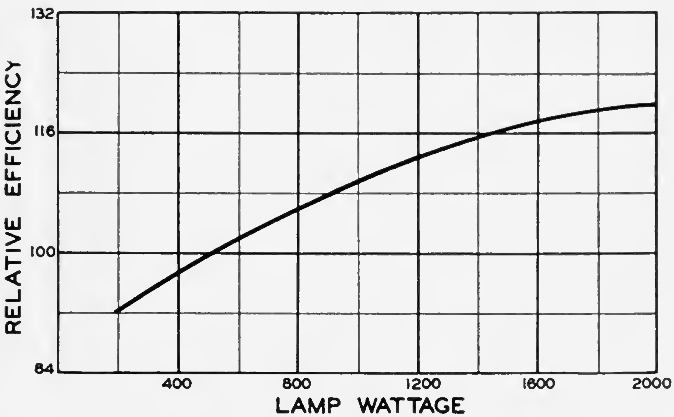


FIG. 7. Increase in efficiency for equal life with increase in wattage (100-volt biplane filament projection lamps).

in screen light output than shown in Figs. 4 and 5 would be afforded for equal life if the higher-wattage lamps were employed.

Curves of the corner-to-center screen brightness ratio are plotted for the spherical and aspheric condensers in Figs. 8 and 9, respectively. It is evident that with spherical condensers, because of the effect of spherical aberration, satisfactory uniformity is achieved only with the larger light-sources. For small sources a dark center occurs at the middle positions of the film-gate, thereby making the corner-to-center screen brightness ratio greater than unity, as is indicated in the curves obtained with the 200- and 500-watt lamps. Except for positions of the film-gate near the plane of the light-source image, the screen brightness curves with the aspheric condensers are very uniform and spaced very closely together. This discloses the fact that, with aspheric condensers, on account of less residual aberration,

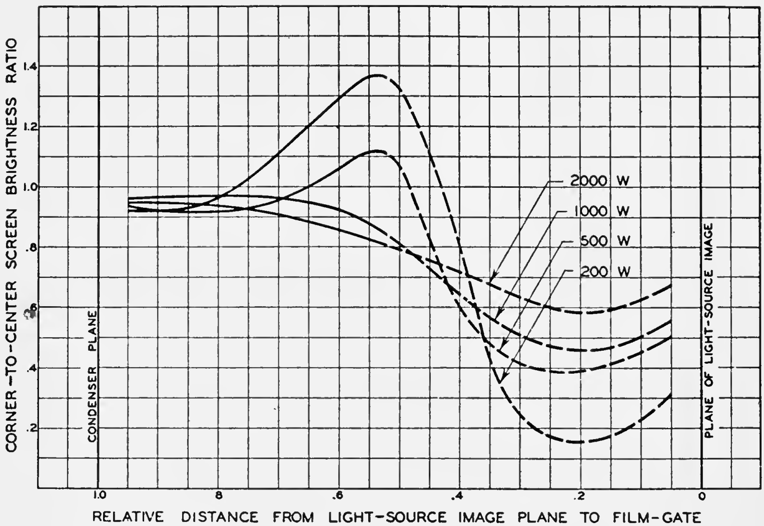


FIG. 8. Screen uniformity data for various light-sources with spherical condensers (65 mm. in diameter, 2.08X magnification).

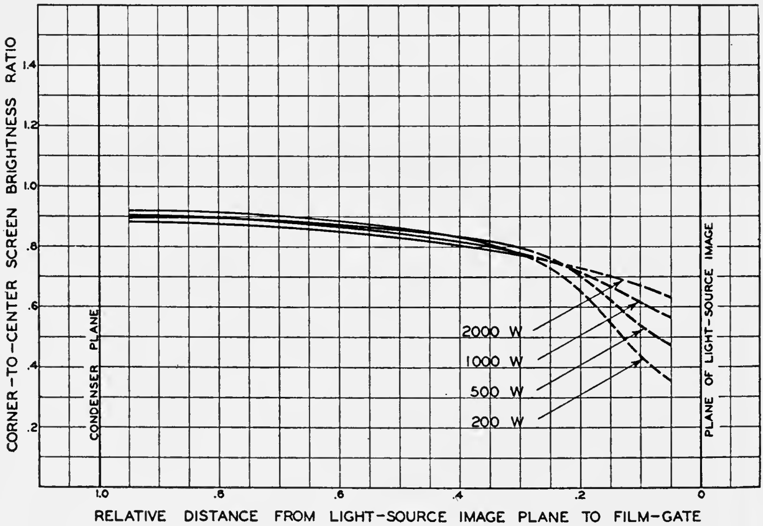


FIG. 9. Screen uniformity data for various light-sources with aspheric condensers (65 mm. in diameter, 2.08X magnification).

the screen brightness uniformity is largely independent of the light-source size.

For the purpose of supplying a more direct comparison, values of the screen light output and the brightness ratio, with the film-gate at the point where screen striations disappear, are listed in Table III. Some of the figures presented for the 500-watt lamp in this table are slightly different from figures already published,[1] check tests having warranted these revisions.

TABLE III

Projection Data

Condenser Data		Effective Light-Source			Screen Illumination Data	
Curvature	Distance* (B − C)** (mm.)	Dimensions (mm.)	Shape	Light-Source, Watts	Relative Brightness** Light Output	Ratio Corner-to-Center
Spherical	45.7	13.7	Round	200	0.44	1.37
				500	1.02	1.11
				1000	1.70	0.84
				2000	2.60	0.81
Aspheric	25.0	10.8 × 11.0	Oval	200	0.63	0.75
				500	1.30	0.77
				1000	1.90	0.76
				2000	2.82	0.76

CONCLUSIONS

It appears from a survey of the test results, Table III in particular, that large increases in screen illumination may be attained with both spherical and aspheric condensers by increasing the wattage of the lamps, even when the light-source size exceeds that required to fill the exit pupil of the optical system. A higher screen light output with satisfactory screen uniformity may be attained with the aspheric than with the spherical condensers, with all the test light-sources. However, this advantage is less marked with increasing light-source size. The foregoing conclusions apply not only to the two systems under test, but also in a proportionate measure to the optical systems previously tested,[1] making use of 26-mm. and 45-mm. condensers.

* Represents separation between film-gate and plane of light-source image necessary to eliminate screen striations (see Fig. 1).

** At equal lamp efficiency.

REFERENCE

[1] MILI, G., AND COOK, A. A.: "Condensers for 16-Mm. Optical Systems," *J. Soc. Mot. Pict. Eng.*, **XXVI** (June, 1936), No. 6, p. 603.

DISCUSSION

MR. CARLSON: How do the levels of illumination obtained with this experimental system compare with the better systems in commercial use today? I notice, for example, that the space between the light-source and the condenser seems to be appreciably greater in the system used for test than is common in present practice. Is, then, the efficiency of light utilization of this experimental system higher or lower than that of present systems?

MR. MILI: The efficiency of utilization, or, to be more specific, the screen lumens per watt, is higher with optical systems employing closely spaced condensers and light-sources. However, the short distance between the light-source and the condenser limits the wattage of the lamp that may be employed, and this in turn limits the level of illumination attainable upon the screen. On the other hand, even though the efficiency of the larger systems is less than that of the smaller systems, it is possible to use lamps of higher wattages and thereby attain higher levels of illumination.

MR. CARLSON: I should like to have more specific information on the level of illumination that could be achieved with a 2000-watt light-source and the system described here, as compared with the most efficient commercial optical system employing a 750-watt light-source.

MR. MILI: A highly efficient optical system available commercially for the 750-watt lamp makes use of a 45-mm. aspheric condenser system. This system would be about 10 per cent more efficient than the 65-mm. condenser employing the same light-source. Now, let us assume that the 65-mm. condenser system could accommodate a 2000-watt lamp, whereas a 750-watt lamp is the maximum light-source that might be used with the 45-mm. condenser. On the basis of equal lamp life, the relative screen lumens attainable with the two systems would be approximately 3.15 and 1.90.

MR. JOY: How could the efficiency of the system be improved to obtain even higher screen illumination levels?

MR. MILI: The tests of the optical systems were made with an $f/1.65$ projection lens, which is at present the fastest lens available. Higher illumination values could be attained either by increasing the aperture of the projection lens or by increasing the filament brightness and reducing the life of the lamp.

MR. CRABTREE: Nothing has been said about the cost of aspheric condensers as compared with spherical.

MR. MILI: Aspheric condensers are more expensive than spherical, although I do not know in what proportion. I notice, however, that there is an increasing tendency toward the use of aspheric condensers because of their better performance, which leads me to believe that the cost of the condensers, either spherical or aspheric, is small compared with the cost of the complete projector.

MR. TASKER: The cost of aspheric condensers is roughly twice that of spherical, but, as has been said, it is a relatively small part of the total cost of the projector.

MEDICAL MOTION PICTURES IN COLOR*

R. P. SCHWARTZ** AND H. B. TUTTLE†

Summary.—*Improvements made during the past year in methods, apparatus, and materials used in making medical motion pictures, particularly Kodachrome, and the characteristics of an emulsion suitable for exposure with artificial light are discussed. The uses of special accessories for medical motion picture photography are described.*

Increasing use of motion pictures as a part of clinical and surgical records has followed each successive improvement intended to meet recognized requirements. Only in the past few years have the remaining essentials for the field of medicine and surgery been fully met.

Since the first 16-mm. medical motion pictures were made in 1922, a continuous effort has been made to attain this objective. A recognized responsibility has been shared by manufacturers, physicians, and motion picture technicians to simplify the technic and improve the quality of clinical and surgical records to be provided by motion pictures.

The special application of telephoto lenses, the development of faster emulsions, improvements in the design of cameras, and the more efficient lighting are available advantages. All these are familiar expressions of advancements in this field of medicine.

The application of Kodacolor Film in medical photography was thoroughly studied by the writers a number of years ago. Satisfactory color values could be obtained although certain limitations prevailed. Among these it was evident that quality of the pictures was defined by the focal length of available lenses, the amount of auxiliary illumination was a detriment in the operating room, while the necessity for using filters, both in making and projecting the

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films, further restricted the usefulness of this process of motion pictures in the field of medicine.

All these limitations are now removed. The new artificial-light type of Kodachrome records the actual color on the film. By virtue of new lenses, minimum accessory lighting, and reproduction of color values with precision, the ideal film is now available for all the fields of medicine in which records can be improved by the permanent and lasting reproduction of color. Limitations heretofore expressed regarding the application of black-and-white or Kodacolor film to medical photography no longer hold with regard to the new artificial-light Kodachrome Film.

With the addition of color, it is possible to bring to the motion picture screen all the realism of the operating room, thus enabling medical students to see not only more of the operations but to see the surgical field in the same size and in the same perspective as the surgeon sees it. Unusual cases can not only be projected many times for a given group, but can be used for teaching and lecturing, and as general case-history records over periods of many years.

Until recently it was necessary to use a blue artificial light compensating filter when making a medical film with Kodachrome Film. Daylight Kodachrome Film when used with the blue filter rendered satisfactory color-films; but the filter, which had an exposure factor of four, or two diaphragm stops, necessitated the use of large-aperture lenses or a degree of illumination of the surgical field that was impracticable.

The artificial-light Type *A* Kodachrome Film eliminates many of the disadvantages of the past. No filter is necessary with it. Its high speed has made it possible to use regular operating room lighting equipment, and, because of the high speed, all standard types of telephoto lenses can be used.

Since the film is color-balanced specifically to match artificial or tungsten light, it is obvious that if it were used in daylight, the high blue-sensitivity of the film would cause a predominance of blues. Therefore, care must be exercised to eliminate daylight from the room when it is used. The film can, of course, be used in sunlight by using an orange filter, which is complementary to the blue filter formerly used with daylight Kodachrome and artificial light.

It has been found that if any standard type 500-watt spotlight is added to the regular operating room surgical field illumination, a lens aperture of $f/5.6$ can be used. This arrangement is particularly desirable when the 2-, 3-, 4$^1/_2$-, or 6-inch telephoto lenses are employed.

The surgical field should be lighted with a flat, even illumination. The 500-watt auxiliary spot and regular operating room lamps should be directed from above, so that none of the light is cut off from the surgical field by the operating team. The 2-, 3-, 4$^1/_2$-, and 6-inch telephoto lenses enable a camera technician to work at a respectful distance from the operating table, thus eliminating the hazard of contaminating the sterile field.

Color motion pictures are actually easier to make than black-and-white. The addition of color more than justifies the additional cost of the film. The medical student now can see not only surgical technic and general detail, but all the slight variations in color of skin and tissue, and the general pathology of the case as well.

Gross specimens can be filmed in color and the pictures preserved in gelatin at a lower cost than it is possible to preserve the specimens in alcohol or formaldehyde. Furthermore, the true colors of the fresh specimens will be preserved in films, whereas the specimens change color when preserved in jars. Medical films in color are not limited in use to medical schools and hospitals; recently medical color-films were used as evidence in deciding a court action. The possibilities of using properly designed films in grade schools for teaching hygiene have not yet been explored.

One has only to pause a moment and imagine the value films would have today if it had been possible to record in this fashion the experiments of Pasteur, the first use of anesthetics, or the technic of any of the early surgeons who made medical history.

There is perhaps more history-making being done today than ever before in medical science. In many instances color motion picture records are being made of these new and startling history-making events. It is hoped that in a short time every teaching hospital and medical school will be properly equipped to portray in color-films, not only to the medical student, but to the layman as well, the fruits of their important discoveries.

(A motion picture of medical subjects in color made on the Type A film was projected at the close of the paper.)

DISCUSSION

MR. TUTTLE: When making the picture, the field was illuminated with one medical spotlamp, and exposures were made with an aperture of $f/4$, on the artificial-light type of film that has been available for the past few months. Within the past week or so, new fast artificial-light film has been placed upon the market that is twice as fast as the old film, so that the same scene can be filmed today at $f/5.6$ with one medical spotlight equipped with a 500-watt, 100- to 105-volt lamp.

This particular surgery was filmed with a regular 1-inch lens with an auxiliary lens fastened over the front of it. The same field size could be obtained by using the 3-, $4^1/_2$-, or 6-inch lens with the focusing set screws removed. A 5-diopter lens was used, with the subject 12 to 14 inches from the camera. The danger of contaminating the field of surgery is not as great in eye operations as in abdominal or other operations, so that the camera can be placed quite close.

MR. GILMOUR: A student recently expressed himself to me in this manner: "I have seen operations in amphitheaters, and being young, and, perhaps very human, I was constantly mentally upset as to whether the operation would turn out successfully or not. It happens that most of my work is in obstetrics, and I worry as to whether the deliveries are going to be successful. On the other hand, when I am shown a picture, I know that the operation has been a successful one and that the technic was perfect. I am not worried, and I get a great deal more out of it as a film than as an operation."

Another point has to do, not necessarily with medical color photography, but with any type of color photography, as to why we feel that the color upon the screen seems more brilliant than the color we see in the original. The thought that I have is that when we darken the room for projection, the color seems very vivid by contrast with the darkened room.

MR. TUTTLE: As regards the first question, I think it is generally accepted as a fact by most doctors in teaching hospitals, that students get very little out of sitting in the gallery and watching operations. It is impossible for the master surgeon to impart very much to them because his responsibility to the patient is uppermost in his mind. Usually the student has to stay well back, and can not see the things that the doctor can see because of the angle and perspective of observation.

Motion pictures are ideally suited for teaching surgery because after the operation is over the surgeon who performed it can go into the teaching room and project the film any number of times. He can prepare a lecture to fit the picture, or cut the picture to fit his lecture, as the requirement may be, to cover the case more completely.

The second question probably has been considered by everyone interested in color photography. The psychological effect of seeing an original subject, and then going into a darkened room and seeing a picture of it projected upon the screen gives one quite a difference in the personal interpretation of color. Imagine, for instance, one who has never been, say, to Bryce Canyon. He gets off the train, the sun shining, the grass green, the flowers filling the air with their aroma. The birds are singing. He has received good news from home, and his spirits are high. All his other senses are contributing to his visual sense. After looking everything over and seeing the beautiful colors, he decides to take a movie of it.

He puts the camera to his eye. It has a limited angle of view, and must record with only one "eye." A picture is made that we shall assume, for all practical purposes, is perfect. After development, processing, and so forth, it comes out as nearly technically perfect as it is possible to make a colored picture.

Returning from his vacation to a pile of work upon his desk, he finds the good news from home was perhaps not so good. His spirits are lowered; perhaps he has a headache. He goes into a darkened room where he sees only a few degrees of the entire picture. He remembers seeing the scene of course, over a much greater angle, and the results are very disappointing because all the essential effects of the other senses are missing or are different.

However, on the other hand, if he should go to Bryce Canyon with one of his eyes bandaged, and his ears and nose plugged up so that those senses are not affected; and sees only what the camera sees through its limited finder; and subsequently goes right back without seeing any more, has the film processed, and looks at it in the darkened room, he is amazed at the beautiful colors he has recorded.

MR. CLARK: Kodachrome Type *A* is balanced for illumination of Photoflood quality. Can not the fact that you make the pictures with normal tungsten illumination account for a certain increase in the redness or yellowness of the picture?

MR. TUTTLE: The pictures were not made with regular tungsten. The lamp was slightly overvolted. A 500-watt lamp, 100 to 105 volts, was used on a 115- to 118-volt line.

NEW METHOD FOR THE DRY HYPERSENSITIZATION OF PHOTOGRAPHIC EMULSIONS*

F. DERSCH AND H. DÜRR**

Summary.—*Hypersensitization by mercury vapor increases the speed of photographic negative emulsions about 50 to 150 per cent, depending upon the emulsions used for the treatment. The important features of this method that make it superior to the well known wet-hypersensitizing methods are:*

(*1*) *The film does not have to be put through a bathing process and then dried.* (*2*) *The mercury vapors are active also upon tightly wound spools of film, the sensitizing effect being uniformly spread over the whole length (e. g., of a 1000-foot roll of 35-mm. motion picture film). If sufficient time is available for hypersensitizing, the films need not even be removed from their original wrappers, as the mercury vapors diffuse sufficiently through the wrapping material.* (*3*) *The increase of sensitivity is general throughout the range of wavelength of light to which the film was originally sensitive.* (*4*) *Not only can unexposed film be hypersensitized by this method, but it is also possible to intensify the latent image with mercury vapors.* (*5*) *The stability of the film is not permanently affected, although the increase in speed is gradually lost over a period of four weeks of aging. The clearness, however, remains the same, and may even improve somewhat. By a second treatment with mercury vapor the hypersensitization can be renewed in a film that has recovered from previous hypersensitizing.*

After the introduction of panchromatic emulsions, methods of increasing the sensitivity of these emulsions by special treatments became generally known by the name of "hypersensitization." These methods were based upon the well known fact that the sensitivity of photographic films and plates can be increased by bathing them in water or in solutions containing small amounts of ammonia. Later, other solutions were recommended for the purpose; for example, solutions containing small amounts of a silver salt and ammonia in water, or solutions containing small amounts of silver nitrate and hydrogen peroxide, and so on. The increase of speed attainable with this *wet*-hypersensitizing method, as it might be called, amounts to

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** Agfa Ansco Corp., Binghamton, N. Y.

100 per cent, more or less, depending upon the type of emulsion used. Emulsions that have been made in the presence of ammonia usually show less increase of speed.

To make the special treatment practicable, for instance, with panchromatic cine negative film, great care had to be observed in manipulating the wet films, and redrying the emulsion carefully was particularly important to the quality of the results. In addition, hypersensitized films always have certain disadvantages, especially with regard to their keeping qualities, which will be discussed later.

With the introduction of the supersensitive types of negative film, interest in these inconvenient, cumbersome, and expensive methods of hypersensitization declined considerably.

Yet, even with the availability of the supersensitive types of panchromatic materials there still exists, and probably always will, a demand for higher sensitivity, if possible without increasing the graininess, especially for processes in which only a rather unsatisfactory compromise can be attained between illumination and the most desirable lens aperture.

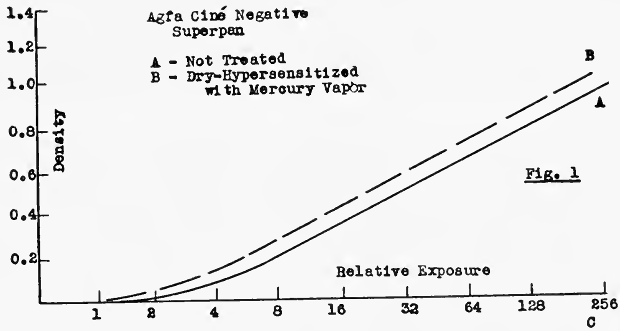
From this point of view, it appears that the method described in this paper may prove to be not only interesting from the theoretical standpoint, but will also offer prospects of its practical application.

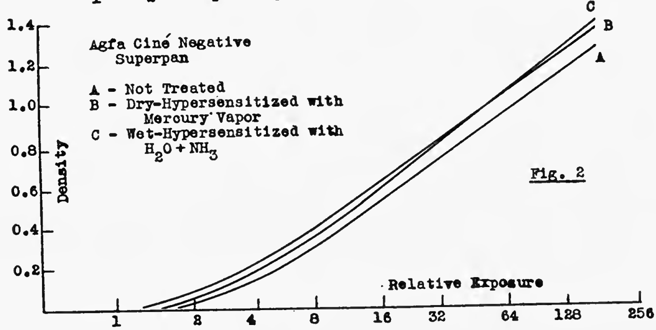
GENERAL

Upon investigating the effect of mercury vapor upon photographic emulsions in the Agfa Research Laboratories, it was found that the sensitivity of nearly all types of negative emulsions can be considerably increased when dry films or plates are exposed to the action of mercury vapor.

This effect was first noticed in 1928 by Baukloh,[1] who found that mercury vapors sensitize silver bromide and, more especially, silver iodide emulsions. Apparently nothing has been done since to account for this effect in theoretical considerations or to make practical use of it. Investigations by Winther[2] in 1933 even contradict in part the findings of Baukloh.

The action of the mercury vapor was found to be relatively slow. In our original experiments, photographic emulsions upon films and plates were exposed to the action of mercury vapor by placing them into a light-tight container, the bottom of which was covered with a thin layer of metallic mercury. In the container, films and plates were treated for approximately thirty hours, after which the





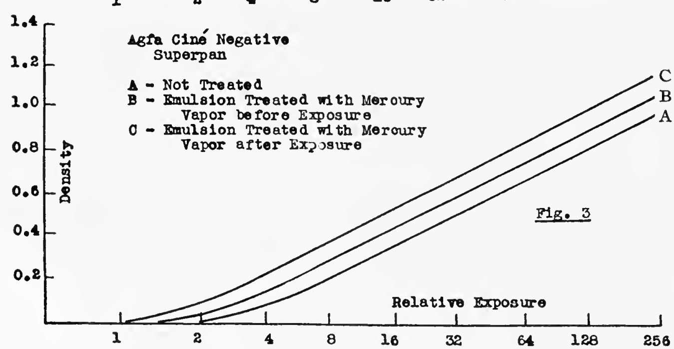


FIG. 1. (*Upper*) Difference of sensitivity between untreated material and material hypersensitized by mercury.

FIG. 2. (*Center*) Difference of sensitivity between material treated with mercury vapor and material hypersensitized by a wet-hypersensitizing method.

FIG. 3. (*Lower*) Effect of mercury hypersensitization before and after exposure.

emulsions showed an increase of sensitivity of about 75 to 150 per cent, depending upon the type of emulsion and upon the mercury vapor concentration within the container.

In Fig. 1 the difference of sensitivity between the untreated material and the material hypersensitized by mercury can be seen, and in this particular case is about 75 per cent. It is interesting to note that the characteristic curve of the mercury-hypersensitized emulsion runs almost parallel to the curve of the untreated material. This fact is pertinent because wet-hypersensitized materials usually show a distinctly steeper gradient than the untreated materials, as will be seen in Fig. 2.

In Fig. 2 the characteristic curve of the untreated material, *A*, is plotted together with the curve of the same emulsion treated with mercury vapor, *B*. The third curve, *C*, is for the same emulsion again, but hypersensitized by one of the wet-hypersensitizing methods. In this case a small amount of ammonia in distilled water was used as the hypersensitizing solution. In Fig. 2 the wet-hypersensitized emulsion shows a somewhat steeper gradient than either the type emulsion or the emulsion dry-hypersensitized by mercury vapor. This increase of gamma is characteristic of wet-hypersensitizing methods, while the hypersensitizing by mercury vapor has practically no influence upon the gradient as far as the useful part of the curve is concerned.

The increase of gamma of wet-hypersensitized panchromatic emulsions is largely due to the fact that bathing methods increase the sensitivity of panchromatic emulsions in the yellowish green and red-sensitive portions of the spectrum much more than they do in the blue. The original ratio of sensitivity, for instance, the blue-yellow or blue-red ratio, becomes changed, which means that the filter-factors of the wet-hypersensitized emulsions are different from those of the original emulsion. In this respect the *dry*-hypersensitized film behaves in a different manner. The mercury does not change the original sensitivity ratio in different wavelength regions; it appears that the increase of sensitivity is proportional throughout the portions of the spectrum to which the emulsion was originally sensitive. This method of dry-hypersensitizing apparently does not change the filter-factors of the original emulsion.

Film and plate emulsions from various manufacturers have been treated with mercury vapor, and no fundamental differences in behavior could be found. There is also no significant difference between the effect of mercury vapor upon ammonia and upon non-ammonia types of emulsions. It has been mentioned already that the action of mercury vapor is rather slow. At normal room temperatures, unwrapped films must be exposed to the vapors for at least twenty-four to thirty hours before the maximum increase of speed is attained. Longer treatment with mercury vapor does not increase the sensitivity to an appreciable extent, but the fog gradually increases. It would, of course, not always be practicable to treat unwrapped and unrolled films for thirty hours in an atmosphere containing mercury vapor. However, it has been found that it is not at all necessary to unwind and unwrap the films completely. The penetration of the mercury vapor into spooled and tightly rolled material is surprisingly uniform and efficient, making the whole process much more practicable and convenient. It is, for instance, sufficient to leave a 1000-ft. roll of motion picture negative film in the original can, and put a few drops of mercury wrapped in porous paper inside the empty space of the film core. The film can must be closed and sealed with tape, and should stand for approximately six to eight days. During that period an increase of speed extending very uniformly throughout the entire 1000-ft. roll can be noticed. The same effect can, of course, be attained with regular rollfilm spools or with spools for the Leica and Contax cameras. In the latter case it is not necessary to open the original cartridge; it is sufficient to put the whole cartridge into a small container containing mercury.

STABILITY OF DRY-HYPERSENSITIZING

The hypersensitization effected with mercury vapor is not permanent. The speed gradually recedes over a period of about four weeks; after which a more or less stable condition is reached when the sensitivity of the material is somewhat below that of the emulsion before the treatment. However, during the aging period, the dry-hypersensitized emulsion remains free from fog. After three to four weeks the fog value of the emulsion is even somewhat lower than the fog value of the original film. It is known that the stability of films or plates that have been hypersensitized by bathing methods is very poor. The fog of the emulsion rapidly increases with age, and materials so treated are usually ruined by excessively high fog in about four weeks. This is another distinct difference in behavior between wet- and dry-hypersensitized materials. After losing their additional sensitivity, dry-hypersensitized emulsions are still in a usable condition. The speed is somewhat less than that of the original untreated film, but the clearness is at least the same or better. There is another advantage. Emulsions that have been treated with mercury vapor, but have not been used before losing the additional sensitivity, can be re-hypersensitized by treatment in the mercury atmosphere a second or even a third time.

As far as could be seen, by comparing treated material with an untreated type, the grain size was not noticeably affected.

EFFECT OF MERCURY VAPOR UPON THE LATENT IMAGE

So far only the effect of mercury vapor upon unexposed photographic emulsions has been considered. Theoretical considerations, which will be discussed later, led to the discovery that the effect of mercury vapor upon the latent image is even greater than it is upon the unexposed emulsion. This action may probably be better described by the expression *intensification of the latent image*, as it has been applied to similar processes utilizing hydrogen peroxide.

In Fig. 3, *A* is the characteristic curve of an untreated emulsion; *B* is for the same emulsion dry-hypersensitized by mercury before exposure; and *C* is for the same emulsion, but in this case the mercury vapor treatment took place after exposure—in other words, the latent image has been intensified *after* exposure but *before* development. From the curves it can be seen that the effect of the mercury upon the latent image is distinctly greater than it is upon the unexposed emulsion. However, except for the difference in intensity of the effect, the characteristic behavior is in both cases the same. The characteristic curve of the intensified latent image, as can be seen in Fig. 3, also runs almost parallel to the original characteristic curve. The stability of intensification of the latent image is limited as to the length of time between treatment and development, as is the hypersensitization of the unexposed emulsion as to time between treatment and use.

The treatment of the exposed film with mercury vapor to intensify the latent image can be done exactly in the same manner as has been described for dry hypersensitization. It is, therefore, possible to correct an underexposed picture by treating the undeveloped film with mercury vapor for a certain length of time, provided, of course, underexposure is known or suspected. After the treatment, the film is developed as usual, and will produce a negative similar to one exposed with 100 to 150 per cent more light. Tightly wound rolls in cans can be hypersensitized if sufficient time, generally six to eight days, is allowed. Due to the relatively slow action, good penetration to all the layers of emulsion is achieved, and the effect is more or less uniform throughout the roll.

PRACTICAL APPLICATIONS

Within the scope of this paper it is possible to describe only very briefly how the material should be handled to obtain the best results. As a matter of fact, it would be very difficult to give exact formulas. Fortunately it is not necessary to do so; because of the slowness of the effect, the time of treatment, and the mercury vapor concentration do not have to be very exact. As a general rule, loose and unwrapped material should be treated from 30 to 40 hours at room temperature, while wrapped and spooled materials require treatment for seven to ten days, in a mercury vapor concentration created, for instance, by 0.5 gram of mercury in a 1000-ft. film container. In place of liquid mercury, of course, all compounds, amalgams, such as silver amalgams, and other preparations that emit mercury vapors can be used for dry hypersensitization or for intensifying the latent image.

THEORETICAL

In attempting to coördinate the mercury vapor effect with existing theories on the photographic sensitivity of silver halide emulsions and on the latent image, it is necessary to mention briefly, at least, these contemporary theories first. According to prevailing concepts, the sensitivity of silver halide gelatin emulsions is attributed mainly to the presence of silver and silver sulfide nuclei upon or within the silver halide grain. Theories proposing the existence of these metallic silver nuclei, so-called photo-silver, as well as the presence of silver sulfide, have been quite generally accepted. Both types of nuclei are already present on the unexposed silver halide grain. The number of atoms of silver contained in one of these nuclei has not yet been definitely agreed upon, and the nuclei can not be seen on unexposed silver halide grains, even with powerful microscopes. The inter-reaction between the silver sulfide specks and the photo-silver nuclei seems to be quite complicated, and no entirely satisfactory theory of the mechanism of this inter-reaction with regard to the sensitivity of the silver halide grain has been advanced. It might be possible that the silver sulfide specks activate or concentrate the relatively few photo-silver atoms upon the grain, as suggested by Sheppard,[3] or that silver sulfide disturbs the crystal structure and thereby facilitates the formation of larger silver nuclei under the influence of light.[4] The effect of mercury upon photographic silver halide emulsions seems to be more closely related to the presence of metallic silver nuclei or photo-silver on the grains of ripened silver halide emulsion, rather than to the presence of the silver sulfide. According to the present theories of the latent image, the metallic silver nuclei are of great importance to the developability of silver halide grains. This photo-silver is supposedly already present on ripened, but unexposed, silver halide grains. However, these nuclei are not yet large enough to catalyze the action of the developer upon any particular grain. If the silver nuclei become larger, through the formation of more photo-silver by exposure or by prolonged ripening, the size of these nuclei, or the number of silver atoms, reaches or passes a certain critical point at, or beyond, which the nuclei can sufficiently catalyze, or accelerate, the reaction of the developer, and the grain thereby is rendered developable. This theory of the action of the silver nuclei and of the latent image has been very helpful in describing the peculiarities of the mercury vapor effect. It can be assumed that the silver nuclei absorb or adsorb mercury atoms, and possibly form silver amalgams. The size of the silver nuclei will become increased by these mercury atoms, which, in turn, could account for an increase of sensitivity of any particular grain. In case too much mercury is absorbed, the grain becomes developable without exposure, causing the emulsion to show fog.

Following this general line of thought, it might be expected that the mercury vapor would show a greater effect upon the latent image than upon unexposed material. Experiments in this direction confirmed the theoretical speculations. The exposed silver halide grains contain a much greater amount of silver as nuclei, and the chances of mercury atoms being absorbed by those exposed grains are that much greater. The gradual loss of hypersensitization upon aging might be due to the loss of mercury through re-vaporization. The final stage at which the sensitivity of the treated and aged emulsion arrives and at which it apparently remains, wherein the speed is somewhat less than the speed of the original untreated material, might be attributed to the possible formation of mercury salts.

These explanations for the mercury effect are, of course, still hypothetical, but the effect apparently opens a new and very interesting avenue of approach to the theory of the latent image.

REFERENCES

[1] *Zeitschr. für wids Phot.*, **25** (1928), p. 250.
[2] *Ibid.*, **32** (1933), p. 157.
[3] SHEPPARD, S. E.: Third Colloidal Symposiums (monograph).
[4] NEBLETTE, C. B.: "Photography, Its Principles and Practices," McGraw-Hill Pub. Co., (1930), New York, p. 207.

DISCUSSION

MR. CRABTREE: After storing the film in the presence of mercury, have you made uniformity tests by flashing and developing the film on a machine?

MR. FYFE: Yes. The variation is no more than 25 per cent either way.

MR. CRABTREE: It is well known that you may get effective hypersensitization or growth of the latent image by merely storing the latent image. Are these hypersensitization values over and above the latent image growth on keeping?

MR. SCHMIDT: I might mention that the work was done in two different ways, practically and sensitometrically. Film was actually used in the camera, part of it exposed, and hypersensitized. During hypersensitization the latent image was kept on parts that were not given the treatment, and both parts were developed together.

MR. SHORNEY: What effect would hypersensitization have upon Kodachrome? Would it affect only the upper emulsion, or would it penetrate to the lower emulsions?

MR. FYFE: I can not answer that. We have not investigated it.

MR. MATTHEWS: I assume that the phenomenon is so new that the investigations have been restricted largely to existing high-speed emulsions.

MR. SCHMIDT: We tried different emulsions, including process and x-ray emulsions. It was interesting to note that with x-ray emulsions the image produced by x-rays and by the short-wave and ultraviolet rays of the fluorescent screen showed intensification.

MR. COOK: Is there a detectable amount of mercury in the film after absorption?

MR. FYFE: Most likely not. The mercury vapor concentration was the concentration at room temperature, and was very, very low. The amount taken up by the film is probably immeasurable by ordinary methods.

MR. CRABTREE: What are the effects of temperature and of storing at pressures below atmospheric?

MR. FYFE: We did not extensively investigate the effect of temperature; we worked at room temperatures. I did make some experiments at lower pressures in vacuum, and apparently there was no change of effect. We got the same effect at reduced pressures as we did at normal atmospheric.

MR. CRABTREE: What is the concentration of mercury in the vapor phase at, let us say, atmospheric pressure and a temperature at 70 degrees?

MR. SCHMIDT: I do not know exactly what the vapor pressure is; 0.0017 millimeter, I think. The percentage of mercury is very low. We are not interested in increasing the amount. We would rather work in the other direction. We tried to have definitely lower pressures because that seems to be more promising.

Evidently, the number of mercury atoms present is much greater than is necessary to show an effect.

MR. CRABTREE: What is the critical mercury concentration necessary?

MR. SCHMIDT: We believe there is a lower concentration that produces an optimal effect. It is undesirable to have excessive amounts of mercury vapors in photographic laboratories.

MR. MISENER: Would there be any difference in the hypersensitization if the latent image were treated immediately after exposure or after a keeping period of a few weeks?

MR. FYFE: As I remember, there was no change in the effect, but we have not gone deeply enough into that to answer definitely.

MR. MILLER: Was any attempt made to accelerate the effects and produce them in a shorter length of time, such as by raising the temperature?

MR. FYFE: The temperature was increased in one or two experiments; and since we ran into fog troubles, and since mercury vapor concentrations at temperatures higher than room temperature are not desirable, we did not investigate further in that direction.

REPORT OF THE MEMBERSHIP AND SUBSCRIPTION COMMITTEE*

The growth of the Society continues at a satisfactory pace. Two hundred and thirteen new members have been added to the rolls this year, ten old members have been reinstated, and, in addition, twenty-five applications are pending. As is usual each year, a number of members have allowed their memberships to lapse, and several resignations and deaths have occurred. However, despite these losses, the membership now totals 950 domestic and 325 foreign members, or a grand total of 1275.

While this number is a fairly impressive one, the Society is not serving as many individuals as it should. Many engineers, technicians, and others prominent in the industry are still not affiliated with the Society. Our task is to convince them of the advantages of membership in the Society, and the Committee requests the assistance of the members in this work.

The charts accompanying this report show the distribution of membership throughout the various states of the United States, and throughout the countries of the world. It will be observed that 37 states and 33 different countries are represented. New York State leads with 365 members. California follows with 180 members. Unfortunately, the distribution by localities is not well shown by the chart. For example, quite a large group of those who are active in the New York district reside in Pennsylvania and New Jersey; and many of those in the locality comprising Philadelphia and Camden reside in the two states, New Jersey and Pennsylvania.

As for the distribution of membership according to the three local sections of the Society, *viz.*, Atlantic Coast, Mid-West, and Pacific Coast, this distribution is determined by a division of the country into three sections by parallels of longitude drawn through points forty miles west of Cleveland and forty miles west of Denver.

Non-member subscriptions for the JOURNAL are likewise increasing, although at a much slower rate because the Society is primarily a

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* Presented at the Fall, 1936, Meeting at Rochester, N. Y.

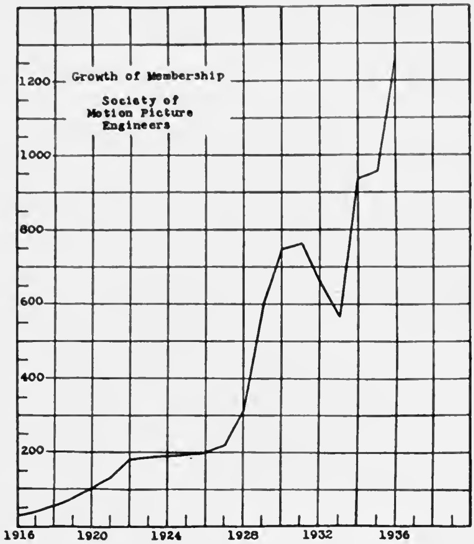

FIG. 1. Growth of membership.

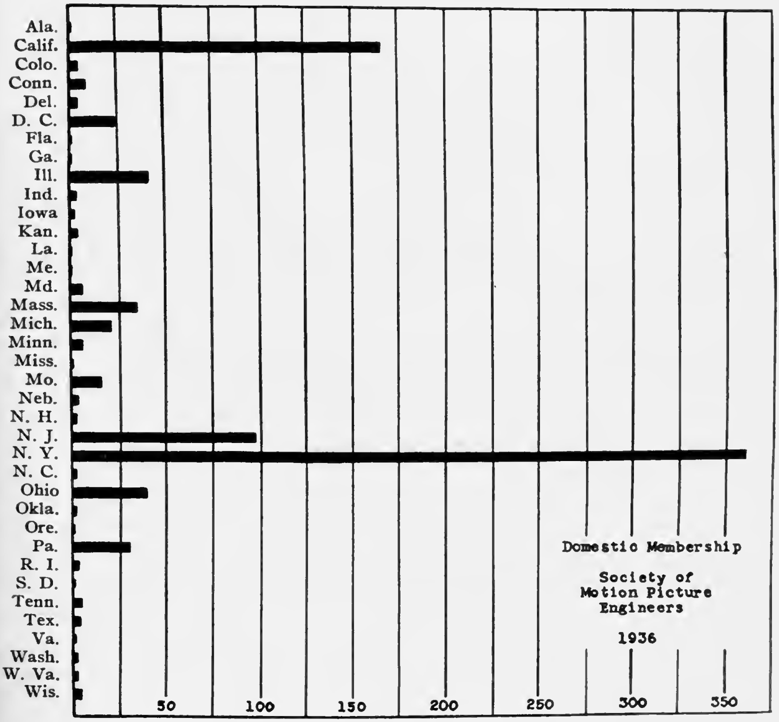

FIG. 2. Domestic membership.

membership organization. During the present year there have been 111 new subscriptions and 65 expirations, making a net increase of 46. During the past two years the number of subscriptions has increased by nearly 40 per cent. These subscriptions are taken mostly by public libraries and by the libraries of educational and large industrial institutions.

E. R. GEIB, *Chairman*

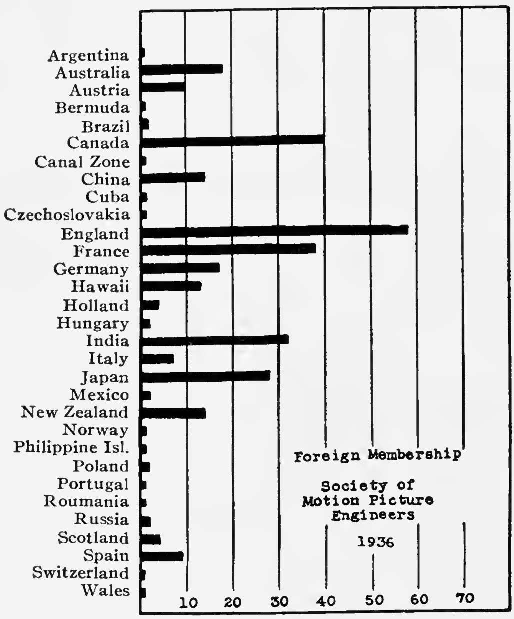

FIG. 3. Foreign Membership.

NEW MOTION PICTURE APPARATUS

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

A NEW HIGH-QUALITY PORTABLE FILM-RECORDING SYSTEM*

F. L. HOPPER, E. C. MANDERFELD, AND R. R. SCOVILLE**

In addition to providing sound records of high quality, a modern recording system must be compact in size, mobile, and require a minimum in the way of operating technic and maintenance. The older type of bulky fixed channel is rapidly being displaced by the newer units.

The new portable film-recording channel described in this paper has been developed as a result of experience in the field with a previous portable channel,[1] and is suitable both from a quality and operating standpoint for studio or location work, simplifies maintenance, and makes possible a single operating technic.

A complete channel consists of: a pick-up or stage unit, containing mixing and monitoring facilities; a main amplifier supplying the light-valve and the monitoring system; a noise-reduction unit of the carrier type, providing biasing current for the light-valve; a high-quality film-recorder, with associated motor system and recorder control unit; and a gain set and oscillator providing transmission-testing facilities. Power for the entire channel may be supplied either by an a-c. operated unit or by batteries.

All units are interconnected by means of six conductor cords equipped with jacks and plugs. A schematic drawing showing the equipment connected for operation is shown in Fig. 1. The units comprising the recording channel are shown in Fig. 2.

General Design Features.—In the design of the system advantage has been taken of recent developments by Bell Telephone Laboratories in the fields of vacuum tubes,[2] communication transformers,[3] and moving-coil microphones[4] and headsets. Contacts with the studios have established operating requirements and the need for certain adjuncts to the sound-recording system to enhance its usefulness. Consideration of these factors has resulted in a recording system that is reliable, and easily operated and maintained.

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* Received October 10, 1936; presented at the Fall, 1936, Meeting at Rochester, N. Y.

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

Each unit is of a new style of construction designed to make the equipment more compact, render the parts readily accessible, and provide adequate protection against rough handling in the field, and results in a considerable saving of space and weight. All units use the chassis type of construction, consisting of a combination of vertical and horizontal panels, rigidly braced and carrying the equipment and controls. All the apparatus is mounted on one side of the panel, the wiring being done on the opposite side, allowing short, direct connections between the various circuit elements. A jack panel is located at the rear of the unit, affording easy access to patching facilities. All panels carrying controls are covered with a thin mat which carries the engraving and is put on after the unit has been assembled, thereby assuring freedom from injury during construction. Fig. 3 shows the panel of a typical unit. Figs. 4 and 5 show, respectively, the

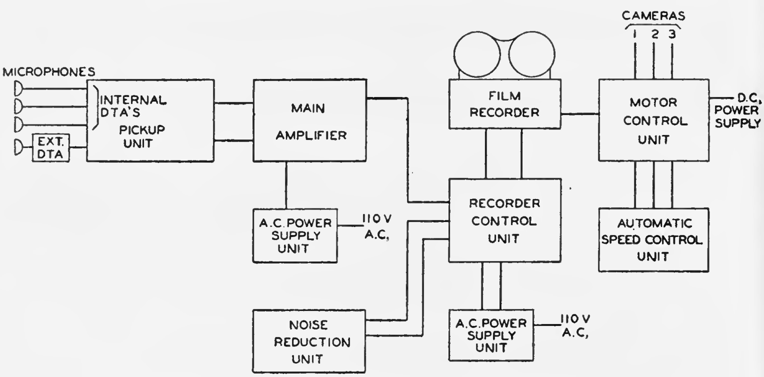


FIG. 1. Schematic arrangement of channel.

equipment and wiring sides of the same unit. The assembled chassis may be slid into a case for general use, or may be easily adapted for mounting in mixer tables,[5] or upon relay racks.

Shock-absorbing mountings are employed for all vacuum tubes, consisting of a channel carrying the tube sockets, the channel being fastened to the chassis through isolating rubber mountings. This form of support is compact and quite effective. Shielding has been employed between vacuum tubes and equipment parts wherever necessary to eliminate cross-talk. Low-level transformers are also shielded magnetically with permalloy to reduce pick-up due to exposure to external power fields. All filament and plate circuit metering is accomplished by means of a switch and meter. The meter indicates percentages, reading 100 per cent when operation is normal.

Transmission Features.—Heater type vacuum tubes are employed throughout the recording system, which allows operating the channel on either a-c. or d-c. sources. Special tubes have been employed wherever required by the particular functions they are called upon to fulfill. Tubes having extremely low noise and microphonic outputs are used in the low-level stages. All tubes are self-biased, requiring no C batteries. Alternating-current operation may be effected by one of two methods: The first requires a power unit supplying rectified current of the A and B circuits, and is normally supplied as a part of the channel. The second consists in supplying alternating current directly to all the heaters by means of a small filament transformer, and direct current to the plates from a rectifier. It is preferable from noise considerations to supply the heaters of the pick-up unit with direct current. Noise measurements indicate that such a-c. operated channels are practically as quiet as those operated completely by batteries.

The grounding system for the channel has been designed to provide protection from exposure to both radio and power circuits. The speech circuit ground is carried back from the pick-up unit to the main amplifier separately, and then connected to the system ground. All shields from the microphone cables, wiring in the pick-up unit, and shields in the transmission and signal cables are connected

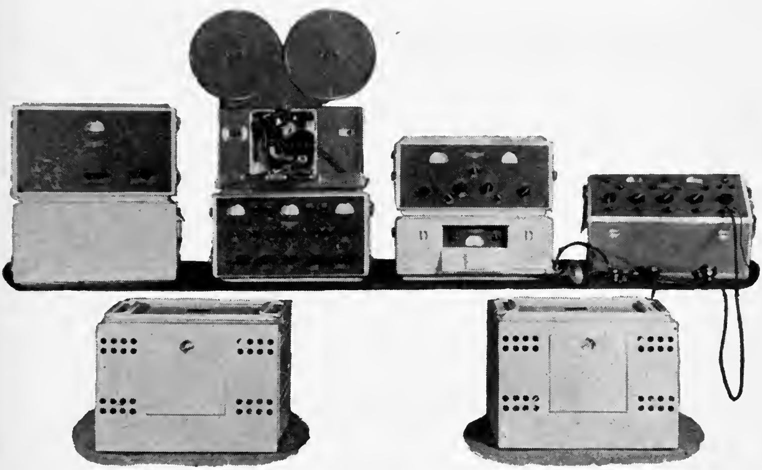
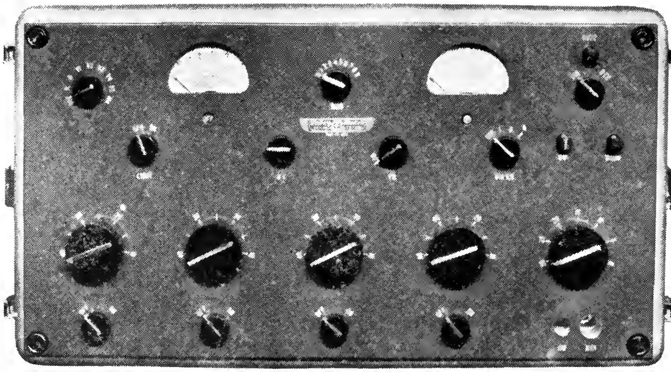
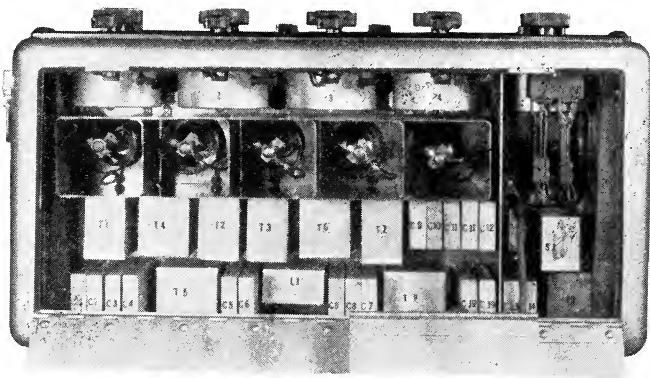


FIG. 2. Entire channel set-up.

through by means of a conductor to the system ground at the main amplifier. All grids and plates are protected by filtering, resulting in a system free from various forms of feedback. The maximum overall system gain is 110 db., which is about equally divided between the pick-up unit and the main amplifier. The frequency-response characteristic is essentially uniform from 40 to 10,000 cps. The amplifier system output is adequate for light-valve operation.

Pick-Up Unit.—The pick-up unit is contained in a case measuring 18 × 10 × $10^3/_4$ inches, and weighing 47 pounds. It contains a four-position mixer, balanced to ground. Three mixer positions are supplied from built-in microphone amplifier stages. Provision has been made for connecting a fourth microphone by means of an external microphone amplifier. Microphone cut-off keys are associated with each mixer position. The output of the mixer is further amplified by a built-in two-stage booster amplifier containing a variable dialog equalizer and





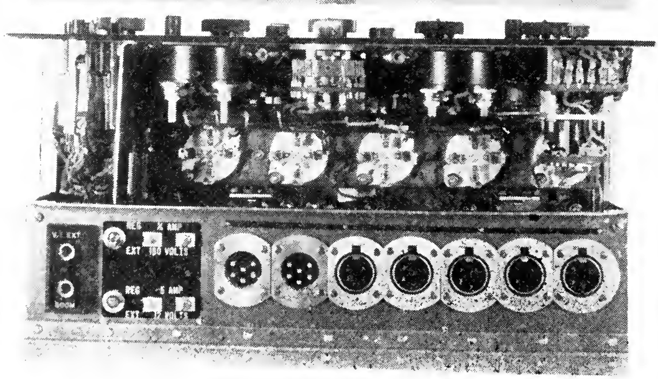


FIG. 3. (*Upper*) Pick-up unit.

FIG. 4. (*Center*) Equipment side of interior of pick-up unit.

FIG. 5. (*Lower*) Wiring side of interior of pick-up unit.

an inclusive volume control. The normal gain of the unit is approximately 55 db., with a substantially uniform response from 40 to 10,000 cps. An internal gain adjustment has been provided so that the gain may be increased to 64 db. to meet special working conditions. Cross-talk between mixer stages has been eliminated by means of careful wiring and shielding.

A power level indicator of the high-speed type is employed for mixing. It is bridged across the output stage, supplying the light-valve, and under operating conditions contributes no bridging loss. A sensitivity potentiometer allows adequate adjustment of its range.

Monitoring is accomplished by means of a high-quality moving-coil head-set. Means are provided for switching the head-set from direct monitoring to photoelectric cell monitoring, a volume control common to both circuits allowing adjustment of volume in the head-set.

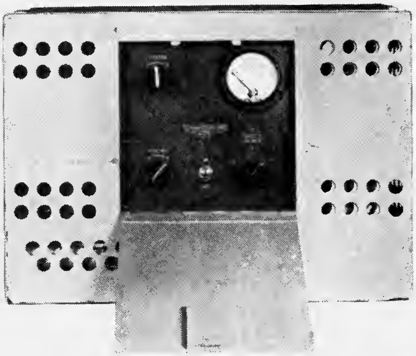
The order-wire system is designed to operate either with a standard order-wire set or with a combination set composed of an operator's breast transmitter and the high-quality head-set used for monitoring. Direct monitoring is also provided to a high-impedance head-set for use at the microphone boom. Provision has been made so that the mixer may talk to the boom man during a "take." The external appearance of the pick-up unit is shown in Fig. 3.

Main Amplifier.—The main amplifier is contained in a case measuring 18 × 10 × 7 inches, and weighing 28 pounds. It consists of a two-stage amplifier having a double push-pull output stage. Tubes of a different type have been used in the two output stages, and, due to their characteristics, it is possible to supply the grids from a common input transformer, and have both sets of tubes reach the overload point at the same input voltage but at different outputs. One output stage supplies the light-valve, and the other the monitoring system. Both the low- and the high-pass filters are located in this unit, and may be cut into or out of the circuit by means of switches. The gain of the amplifier is approximately 55 db., with a characteristic essentially uniform from 40 to 10,000 cps. The harmonic output of the amplifier at 1000 cps. is approximately 1 per cent in total harmonics at an output of +16 db. referred to the 0.006-watt level.

Power Supply Unit.—The power supply unit is contained in a case measuring 18 × 14 × 10 inches, and weighing 137 pounds. Two of these units per channel are required, one supplying power to the pick-up unit and main amplifier, and the other to the recorder lamp and the noise-reduction and recorder control unit. Power consumption is moderate, being approximately 375 watts for each unit. For locations where extreme variations in voltage occur, a compact voltage regulator may be supplied. The appearance of the power unit is shown in Fig. 6.

Gain Set and Oscillator.—The portable gain set and oscillator is contained in a case measuring 18 × 13 × 10 inches, and weighing 59 pounds. It combines in one unit an oscillator and gain set which may be used as an adjunct to the recording channel, or may find considerable use in general studio maintenance work. The oscillator is variable over a frequency range from 40 to 14,000 cps. while the gain set will measure gains varying from 0 to 120 db., or losses from 0 to 10 db. Small plug-in impedance-matching units are provided for converting the gain set to operate with impedances other than 500 ohms. The equipment may be operated from an a-c. power supply unit or from batteries.

The oscillator is of the beat-frequency type, and the frequency dial has been



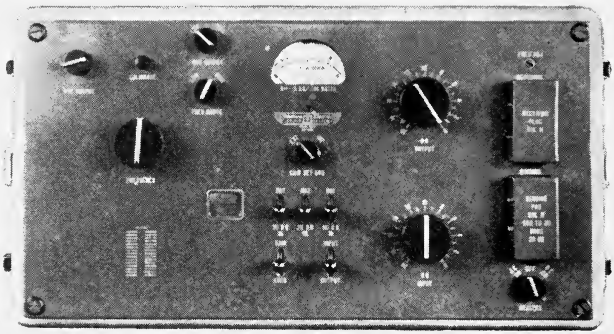


FIG. 6. (*Upper*) Power supply unit.

FIG. 7. (*Lower*) Portable gain set.

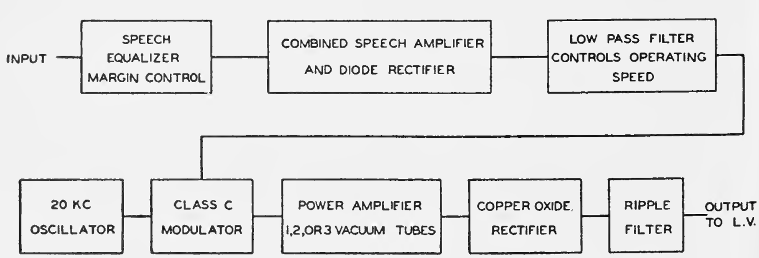


FIG. 8. Schematic arrangement of noise-reduction system.

calibrated in two ranges, one varying from 40 to 8500 cps., and the other from 8000 to 14,000 cps. From 40 to 8500 cps. the output of the oscillator is uniform. The maximum output is +7 db. referred to the 0.006-watt level. The harmonic output of the oscillator is practically independent of the oscillator output, and contains approximately 1 per cent in second harmonic and 1 per cent in third harmonic for any frequency above 100 cps. Below 100 cps. the harmonic content is slightly greater.

The oscillator is calibrated by one of two methods: The first combines a portion of the 50- or 60-cycle heater voltage with the output of the oscillator, producing a visible beat in the power level indicator of the gain set. The second makes use of a 1000-cycle tuning fork to produce an audible beat with the oscillator output supplied to a receiver. The latter method may be used whether the oscillator is a-c. or d-c. operated. Frequency drift due to temperature changes will be found to be quite small after a short initial warming period. The frequency is also quite stable with respect to either A or B voltage variation.

The gain set consists of a measuring and reference circuit connected to the output of the oscillator, and a receiving circuit. The measuring circuit contains various pads on keys, a variable attenuator, and a jack into which impedance-matching pads may be plugged. The reference circuit normally contains no attenuation, but for loss measurements the variable attenuator in the measuring circuit may be transferred to it by means of a key. The receiving circuit is entered through a jack into which impedance-matching units may be plugged. Preceding the power level indicator is another variable attenuator. The sensitivity of the power level indicator may, therefore, be reduced according to the attenuation used. The power level indicator is of the high-speed type and is built out to 500 ohms, and has a sensitivity of −5 db. referred to the 0.006-watt level at mid-scale. The input-output key is arranged so that the circuit not connected to the power level indicator will be terminated in 500 ohms. A number of impedance-matching units are supplied to convert either the sending or receiving circuits to impedances other than 500 ohms, or from a balanced-H to a T type of circuit. These pads are stored inside the case. Fig. 7 shows the appearance of the oscillator gain set.

Noise-Reduction.—The general principles underlying noise-reduction have been previously described.[6] Briefly, a varying biasing current is generated which causes the mean spacing of the light-valve to open or close in proportion to the amplitude of the signal wave. This results in a relatively dark print during low-volume intervals, with consequent reduction in noise.

The equipment described herein employs a modulated high-frequency carrier current. The advantages of this method are that: (*1*) the size of the units can be reduced, (*2*) the power efficiency is high, (*3*) circuit characteristics having optimal time-factors and filtering properties are readily obtained.

The carrier-frequency method for noise-reduction has previously been used in a portable recording system.[1] The equipment herein described embodies further refinements of apparatus. The chassis of the unit slips into a duralumin case approximately 18 inches long, 10 inches wide, and 8$^1/_2$ inches high. The weight is about thirty pounds.

The noise-reduction unit supplies 300 milliamperes or less to a 1-ohm light-valve circuit. The addition of one or two vacuum tubes in the output stage, provision for which is made, increases the output current to as much as 900 milliamperes if required.

A 1000-cycle input signal of approximately −6 db. relative to 6 milliwatts cancels whatever value of biasing current may be set. Thus the biasing current may be changed without readjusting the margin control. The latter is a potentiometer having 0.5-db. steps associated with the input to the amplifier portion of the unit.

The rate of change of biasing current when a signal is applied is such that the bias is reduced to 90 per cent of its initial value in 18 to 20 milliseconds. If signals of amplitude greater than just sufficient to cancel are applied, the time is shorter. On removal of the normal input signal, the biasing current is restored to 90 per cent of its original value in 18 to 26 milliseconds. The filtering of unwanted frequencies is such that when the noise-reduction is adjusted to 10 db., with 6-db. margin and half-cancelling biasing current, the noise components are 38 db. below the signal at 50 cps. and 43 db. below at 100 cps. Extensive investigation has been made of the relation of the rate of change of biasing current to the filtering, and the results attained with this equipment are believed to be near the optimal for single-track recording.

The circuit arrangement of the new noise-reduction unit is shown in Fig. 8. An input signal from the main recording amplifier is first equalized in accordance with the frequency characteristic of the light-valve, then amplified, and subsequently rectified by a duodiode-triode vacuum tube. The audible-frequency components are filtered to the maximum that will permit an optimal rate of change of biasing current. The output voltage is of an amplitude proportional to the envelope of the recorded signal, and is impressed upon a class *C* modulator stage to which is also connected the 20-kilocycle output of a vacuum tube oscillator. The circuit characteristics are such that the amplitude of the 20 kilocycles transmitted through the modulator stage is in inverse proportion to the voltage output of the rectifier filter. The modulator output is coupled to a power-amplifier stage utilizing a pentode and then to a copper-oxide rectifier. The high-frequency ripple is filtered out, and the final current transmitted to the light-valve simplex circuit.

Film Recorder.—The fundamental requirement of any type of film recorder should be to propel film past the modulating light-beam at constant speed. For a studio type of recorder, where weight is of no importance, the problem of speed constancy is materially aided by designing the moving parts, such as shafts, rollers, flywheels and driving motor, considerably oversize, and thus allowing reasonable tolerances in manufacture. For a portable recorder such a procedure is obviously undesirable. It is necessary, therefore, to analyze the entire structure carefully, and drastically eliminate weight wherever possible. This, in turn, places a much more severe requirement upon the mechanical precision throughout. It also precludes the incorporation of unessential automatic devices.

The film recorder used with this channel is shown in Fig. 9. The film path is quite short and simple. A sprocket pulls the film from the magazine at the left, whence it is passed on, with a free loop intervening, to an impedance roller of considerable mass. The recording is done on this roller, which is driven only by the film as the latter is pulled by the filtered pulling sprocket, located approximately n the center of the film compartment. As the film passes from the impedance roller to the pulling sprocket, it comes into light contact with a fixed shoe partially surrounding the pulling sprocket. The friction between the film and this shoe is instrumental in eliminating sprocket-hole disturbances.

The film is guided from the filtered sprocket by two idler rollers, one fixed and one movable, which act as strippers, to minimize sprocket-hole disturbances. The film passes from these stripper rollers to the hold-back side of the upper sprocket, through another free loop. From the hold-back sprocket the film passes over rollers into the take-up side of the film magazine.

It should be particularly noted that the filtered sprocket is isolated from the pull-down hold-back sprocket by means of two free film loops. The only impedance offered to the filtered sprocket is therefore that of the impedance roller. As this roller has considerable inertia, any high-frequency sprocket-hole fluctuations are effectively attenuated.

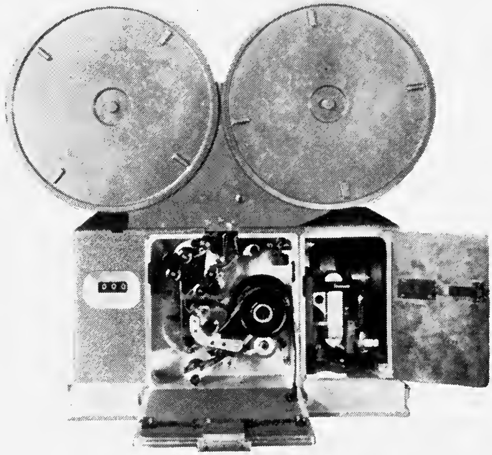
Lower-frequency disturbances due to mass unbalance and inaccuracies of gear teeth are most effectually eliminated by means of a mechanical filter. In this portable recorder, the mechanical filter is similar to that used in the standard Western Electric studio recorder. It consists of a driven gear coupled to the sprocket shaft by means of springs. Upon the sprocket shaft is mounted a heavy flywheel. The elasticity of the springs in combination with the mass of the flywheel, plus the proper amount of frictional damping, constitutes a filter providing extremely constant rotational speed of the filtered pulling sprocket.

The sundry gearing, along with the spring coupling of the mechanical filter, are placed at the rear of the recorder housing in an oil-tight compartment. To eliminate flexible couplings, and also to conserve space, the driving motor projects into the gear compartment. Two worms (actually one unit) are mounted directly upon the tapered end of the motor shaft. The larger of the two worms drives downward to the worm gear coupled to the filtered sprocket shaft assembly, whereas the smaller worm drives upward to the pull-down hold-back sprocket assembly. The end of the motor shaft also couples to the footage counter drive.

The spring coupling and friction damping assembly are surrounded by a light metal cover. The oil level is such that the metal cover dips well into the lubricant; and as the cover rotates it carries considerable oil upward, by passing it to the driving worms mounted upon the motor shaft. Thus an adequate supply of oil is always assured for the gears. All the bearings, except those used in the footage counter assembly, are of the precision oil-sealed ball-bearing type. When the recorder is in the normal position the level of oil is always well below any of the bearings, so that no hydrostatic pressure is exerted against any bearing connecting to the outside of the oil reservoir. This insures the film compartment against leakage of oil. For positions other than normal, the oil chamber is so designed that only a very small amount of oil can be in contact with any bearing, and thus the leakage through the bearing, if any, is insignificant.

To assist in assembling or disassembling the recorder motor and gearing, a circular clear celluloid window has been provided at the top of the recorder case which is normally covered by a quickly removable cover plate. This window is also a means of inspecting the oil level. Since all lubrication is provided automatically, maintenance is considerably reduced.

By removing the cover from the right end of the recorder, Fig. 10, the modulator unit, driving motor, transformers, resistances, and jacks are exposed to view.



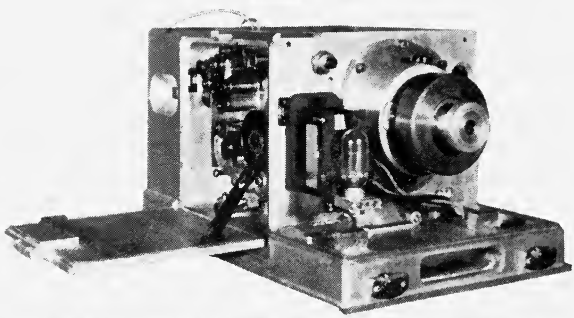


FIG. 9. (*Upper*) Film recorder, magazine film compartment and modulator door open.

FIG. 10. (*Center*) Film recorder, right front end, with cover plate removed.

FIG. 11. (*Lower*) Recorder control unit.

The modulator unit uses the permanent-magnet type of light-valve. The 4-ampere exciter lamp is mounted in a quickly adjustable lamp mount.

The motor shown in Fig. 10 is of the 12-volt d-c. interlocking type. However, a 110-volt d-c. interlock motor, as well as regular synchronous and standard Western Electric interlock motors, are available for this recorder.

Photoelectric cell monitoring is effected by deflecting some of the stray modulated light, by means of a curved mirror, downward to a small photocell mounted in the base of the machine. This photocell is coupled directly to a two-stage amplifier located in the left end of the recorder. The output of this amplifier, as well as the other electrical circuits for the recorder, except that of the motor, are carried, by means of short cables, down to the recorder control unit.

The recorder control unit houses all the necessary switches and meters to operate or control the recorder except those connected with the driving motor. As any one of several types of motor may be used, it would unnecessarily complicate the recorder control unit to supply adequate control facilities for all of them. Consequently, the motor control is located in a small switch box, which is supported from the side of the recorder during operation.

The recorder in Fig. 9 is shown with a Mitchell magazine. By means of an adapter plate, which can be permanently mounted upon the recorder if desired, standard Bell & Howell magazines can be used. The take-up drive is through either a spring or leather belt. Ordinarily either type of belt would slip sufficiently on the magazine pulley to avoid the necessity of a separate friction take-up clutch. As a safety precaution, however, a clutch has been provided, adjustable by means of three screw-pins mounted in the face of the pull-down and hold-back sprocket.

In case the take-up fails for any reason, a film buckle release switch has been provided for disconnecting the motor from the power supply following the formation of a small loop of film next to the take-up sprocket.

The overall dimensions of the recorder are $17^5/_{16} \times 9^{11}/_{16} \times 11^5/_{16}$ inches. The weight is approximately 100 pounds, although by removing the filter flywheel about 15 pounds can be eliminated. Handles are provided so that the recorder can readily be moved about upon a set.

The recorder is finished in a gray lacquer that is quite resistant to rough usage and can easily be cleaned by wiping whenever necessary.

Speed Regulation.—For accurate speed control a portable speed-regulating unit has been provided. When using either the synchronous or the standard Western Electric interlock motor, no additional speed-regulating equipment is necessary. For recording work not requiring very exact speed regulation, a 12-volt d-c. driving motor may be used, the speed being manually adjusted by means of a speed indicator. The change from this set speed during a take is very slight as the power is supplied by storage batteries.

Recorder Control Unit.—The recorder control unit is contained in a case $18 \times 10 \times 11$ inches in size, weighing 42 pounds. It contains the various switching facilities required to control the recorder lamp, the noise-reduction unit, and the light-valve. Special features contributing to ease of channel operation include an oscillator for checking light-valve overload and tuning, and a bridge circuit for determining valve overload. The appearance of the unit is shown in Fig. 11.

The units that have been described form a compact, mobile sound-recording system, capable of producing high-quality sound records. Operation of the channel has been simplified and made flexible by the use of a number of new features. Maintenance is minimized by the easy accessibility of the parts and by the fact that any unit may be quickly removed from the channel and another substituted for it.

REFERENCES

[1] DAILY, C. R.: "A New Western Electric Double-Film Portable Sound Recording System," *J. Soc. Mot. Pict. Eng.*, **XX** (Feb., 1933), No. 2, p. 128.

[2] PEARSON, G. L.: "Quiet Amplifier Tubes," *Bell Laboratories Record* (Oct., 1935), No. 2, p. 56.

[3] GANZ, A. G., AND LAIRD, A. G.: "Improvements in Communication Transformers," *Bell Syst. Tech. J.* (Jan., 1936), No. 1, p. 136.

[4] MARSHALL, R. N., AND ROMANOW, F. F.: "A Non-Directional Microphone," *Bell Syst. Tech. J.* (July, 1936), No. 3, p. 405.

[5] Progress in the Motion Picture Industry: Report of the Progress Committee, *J. Soc. Mot. Pict. Eng.*, **XXVII** (July, 1936), No. 1, p. 22.

[6] SILENT, H. C., AND FRAYNE, J. G.: "Western Electric Noiseless Recording," *J. Soc. Mot. Pict. Eng.*, **XVIII** (May, 1932), No. 5, p. 551.

A NEW HIGH-QUALITY FILM REPRODUCER*

J. C. DAVIDSON**

Talking motion pictures became a commercially successful fact in August, 1926, and many of the original Western Electric reproducing equipments installed soon after that date are still in daily use. These machines were the result of a careful analysis of the requirements of the industry as they were then understood.

During the past two years, surveys have been made, concurrently with developmental work, with a view to the production of a reproducer that will meet not only today's requirements as we see them, but will accommodate future developments in recording technic for several years to come.

Requirements.—In order to give to the theater owner full measure of improvement, together with the years of service he is entitled to expect, the film propelling mechanism should be capable of moving the film past a scanning point with a degree of constancy of speed substantially equal to that attained in the more costly studio recording equipment. This accomplished, the equipment should be able to reproduce, without distortion, a far greater volume range than is at present attainable. Machine noise should be reduced to a degree that will

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

permit deriving full advantage from the quiet passages, and, in addition, the reproducer should be ruggedly constructed, easy to operate, and simple to maintain. Parts in which unavoidable wear occurs should be readily replaceable. As a whole, the machine should be a complete, compact, symmetrical unit, and should not present the appearance of an appendage to its associated projector head.

Mirrophonic Reproducer Set.—The Mirrophonic heavy duty reproducer set has been designed to fulfill the above-described requirements. It consists of three units which interchangeably fit together to form a single symmetrical unit.

The main film compartment consists of an accurately machined casting containing the film-propelling mechanism, gears, the kinetic scanner, and a sub-

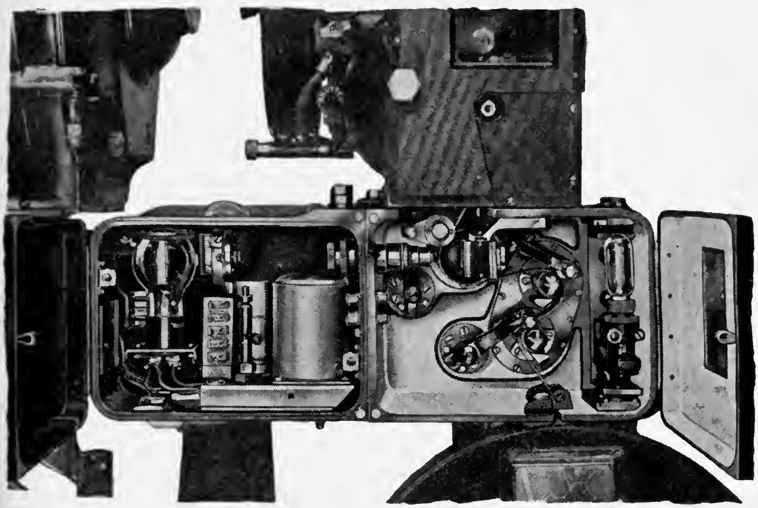

FIG. 1. View of film and photocell compartments.

compartment in which the exciter lamp is located. The photocell compartment is attached to the rear end of the main casting (and is interchangeable). It contains the photocell, the scanning slit, and coupling transformer. Fig. 1 is a view of the film and photocell compartments. The motor assembly (Fig. 2) is attached to the forward end of the main casting as a unit, and is interchangeable, self-aligning, and can be replaced within a few minutes.

The film path is from the hold-back sprocket in the projector head, around the drum of the kinetic scanner, over the drive and hold-back sprockets, and thence to the lower magazine. The mechanical drive consists of a worm directly coupled to the motor, driving a gear at 360 rpm. The gear is on the cross-shaft that supports the main drive sprocket as well as the necessary gears for driving the projector head and the lower magazine take-up. The cross-shaft, as well as the worm shaft, is supported in sealed ball bearings, and their accuracy of alignment is held to very close tolerances. The cross-shaft is coupled to the hold-back sprocket shaft by means of a set of steel and fiber gears; and in order to minimize noise, the lower magazine take-up is driven by a silent chain.

The lubrication is fully automatic. All shafts but the one bearing the hold-back sprocket, and including the motor shaft, rotate in sealed ball bearings. The worm gear operates in oil in a sealed chamber in the main casting, and the hold-back sprocket shaft is rifle-drilled to permit lubrication from this chamber.

The kinetic scanner (Fig. 3) is a completely sealed unit, consisting of a hardened nitralloy scanning drum, ground to a concentricity of better than 0.0001 inch, rotating on a shaft running in sealed ball bearings. It is a complete unit, mounted in the main frame casting. A two-element film speed governor, mounted upon the rear end of the shaft, insures uniform speed of film propulsion.

The film is held in contact with the scanning drum by a pressure pad roller which serves also to maintain scanning alignment. This assembly consists of a shaft, mounted on ball bearings, upon which is a felt pressure roller built up of a series of felt rings cemented together, thus assuring a uniform hardness of surface capable of maintaining its original concentricity. The felt roller is mounted upon a steel sleeve and is easily replaceable as a unit.

FIG. 2. The motor assembly.

The optical system (Fig. 4) is the projection type of scanner. An exciter lamp is mounted in a pre-focused lamp bracket having the usual adjustments, which is mounted upon a damped chassis merely by being pushed upon two locating studs and locked into place. The light is focused upon the film by a condenser and prism combination monnted in a slot in the main frame casting which is adjustable along the optical axis for optimum setting. The optical axis is fixed throughout by the exceedingly close manufacturing tolerances employed.

The objective lens is a standard microscope objective mounted upon a precision sleeve that provides movement along the optical axis for obtaining a sharp focus. This objective projects an image of the sound-track, magnified ten times, upon a scanning slit in the photocell compartment. Provision has been made for masking the width of the track scanned at the focal plane, thereby insuring against the decrease of illumination at the edges of the beam that occurs when masking is attempted at points other than on the focal plane. The height of the slit is adjusted at the factory to be an optimum for the frequency range to be scanned. The azimuth of the scanning slit is readily adjustable.

The principal immediate advantage of projection scanning is its flexibility and simplicity of adjustment. It bids fair to take the scanning system out of the hands of the optical laboratory and place it with the projectionist, who will find the adjustments as simple as those he has always been accustomed to make in projecting pictures upon the screen. The magnified image of even an 8000-cycle sound-track is so large that focus and azimuth can readily be adjusted by visual inspection, and will not be more than a decibel or so from the optimum obtained by the more laborious method employing the film loop and volume indicator. A septum is provided at the center of the scanning slit for the reproduction of push-pull recordings. It is mechanically connected to the switch controlling the electrical circuits for reproducing either standard or push-pull sound-track.

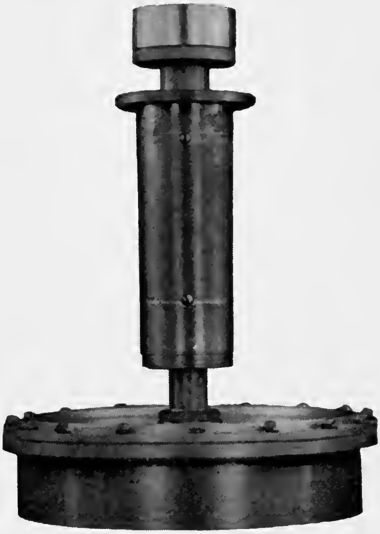

FIG. 3. The kinetic scanner.

The electrical circuit is in the photocell compartment, and consists of the photocell (which may be of the usual single-element type for standard track, or double element type for either push-pull or standard track) and a carefully balanced and shielded transformer having an impedance ratio of somewhat more than a third of a megohm to 200 ohms. The electrical balance between the elements of the cell and the coils of the transformer is such that no provision is required for equalizing the output from the two halves of a push-pull sound-track, so that operation is simplified merely to throwing a switch for the type of sound-track to be scanned.

From the installation and operating standpoints, the question of simplicity has been given serious consideration. With the selection of the correct pedestal

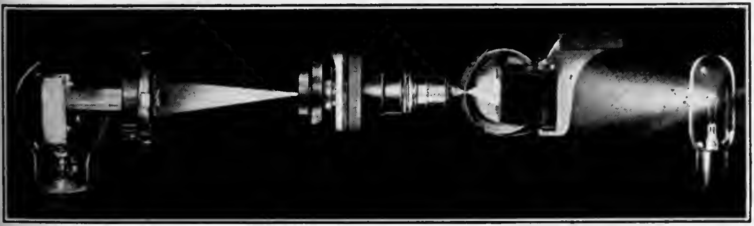

FIG. 4. The optical system.

arm, the reproducer set may be readily mounted upon any of the pedestals manufactured today in the U. S. A. Adapters are provided for the various projector heads in current use. The projector head is fastened to the adapter, which slides into a groove in the top of the main frame casting, providing a simple means of correctly meshing the reproducer and projector gears. It is possible, therefore, to remove the projector head, together with the adapter, by removing four readily accessible bolts, and to mount the projector head again without in any way changing the focus or alignment of the picture upon the screen.

Performance—The performance of this reproducer set fulfills all requirements indicated by present-day standard of reproduction of sound recorded on film, and also anticipates any future developments that at present can be foreseen. The flutter content of the average machine, measured in production, is about 0.1 per cent; and with special adjustment the machine is capable of bettering this performance. The frequency characteristic conforms to the theoretical response for a scanning beam of the height employed. The introduction of calculated damping materials insures that the machine introduces no noise during the quiet passages of sound-track.

The reproducer set has been designed to have the appearance of a complete symmetrical machine. The inside is finished in white, to promote cleanliness and provide better visibility for threading the film. The materials used, the care in manufacture, and the finishes applied are all of the best, and it is confidently felt that the new reproducer set will give even longer service than its predecessors, many of the earliest of which are, as already mentioned, still in daily use.

RECENT DEVELOPMENTS IN HIGH-INTENSITY ARC SPOTLAMPS FOR MOTION PICTURE PRODUCTION*

E. C. RICHARDSON**

The high-intensity carbon arc affords certain advantages as a light-source for photography that are not possessed by other illuminants. Within the restricted area of its positive carbon is concentrated an intrinsic brilliancy greater than that afforded by any other artificial light-source. Fortunately, the distribution of radiant energy throughout the spectrum of a high-intensity carbon arc coördinates well with the spectral sensitivity of photographic emulsions and the transmission factors of camera lenses.

For the purpose of more effectively utilizing high-intensity arc sources in motion picture photography, two lamps have been recently developed. The *M-R* Type *90* lamp (Fig. 1) operates at 120 amperes. The *M-R* Type *170* lamp (Fig. 2) has a capacity of 150 amperes. The designs of these two lamps, which are in general quite similar, embody many new factors that greatly enhance their utility and add to the convenience of operating them. Fig. 3 shows the mechanism of the Type *90* high-intensity arc lamp, in which the following vital improvements have been incorporated: (*1*) increased rotational speed of positive carbon; (*2*) continuous non-intermittent feeding of both positive and negative electrodes; (*3*) rapid-action positive and negative manual adjustments.

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** Mole-Richardson, Inc., Hollywood, Calif.

When these new high-intensity arc lamps were being designed it was known that hey would find extensive use in color motion picture photography. The require- ıents of illuminants for color cinematography are very rigid as to uniformity of pectral distribution and intensity. Considerable experimenting was done with

FIG. 1. (*Left*) *MR* Type *90* high-intensity arc spotlamp (rear view).
FIG. 2. (*Right*) *MR* Type *170* high-intensity arc spotlamp (front view).

arious rotational speeds of positive electrode. It was found that at approxi- ıately 14 rpm. an optimal condition was established and that the crater was very ymmetrical. It was noted that at that speed crater rims that had been chipped, ither by careless striking or other causes, were quickly restored to symmetry.

The maintenance of a properly shaped, symmetrical crater is one of the most nportant requirements for stability of the arc. In the arcs under discussion, he angle between the positive and the negative electrodes is 127 degrees. It has been found that at that angle practically any carbon suitable for use under high-intensity conditions performs reasonably well. The 127-degree angle results in better performance than the much flatter angle generally used in the design of searchlights and Sun-arc lamp mechanisms. The objection to this angle is that in striking the negative to the positive, the contact between the two electrodes comes at the rim of the positive crater, which tends to cause chipping. That was one of the reasons why the lamp was designed to be struck manually rather than automatically. The other reason was that automatic striking would have increased the cost of the mechanism to a very considerable extent.

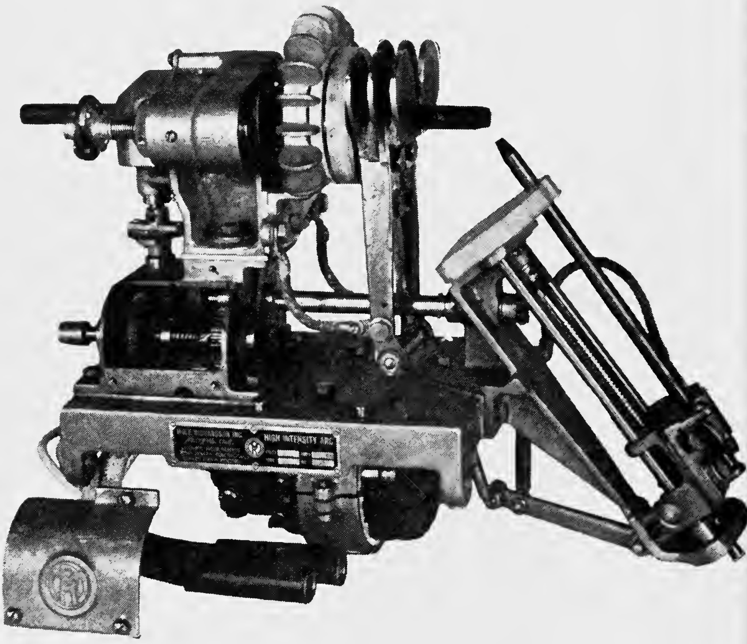

FIG. 3. Mechanism of *MR* Type *90* high-intensity arc spotlamp.

The feeding arrangements of these new high-intensity arc mechanisms diffe from other designs in combining continuous, non-intermittent feeding of the posi tive and negative electrodes with rapid positive electrode rotation. So far as th writer is aware, all high-intensity arc mechanisms used in motion picture photog raphy, having rotational speeds sufficiently rapid to maintain good crater condi tions, have had feeding arrangements of the "stop and go" type. Only by uni form, non-intermittent feeding and positive electrode rotation faster than 10 rpm can the constant stability of performance be attained in high-intensity arcs use for illumination in color photography. The mechanics of the feeding arrange ments in these lamps permitted a rapid hand control: one revolution of th negative hand-feeding crank advances the negative electrode 0.1 inch. A simila movement of the positive hand control moves the positive electrode 0.08 inch.

Quietness of operation is, of course, essential in all motion picture equipment designed for use in conjunction with sound-recording apparatus. The motors of these new high-intensity arc lamps have grease-packed reduction gears, and no shafts or parts other than the motor reduction gearing have rotational speeds greater than 46 rpm. All shafts and rotating members, other than those rotating at the slowest speeds, are mounted upon either oil-less or ball-bearings. Again and again, in recent productions, these lamps have been operated satisfactorily within six or eight feet of the microphones. Provision has been made for com-

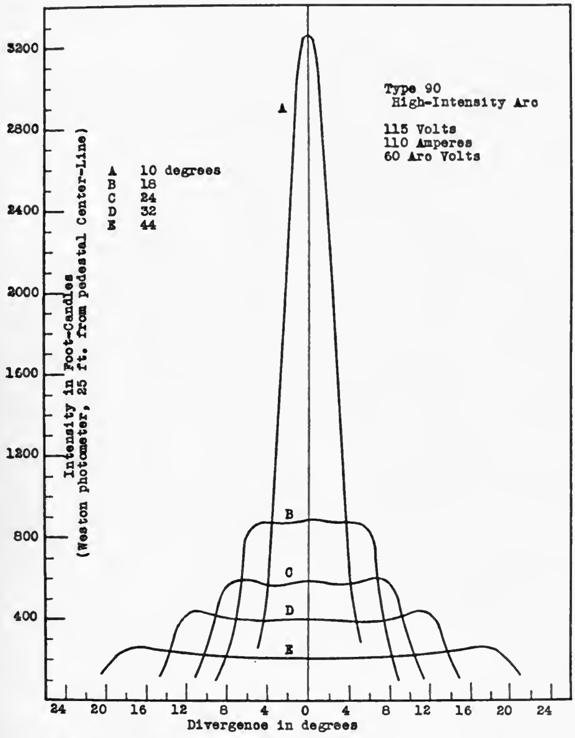

FIG. 4. Typical distribution curves of Type *90* high-intensity arc.

pletely stopping the driving motor in the few situations that arise when the microphone has to be placed within six feet of the lamp.

Aside from improvements in the mechanism, probably the most outstanding other improvement in these new equipments is the application of "Morinc" flat corrugated lenses as a means of collecting and projecting the light of the arc. The carbons used in the Type *90* are a 13.6-mm. positive and a $^3/_8 \times$ 9-inch copper-coated negative. The Type *170* uses a 16-mm. positive carbon and a $^7/_{16}$-inch copper-coated negative carbon. It is characteristic of these high-intensity arc combinations that the most effective portion of their radiation falls within an angle of 60 degrees each side of the axis, and principally within a total angle of 80 degrees. Within 80 degrees the intensity is not less than 10 to 17 per cent of the intensity at the axis. Heretofore, in order to project the light from a high-intensity motion picture arc spotlamp effectively, the principal optical means em-

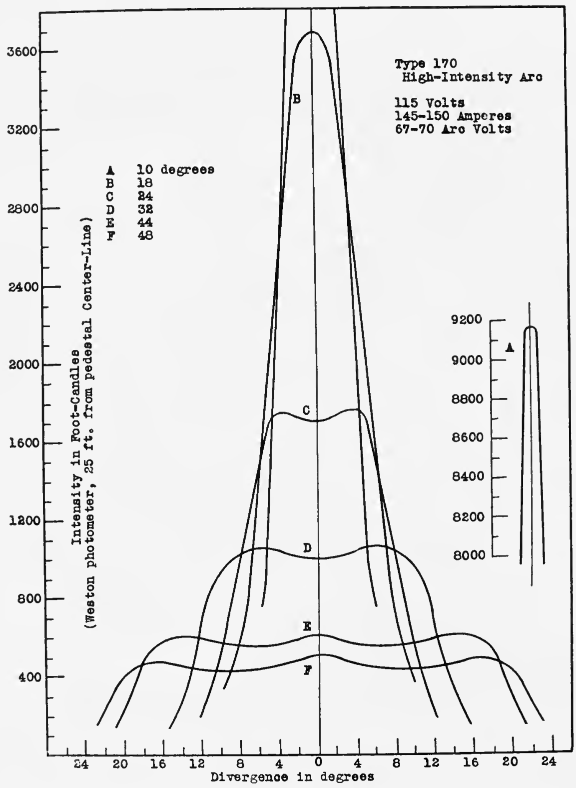

FIG. 5. Typical distribution curves of Type *170* high-intensity arc.

ployed have been parabolic reflectors and spherical lenses. The high temperature developed directly in front of the positive crater in arcs operating at currents greater than 100 amperes is such that lenses, for practical use, have been limited in diameter to 8 inches, and to focal lengths such that the arc would not be closer to the lens than 6 inches when the desired flooding angle was attained. Experience has demonstrated that if lenses greater than 8 inches in diameter were used, or if the arc were brought closer than 6 inches, the glass elements were subjected to pitting by the copper coating of the negative electrode and the hazard of breakage was greatly increased, regardless of the efforts of lens manufacturers to make use of the advantages of heat-resisting glass having low coefficients of expansion.

The 24- and 36-inch parabolic mirrors, which have given the best performance, have both been limited to the $18^3/_4$-inch focus. The mechanical limitation has been imposed by the fact that there must be room for interposing a negative carbon of suitable length between the crater and the mirror surface when the lamp is adjusted for flooding. This prevents the positive crater from being placed nearer than $11^3/_4$ inches from the center of the mirror surface. Even though the lamp operators on the stages exercise the utmost care to protect their sun arcs from wind and sudden changes of temperature, there has always been a great deal of dissatisfaction regarding the breakage of parabolic mirrors in studio use. The "Morinc" lens, designed for these new high-intensity arc lamps affords ideal distribution of illumination for photographic purposes. Figs. 4 and 5 illustrate the distribution attained at various angles of divergence when the lamps are used for flooding, and show the wide range of divergence attainable. Variations from spot beams of 8 degrees to floods of 44 degrees are produced having smooth fields of photographically useful light. The edges of the various beams vignette and make it practicable to overlap fields of illumination, as is often necessary in motion picture set lighting, without creating high-intensity areas in the overlaps or distinct markings defining the circumference of the field.

In both lamps every effort has been made to facilitate operating them in their many applications in the studios. Each has a resistance grid, so designed that it may be removed from the pedestal, permitting the grid and lamp head to be taken as a complete operating unit to the overhead cat-walks and parallels.

The Type *90* lamp weighs 224 pounds and is tending to replace the 24-inch Sun arc, which as a rule weighs more than twice as much. The Type *170* lamp, which weighs 311 pounds, is, in most cases, replacing the 36-inch Sun arc, many of which weigh considerably more than 600 pounds each.

In recognition of the value of reflector arcs of the type generally classed as Sun arcs, it should be noted that for divergences of less than 15 degrees they show definite superiority, and it is not anticipated that projectors of the lens type will displace them for uses requiring such narrow beams.

Lamps of the types described have carried the major burden in all artificial lighting used in the Technicolor productions *Trail of the Lonesome Pine*, *Dancing Pirates*, *Garden of Allah*, *Ramona*, and *God's Country and the Woman*. Very considerable numbers of lamps are now in use at the Warner Brothers, Metro-Goldwyn-Mayer, Paramount, United Artists, and Columbia studios in Hollywood, and at London Films Denham Studio in England for both black-and-white and color photography.

DISCUSSION

MR. PALMER: Is the motor connected directly across the line, so that the speed does not vary with arc voltage?

MR. RICHARDSON: It is a shunt motor, connected across the arc. We experimented with placing the fields across, or ahead of, the resistance, but adopted the present arrangement because we have to separate the rheostat from the lamp head on account of the heat. The motor changes speed somewhat with the slight voltage fluctuations resulting from changes of arc length, so we have some degree of regulation.

The mechanism will work the positive carbon down to about $3^5/_8$ inches, when consumed to the limit. There have been many attempts to devise ways of saving carbons; but using such heavy currents as we do in the high-intensity lamps, perfect conductors are required to get the current to the tip of the positive carbon.

MR. MISENER: Are the motors sealed?

MR. RICHARDSON: They are entirely enclosed, and require very little servicing. In fact, I do not believe that, of 250 lamps we have in operation, more than 10 have ever required servicing. Eventually brushes will have to be replaced; but if the motor is used, say, two hours a day, the brush life should be quite long.

MR. CRABTREE: We read in the newspapers about the high temperatures existing in the Hollywood studios. What is being done in the way of air conditioning?

MR. RICHARDSON: That question has been asked a number of times. I have not heard of the terrific heat, except that the temperature does get rather high at the studios in the San Fernando Valley. The outdoor summer temperature there is occasionally 100 or over. As far as I know the stages are not refrigerated, although many of them pass the air through water sprays, which have some cooling effect.

MR. TASKER: Many stages are now equipped with blowers for changing the air during takes. There are three conditions under which the heat becomes uncomfortable: when one is working in a small closed room, particularly for photographic reasons; when the actors are wearing arctic or winter costumes on the stages; and when working with color.

MR. RICHARDSON: A large cold-storage company in Hollywood had an enormous ice storage building that had become obsolete due to the activities of the electric refrigerator manufacturers. They conceived the idea of turning it into a cold stage, and installed refrigerating equipment. When you see Columbia's *Lost Horizon* you will see the actors walking about with vapors coming from their nostrils—a very convincing arctic scene, because the temperature may be as low as 20 degrees, even on a summer's day.

THE SCHWARZKOPF METHOD OF IDENTIFYING CRIMINALS*

J. FRANK, JR.**

During the past two years experiments have been conducted that have resulted in a recognized contribution to the science of sight identification. This paper describes the background indicating the need for such a method, some of the ex-

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** International Projector Corp., New York, N. Y.

periments conducted, the equipment and technic finally agreed upon, and some of the results to date.

There are two systems of identifying human beings: sight and positive. The law enforcement officers must use both types in apprehending criminals. The positive system is applicable only when a criminal is in custody. It consists in taking measurements, recording tattoo marks, scars, and other features, and comparing the records with any previous records the individual may have. Frequently during the process of establishing the records for positive identification, full-face and profile still pictures are taken of the individual.

Identification by sight is, on the other hand, applied to criminals who are at large and are wanted by the police. The field of development of sight identification has been sadly neglected. It is necessary for the law enforcement officer to identify a wanted criminal by sight first, and then take him into custody before positive identification can be effective. With improved modes of transportation, improved methods of disguise, and increasingly larger crowds in cities, more highly scientific methods of sight identification are required.

In the earlier days, law enforcement officers had only verbal descriptions of the wanted criminal to guide them. A few of the officers might have actually seen the criminal when he was previously in custody. Then came the printed description, with reproductions of photographs, the familiar "Wanted" circular, with its full-face and profile views. The "Wanted" circular, because it is inexpensive and can be widely and quickly distributed, is a useful tool. At the very best, however, the halftone reproductions on the printed circular are several steps removed from the original photograph, and represent the subject as he appeared during only a fleeting moment—the fraction of a second during which the camera exposed the film—and during which the criminal may have distorted his countenance somewhat.

To compensate for the deficiencies of the still-picture likenesses, modern large city police departments use the "line-up." The advantages of the line-up are that the police see the criminals in action; they see his characteristic gestures, the way he stands and walks; and hear his voice. This is the most effective means of promoting sight identification. The disadvantages of the line-up are that only a handful of all interested law enforcement officers can be present at the line-up while the criminal is in custody.

As the modern and most effective method known of familiarizing law enforcement officers with the identifying characteristics of wanted persons, the New Jersey State Police, working in collaboration with the RCA Manufacturing Co., the J. M. Wall Machine Co., and the International Projector Corp., have developed a method of using talking motion pictures—the Schwarzkopf method of identifying criminals. Experiments were made using 16-mm. sound motion picture equipment, which demonstrated the great value that such records would have in assisting in establishing identification by sight. Further development was carried on with 35-mm. equipment of both the single- and double-film type over a period of more than six months.

Because the films are to be used for identification, the first requirement for police work is realism in the projected picture and reproduced sound. The pictures must have clear, sharp details, and the sound must reproduce in recognizable form the inflection, pitch, and other characteristics of the subject's voice.

The equipment must be so simple that one person can operate it without considerable training, and must be so designed as to be easily transported and quickly set up at any place where electric current is available.

The experiments resulted in the decision to use, for high-quality results, double-film recording equipment originally designed for location and industrial purposes. For certain other applications the 16-mm. equipment fulfilled the requirements. Further development of a single-film system employing a noise-reduction system will result in a satisfactory set-up at lower cost.

Recording equipment, camera, and illuminating equipment were modified for this particular application. Ease of focusing and suitable acoustical conditions were attained by using a floor mat of canvas and gray cloth drapes forming a triangle open at the apex. The floor mat has fixed sockets for the legs of the

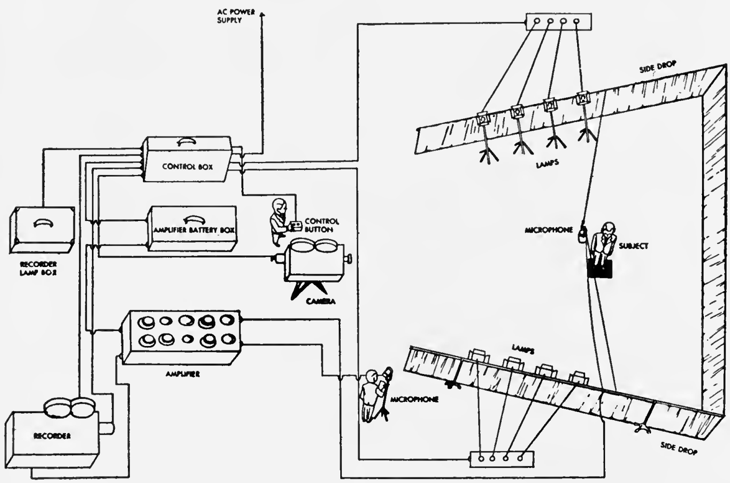

FIG. 1. Complete set-up of equipment and stage.

camera tripod, and the proper location for the subject is marked so that he will not get out of focus or out of the range of the camera lens. The side and back drapes provide a suitable photographic background, concentrate attention upon the subject, and eliminate echoes or reverberations that might be picked up by the microphones. The positions and the wattages of the necessary lamps are predetermined to provide the proper lighting.

Setting up the equipment requires perhaps fifteen minutes. When all is ready and the subject is placed in the position marked upon the floor mat, with the microphone suspended immediately above and in front of him, the inquisitor takes his position at the other microphone and the operator standing at the camera presses the control button that he holds in his hand. At once the subject is brightly illuminated by the flood lamps. To allow the subject to regain his composure, and to give the operator time in which to glance at his lights and meters, the automatic controls have been so arranged that a lapse of three seconds occurs between the instant the lights go on and the instant the camera and recorder are started. The inquisitor then puts his questions and directions to the subject, according to a prearranged plan, so that the interview requires three minutes and uses approximately 300 feet of film. Three minutes has been found, after considerable experimenting, to be sufficient time in which to describe the subject from four different angles, using long, medium close-up, and close-up shots, as well as to ask the customary questions and have the subject perform certain distinguishing actions.

In most cases, portable reproducing equipment will fulfill all requirements,

FIG. 2. Stage and equipment in use.

with the advantage that showings may be made in various locations. In some police headquarters in the larger cities it may be desirable to have one of the permanent installations such as is supplied to theaters.

The possibilities of the Schwarzkopf method of identifying criminals indicate that it is an important step forward in police methods. It is the plan to locate recording apparatus in the large cities, and in the possession of State police authorities as required to meet the needs of the State. Each State and Federal prison should be likewise equipped. Sound motion pictures of criminals should be made when they are apprehended, when they arrive at prison if convicted, and immediately before their release, to insure getting accurate likenesses of the prisoners' voices and customary appearances. Habitual criminals and those suspected of more serious crimes will be photographed and recorded upon film as a matter of routine, just as they are now fingerprinted. At regular intervals police officers will be shown sound motion pictures of all criminal persons known to be in the vicinity.

The police departments of even the smaller towns are to have reproducing equipment, either for standard 35-mm. or for 16-mm. film. Large cities should have 35-mm. reproducers in each precinct police station as well as at headquarters. Instead of having only a few headquarters' police officers and detectives see the criminals when they are picked up, every law enforcement officer, from the patrolman on the beat to the highly trained detective, can see and hear the wanted persons, not after they are in custody, but when they are wanted; and not only in the headquarters of the police force that arrested them, but anywhere or everywhere they are likely to be. They can see and hear the picture monthly, weekly, or daily if they desire.

Undoubtedly, in these days of fast travel, when criminals roam from one end of the country to the other, some means of coördinating the sound-film activities of local police departments will be needed. Probably this may be achieved by a national library, which will maintain files of films just as fingerprint files are now maintained. Local police would record the criminal on film and have made whatever number of projection prints may be required. The original negative would then be sent to the national library, which would supply prints, either 35-mm. or 16-mm., to the various police departments as needed.

In the cases of the more notorious criminals, their pictures could be shown even in the theaters of the country, as part of the newsreels. Newsreel producers have already indicated their eagerness for such films. What chance of escaping detection would a "public enemy" have when every police officer and millions of citizens have seen him in action and have heard him talk?

A demonstration was held on May 27, 1936, at Trenton, N. J., under the sponsorship of Gov. Harold G. Hoffman before an audience of 500 persons representing the most important law enforcement agencies in the United States, England, and Canada. Four pictures of actual criminals in New Jersey were made for this demonstration.

On August 25th, John A. Byers escaped from the Middlesex County workhouse. It happened that Byers was one of the four criminals whose pictures had been taken. Before it was possible to complete arrangements to use the picture to assist in capturing him an extraordinary thing happened.

On September 5th, Byers telephoned to a friend from a pay-station in Asbury Park. County Detective Drosdick, a former state trooper, who had never actually seen Byers but had seen the motion picture of him once, received the information and decided to drive to Asbury Park to look for him. On the way, 35 miles from Asbury Park, he passed a man who had a definitely familiar appearance; he turned around, looked again, and arrested John A. Byers. The only thing that he had to rely upon was his memory of the sound motion picture he had seen of Byers. He certainly did not expect to find him 35 miles from Asbury Park, but the impression left by the motion picture was so complete that, from a passing automobile, he made an identification and picked up the man he was looking for.

(*Following the paper, sound motion pictures of male and female actor-criminals going through the required technic were shown.*)

DISCUSSION

MR. RICHARDSON: I wonder whether, when the criminal realizes what is going on, he will act very naturally.

MR. FRANK: I think so. There is some feeling on the part of law enforcement officers that so many persons want to get into the movies that they will commit crimes just to have their pictures taken. Furthermore, law enforcement officers tell me that they have pretty good control of the criminals, and that taking the pictures at different times, as suggested, will doubtless overcome the difficulty.

MR. ELLIS: Is monitoring necessary? If so, I suppose a second person would be required for handling the equipment.

MR. FRANK: No; we do not require monitoring.

MR. PRESGRAVE: Why is a double system necessary?

MR. FRANK: The only reason why the double system has been used is that we did not have a single system available employing a ground-noise reduction system. Because of the high quality of speech required, that is the only system that has been used.

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SPRING, 1937, CONVENTION

SOCIETY OF MOTION PICTURE ENGINEERS

HOLLYWOOD-ROOSEVELT HOTEL

HOLLYWOOD, CALIF.

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Headquarters

Headquarters of the Convention will be the Hollywood-Roosevelt Hotel, where excellent accommodations are assured. A reception suite will be provided for the Ladies' Committee, and an excellent program of entertainment will be arranged for the ladies who attend the Convention.

Special hotel rates, guaranteed to SMPE delegates, European plan, will be as follows:

One person, room and bath	\$3.50
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	6.00
Parlor suite and bath, 1 person	9.00
Parlor suite and bath, 2 persons	12.00

Room reservation cards will be mailed to the membership of the Society in the near future, and everyone who plans to attend the Convention should return his card to the Hotel promptly in order to be assured of satisfactory accommodations. Special garage rates will be provided for SMPE delegates who motor to the Convention.

Railroad Fares

The dates of the Convention have been chosen in order that delegates may avail themselves of the summer tourists' rates, which go into effect May 15th. The following table lists the railroad fares and Pullman charges:

City	Railroad Fare (round trip)	Pullman (one way)
Washington	$120.75	$20.50
Chicago	86.00	15.75
Boston	132.80	22.25
Detroit	98.30	18.00
New York	126.90	21.75
Rochester	112.50	19.25
Cleveland	101.35	18.00
Philadelphia	122.85	21.00
Pittsburgh	107.10	18.75

The railroad fares given above are for round trips, forty-five day limits. Arrangements may be made with the railroads to take different routes going and coming, if so desired, but once the choice is made it must be adhered to, as changes in the itinerary may be effected only with considerable difficulty and formality. Delegates should consult their local passenger agents as to schedules, rates, and stop-over privileges.

New streamlined trains will be operating from Chicago to Los Angeles and San Francisco, making the trip to Los Angeles in 39 hours. Special fares are levied on these trains.

Technical Sessions

An attractive program of technical papers and presentations is being arranged by the Papers Committee. 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.

Semi-Annual Banquet

The Semi-Annual Banquet of the Society will be held at the Hotel on Wednesday, May 26th. 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.

Inspection Tours and Diversions

Arrangements are under way to visit one or more of the prominent Hollywood studios, and passes will be available to registered members to several Hollywood motion picture theaters. Arrangements may be made for golfing and for special trips to points of interest in and about Hollywood.

Ladies' Program

An especially attractive program for the ladies attending the Convention is being arranged by Mrs. K. F. Morgan and Mrs. P. Mole, *hostesses*, and their Ladies' Committee. A suite will be provided in the Hotel, where the ladies will register and meet for the various events upon their program. Further details will be published in a succeeding issue of the JOURNAL.

Points of Interest

En route: Boulder Dam, Las Vegas, Nevada; and the various National Parks.

Hollywood and vicinity: Beautiful Catalina Island; Zeiss Planetarium; 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 SMPE motion picture exhibit); Mexican village and street, Los Angeles.

TENTATIVE PROGRAM

Monday, May 24th

10:00 a.m.	*Blossom Room* Registration Society Business Committee Reports Technical Papers Program
12:30 p.m.	*Florentine Room* Informal Get-Together Luncheon for members, their families, and guests. Brief addresses by several prominent members of the industry.
2:00 p.m.	*Blossom Room* Technical Papers Program.
8:00 p.m.	(To be announced later.)

Tuesday, May 25th

10:00 a.m.	*Blossom Room* Technical Papers Program
2:00 p.m.	(To be announced later.)
8:00 p.m.	*Blossom Room* Technical Papers Program

Wednesday, May 26th

10:00 a.m.	*Blossom Room* Technical Papers Program
2:00 p.m.	(To be announced later.)
8:00 p.m.	*Blossom Room* Semi-Annual Banquet and Dance of the SMPE; Addresses by eminent members of the industry; dancing and entertainment.

Thursday, May 27th

10:00 a.m.	Open morning
2:00 p.m.	*Blossom Room* Technical Papers Program
8:00 p.m.	*Blossom Room* Technical Papers Program

Friday, May 28th

10:00 a.m.	*Blossom Room* Technical Papers Program
2:00 p.m.	*Blossom Room* Technical Papers Program Open Forum Adjournment of the Convention

NOTE: All technical sessions will be held in the *Blossom Room* of the Hollywood-Roosevelt Hotel. There will be no public exhibit of apparatus anywhere in the Hotel; although members registered in the Hotel will, of course, be privileged to display any equipment they wish in their own rooms.

SOCIETY ANNOUNCEMENTS

BOARD OF GOVERNORS

Further plans for the approaching Hollywood Convention in May were formulated by the Board of Governors at a meeting held in the Hotel Pennsylvania, New York, N. Y., on January 7th. In addition, the budget for 1937 and various other administrative matters were completed. The Financial Vice-President reported favorable performance during the past year, and that the membership of the Society had attained a new all-time high, the total paid membership at the end of the year numbering 1230.

The new West-Coast Office of the Society, located in Suite 226 of the Equitable Building, Hollywood, has begun to function, under the charge of Mr. Walter Greene, and a European Advisory Committee has been established under the Chairmanship of Mr. J. Van Breukelen, of Eindhoven, Holland. The other members of the European Committee are: F. H. Hotchkiss, of Paris; H. Warncke, of Berlin; and I. D. Wratten, of London.

As a result of the recent election, the Officers and Managers of the West-Coast Section for the year 1937 are as follows:

Chairman: K. F. Morgan
Past-Chairman: G. F. Rackett
Sec.-Treas.: G. A. Chambers
Governors: J. O. Aalberg
H. W. Moyse

In the recent elections for officers of the national Society for 1937, Mr. H. G. Tasker, who automatically retained membership upon the Board of Governors in the capacity of Past-President, was elected Executive Vice-President of the national Society. In view of the fact that he would be holding two offices concurrently, Mr. Tasker submitted to the Board his resignation as Executive Vice-President. By unanimous vote Mr. G. F. Rackett was elected by the Board to serve as Executive Vice-President for 1937.

The complete list of Officers and Members of the Board of Governors of the Society will be found upon the reverse of the contents page of this and subsequent issues of the Journal, and the personnel of the Boards of Managers of the Local Sections following the list of technical committees, also in each issue.

ADMISSIONS COMMITTEE

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

ABBOTT, L. R.
2323 N. Kostner Ave.
Chicago, Ill.

ANDERSON, J. C.
6114 Stanton Ave.
Pittsburgh, Pa.

BANG, P.
Kodak Aktieselskab
Vodroffsvej 26
Copenhagen V, Denmark

BINDER, O. C.
Universal Pictures Corp.
1250 Sixth Ave.
New York, N. Y.

BLACK, J. G.
3333 N. Marshfield Ave.
Chicago, Ill.

BRIGHTON, A. F.
913 E. Kilbourn Ave.
Milwaukee, Wis.

CHALLENNER, A.
3139 N. W. 14th St.
Oklahoma City, Okla.

CLARK, L. M.
187 Westminster Road
Rochester, N. Y.

DAY, G.
701 Franklin Ave.
Brooklyn, N. Y.

DEWEY, D. H.
300 Capitol Theater Bldg.
Des Moines, Iowa

FROSCH, M. E.
56 Glenwood Ave.
Minneapolis, Minn.

GALLAGHER, L. W.
7602 E. Lake Terrace
Chicago, Ill.

HILTON, R. G.
35–08 146th St.
Flushing, N. Y.

KEEP, N.
599 Eighth St.
San Francisco, Calif.

MARTIN, P., JR.
U. S. Soldiers Home
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PALMER, W. A.
369 Churchill Ave.
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SCHUYLER, J. B.
3925 N. Downer Ave.
Milwaukee, Wis.

SENNETT, P. T.
Tiffin Scenic Studios
Tiffin, Ohio

SHARP, T. C.
4379 Camellia
North Hollywood, Calif.

SHOLKIN, A. N.
RCA Communications, Inc.
66 Broad St.
New York, N. Y.

SKIMIN, G. J.
542 Neff Road
Grosse Pointe, Mich.

STIMSON, S.
2236 82d St.
Brooklyn, N. Y.

WETTER, R.
40 Piedmont St.
Boston, Mass.

WILLEY, L. E.
717 N. Ramage St.
West Hollywood, Calif.

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

ARNOLD, E. L. (*M*)
Eastman Kodak Co.
Kodak Park B/26
Rochester, N. Y.

BUB, G. L. (*M*)
Building 3
Second & Arsenal Sts.
St. Louis, Mo.

GOLDEN, N. D. (*M*)
Bureau of Foreign and
Domestic Commerce
U. S. Government
Washington, D. C.

GREEN, W. E. (*F*)
National Theater Supply Co.
92 Gold St.
New York, N. Y.

HARTMANN, G. (*M*)
7130 La Presa Drive
Hollywood, Calif.

OSWALD, C. L. (*M*)
433 W. 21st St.
New York, N. Y.

SHIMEK, J. A. (*M*)
American Film Corp.
6227 Broadway
Chicago, Ill.

TRIVELLI, A. P. H. (*M*)
Eastman Kodak Co.
Research Laboratories
Rochester, N. Y.

INTERNATIONAL EXHIBITION OF APPLIED AND SCIENTIFIC PHOTOGRAPHY

ROCHESTER, MARCH, 1937

An International Exhibition of Applied and Scientific Photography will be held at Rochester in March, 1937, under the sponsorship of the Rochester Scientific and Technical Section of the Photographic Society of America. The objective of the exhibition will be to show examples of the application of photography to the various branches of science and technology.

The following sections have been organized:

(*1*) Color photography: (*a*) processes in detail, (*b*) transparencies, (*c*) prints.
(*2*) Astronomy and metrology.
(*3*) Aerial photography.
(*4*) Photomicrography: (*a*) metallography, (*b*) other subjects.
(*5*) Medical photography: (*a*) prints, (*b*) radiographs, (*c*) motion pictures.
(*6*) X-Ray in industry.
(*7*) Documentary photography: (*a*) small-film library work, (*b*) instrument reading, (*c*) miscellaneous.
(*8*) High-speed photography.
(*9*) Stereo-photography: (*a*) prints, (*b*) transparencies, (*c*) motion pictures.
(*10*) Photography in physics and chemistry: (*a*) x-ray spectrography, (*b*) cosmic and other ray effects, (*c*) miscellaneous.
(*11*) Photographic sensitivity: (*a*) photographic effects, (*b*) light-sensitive substances.
(*12*) Natural history.
(*13*) Miscellaneous.

Photographs or apparatus showing the applications of photography to typical problems in any branch of science and technology will be welcomed. All correspondence in regard to the exhibition, or requests for entry blanks should be addressed to the Secretary, C. B. Neblette, F.R.P.S., Department of Photographic Technology, Rochester Athenaeum and Mechanics Institute, Rochester, N. Y.

COURSE IN PROJECTION PRACTICE

Members of the IATSE from various locals of Florida attended a short course in projection practice and sound theory at the University of Florida School of Adult Education at Camp Roosevelt, the week of December 14th, with more than forty registered projectionists in attendance.

The School of Adult Education, a new branch of the University of Florida, is conducting a broad program in training adults, utilizing the facilities of the base camp of the Atlantic-Gulf Ship Canal. Major B. C. Riley, dean of the General Extension Division, is in charge of the program. This short course for projectionists is the first of a series that the University School of Adult Education expects to conduct this year.

Prominent representatives from the leading motion picture sound and projection apparatus manufacturers attended, and conducted classes in the proper operation and maintenance of their products. Equipment displayed and demonstrated was of the latest design and incorporated many features yet not on the market. The manufacturers spared no expense in coöperating with University officials in making the venture a success.

It is believed that this is the first time that a study course of this type has been offered to IATSE projectionists. R. J. Gavin of local 511, Jacksonville, and George E. Raywood of local 316, Miami, assisted the University with arrangements.

SOCIETY SUPPLIES

The following are available from the General Office of the Society, at the prices noted. Orders should be accompanied by remittances.

Aims and Accomplishments.—An index of the *Transactions* from October, 1916, to December, 1929, containing summaries of all articles, and author and classified indexes. One dollar each.

Journal Index.—An index of the JOURNAL from January, 1930, to December, 1935, containing author and classified indexes. One dollar each.

SMPE Standards.—Reprints of *SMPE Standards and Recommended Practice.* Twenty-five cents each.

Membership Certificates.—Engrossed, for framing, containing member's name, grade of membership, and date of admission. One dollar each.

Lapel Buttons.—The insignia of the Society, gold filled, with safety screw back. One dollar each.

Journal Binders.—Black fabrikoid binders, lettered in gold, holding a year's issue of the JOURNAL. Two dollars each. Member's name and the volume number lettered in gold upon the backbone at an additional charge of fifty cents each.

Test-Reels.—See advertisement on following page.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

Volume XXVIII **MARCH, 1937** **Number 3**

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JOURNAL
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MOTION PICTURE ENGINEERS

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See p. 323 for Technical Committees

THE INFLUENCE OF SPROCKET HOLES UPON THE DEVELOPMENT OF ADJACENT SOUND-TRACK AREAS*

J. G. FRAYNE AND V. PAGLIARULO**

Summary.—*An unmodulated sound-track shows 96-cycle modulation on development. The effect is a maximum at the edge of the sprocket holes and diminishes exponentially for a distance of approximately 30 mils into the sound-track. A film modulated by a constant frequency shows 96-cycle amplitude and frequency modulation over the same area. Both effects are introduced principally during processing of the film. A film having no sprocket holes on the sound-track side is entirely free of these effects. The conclusion is that processing standards in many laboratories require improvement to eliminate distortions of this type.*

It has been generally understood for at least the past three years that uneven development of motion picture film occurs in the neighborhood of the sprocket holes, the effect being usually referred to as sprocket-hole modulation.[1] While the modulation has usually been considered as of the amplitude type, studies of flutter in film-pulling mechanisms has led to the belief that frequency modulation was also induced in the neighborhood of the sprocket holes. This was first noticed when the flutter or frequency modulation induced by sprocket teeth in a film recorder appeared to vary with the laboratory chosen to develop the negative film, and also varied from day to day in any particular laboratory. Also any change of location of the scanned image appeared to result in a change in the amount of flutter present in the record.

In order to investigate the nature of these development irregularities, a series of exposures, both unmodulated and modulated with a frequency of 3000 cps., were made on a single roll of variable-density sound-track negative film. The recording machine used for this work was specially selected because of its freedom from the 96-cycle modulation commonly called flutter. The recorded film was then broken down, and a strip containing both unmodulated and 3000-

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* Received October 14, 1936; presented at the Fall, 1936, Meeting at Rochester, N. Y.

** Electrical Research Products, Inc., Hollywood, Calif.

cycle exposures was sent to each of six different laboratories. The negatives were developed, and prints were made and developed in routine manner.

ANALYSIS OF UNMODULATED TRACK

The unmodulated strips, negatives, and prints were scanned on a recording microphotometer furnished through the courtesy of Mr. Douglas Shearer of the MGM Sound Department. The important parts of the apparatus are shown in Fig. 1, and consist of a sound

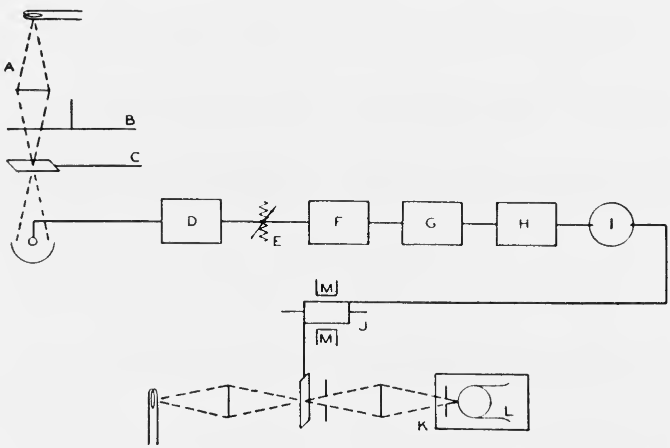


Fig. 1. Schematic arrangement of microphotometer:

(*A*)	Reproducer head	(*G*)	Band-pass filter
(*B*)	Tone wheel	(*H*)	Rectifier
(*C*)	Moving platform	(*I*)	Milliameter
(*D*)	P.E.C. amplifier	(*J*)	Shutter
(*E*)	Potentiometer	(*K*)	Recording machine
(*F*)	Amplifier	(*L*)	Film

reproducing head, the light-beam of which is interrupted by a tone wheel at the rate of 400 times per second; a moving platform upon which the film to be scanned is placed; a photoelectric cell and associated amplifier, to receive the light impulses and change them into electrical impulses the intensities of which are controlled by a potentiometer; an amplifier; a band-pass filter; and a low-impedance full-wave rectifier. The output of the rectifier is impressed upon a d-c. voltmeter mechanism of very low natural period, which moves a shutter located in the optical path of a special film-recording machine.

The movement of the shutter is proportional to the change of transmission of the sample of film being scanned. The speeds of the scanning platform and the film in the recording machine upon which the record is made may be changed to obtain any amplification ratio desired. In the present case a magnification of about 1:3 was used. It was found that sprocket-hole modulation was evident in every negative and print, although the magnitude of the effect varied consider-

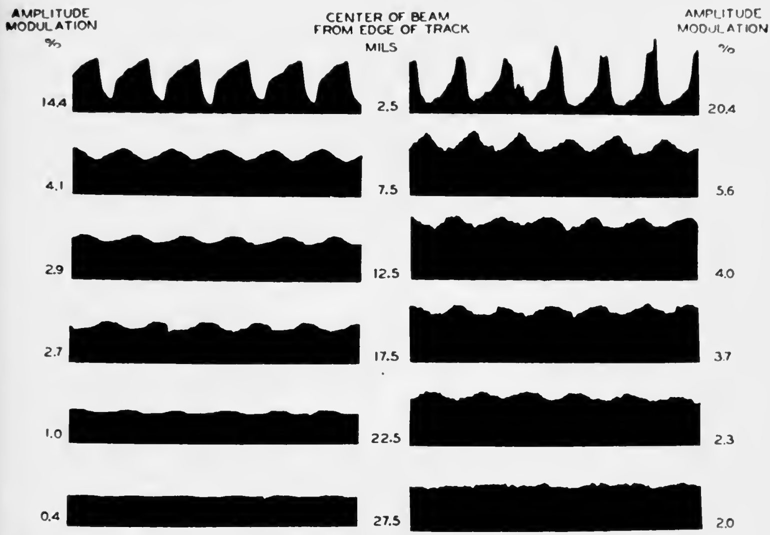


FIG. 2. (*Left*) Typical amplitude modulation induced by sprocket holes in sound negative.
FIG. 3. (*Right*) Typical amplitude modulation induced by sprocket holes in sound print.

ably with the laboratory. The results shown in Figs. 2 and 3 are typical of sprocket-hole amplitude modulation found in all six laboratories, the former showing the effect upon a negative and the latter upon a print made from the negative, processed at the same laboratory. Reference to these sketches will show that the sound-track area was scanned in 5-mil widths beginning at the edge of the sound-track, the height of the scanning beam being adjusted to 5 mils so as to provide sufficient output for satisfactory operation of the microphotometer. In every case the height of the dark portion of the graph is proportional to the transmission of the sample. Fig. 2 indicates that the modulation induced by the presence of the sprocket holes diminished from 14.4 per cent next to the holes to 0.4 per cent 27.5 mils from the holes.

In order to determine the position of maximum development in the region of the sprocket holes, a fine black line was drawn upon the developed samples between the sprocket holes. Fig. 4 shows the result of scanning these samples. The graph for the negative shows that the opacity at this point lies near the trough of the wave corresponding to the point of lowest transmission on the film. Conversely, the crest of the wave on the record lies between the vertical lines forming the boundaries of the sprocket-hole area. This shows

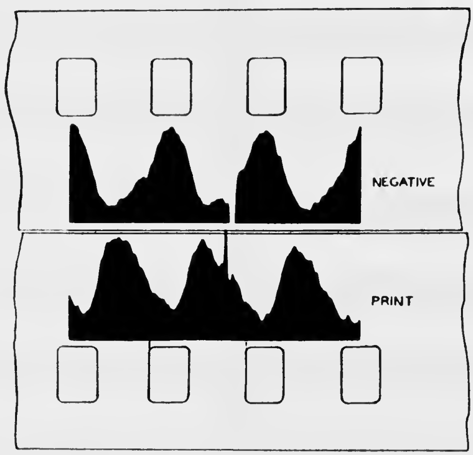


Fig. 4. Location of local development action around sprocket holes, for negative and print.

that the density of the sound-track area was below average in the region opposite the sprocket hole, and above average in the region opposite the area between successive sprocket holes. Fig. 4 also shows that the effect is reversed in the print. In this case the maximum transmission occurred in the area opposite the region between sprocket holes. Further experiments indicated that sprocket-hole modulation in the print must be largely attributed to modulation in the negative from which the print is made, rather than to that inherent in the development of the print. This may be accounted for by the low gamma of approximately 0.35 of the negative development in a film stock having a gamma infinity of over 2.0. In such stock, local developing action, due to sprocket-hole turbulation in the solution, may produce a silver deposit corresponding to what might be obtained in a more normal development at a much higher gamma. On the print, the gamma of 2.10 used is so near the gamma infinity value that the effects of excess local development become minimized.

The sprocket-hole modulation generally extended for 30 mils

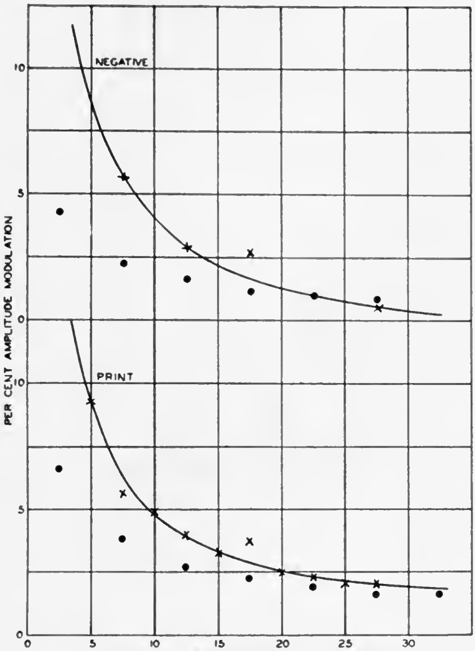


FIG. 5. Variation of per cent amplitude modulation with distance (in mils) from edge of sound-track near sprocket holes: (·) measured with microphotometer; (x) measured with modified flutter set.

into the sound area. The rate of decrease of the amplitude of the effect is shown for a laboratory, among those checked, in Fig. 5, the curves being of an exponential nature. The points indicated by circles were obtained from measurements made in a manner to be described later in this paper. The residual modulation indicated at a distance of 30 mils in from the sprocket holes might be attributed to the grain structure of the silver deposit, is generally higher in a print than in a negative, and is not typically 96 cycles.

ANALYSIS OF A 3000-CYCLE RECORDING

This analysis was made using a flutter-measuring equipment[2] modified so that amplitude as well as frequency modulation could be

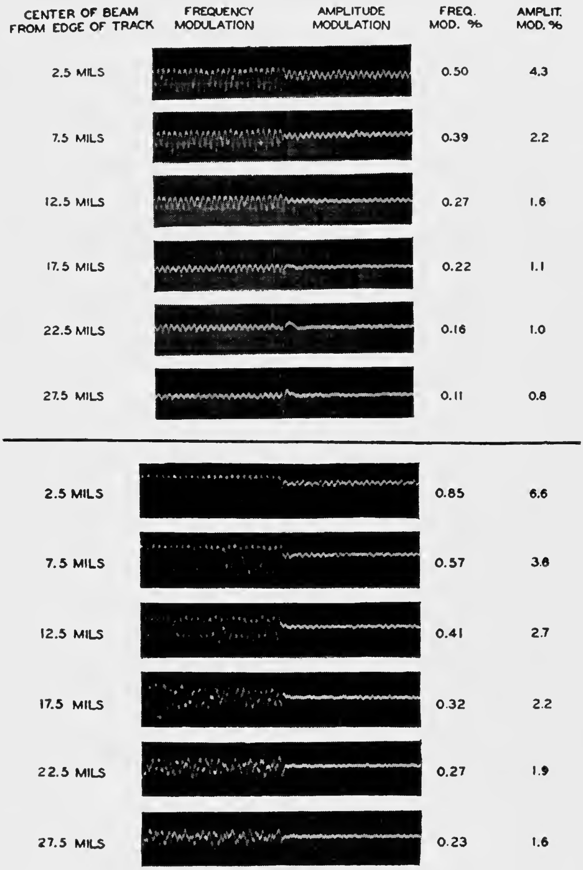


FIG. 6. (*Upper*) Oscillograms of frequency and amplitude modulation from negative with sprocket holes near sound-track. Film modulated 3000 cps.

FIG. 7. (*Lower*) Oscillograms of frequency and amplitude modulation from print with sprocket holes near sound-track. Film modulated 3000 cps.

measured. In this analysis the procedure followed was that used in making ordinary flutter measurements, except that the scanning beam, normally 80 mils wide, was made adjustable. The output of the flutter equipment, after suitable amplification, was impressed upon a string of the rapid-record oscillograph,[3] and records made as shown in Figs. 6 and 7. The left-hand portion of these records indicates frequency modulation, the right-hand portion indicating amplitude modulation of the same piece of sound-track. When the per cent of amplitude modulation is plotted as a function of the distance of the scanning beam from the sprocket-hole edge, the results shown by the dotted circles on the curves of Fig. 5 agree roughly

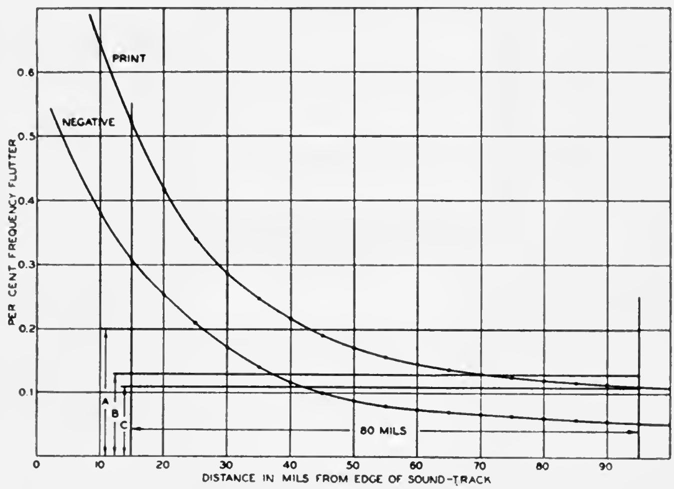
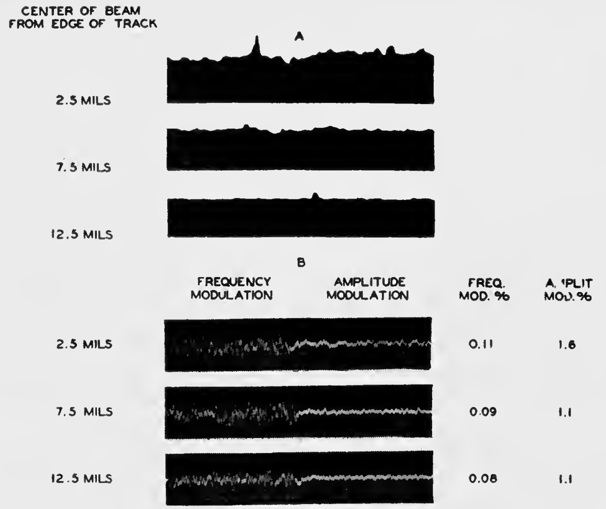


FIG. 8. Variation of per cent frequency flutter with distance (in mils) from edge of sound-track near sprocket holes.
(*A*) Measured and computed per cent frequency flutter for 80 mils scanning in print.
(*B*) Measured per cent frequency flutter for 80 mils scanning in negative.
(*C*) Computed per cent frequency flutter for 80 mils scanning in negative.

with the curves obtained from the microphotometer measurements. The discrepancies may be partially attributed to the fact that in some cases the film zone that was scanned may have differed by a few mils in the two methods followed.

Examination of the records in Figs. 6 and 7 shows that the frequency of both types of modulation is 96 cps., corresponding to the number of sprocket holes per second passing the scanning beam. It will be noted that as the scanning zone is moved away from the sprocket holes, the regular 96-cycle modulation is replaced by an



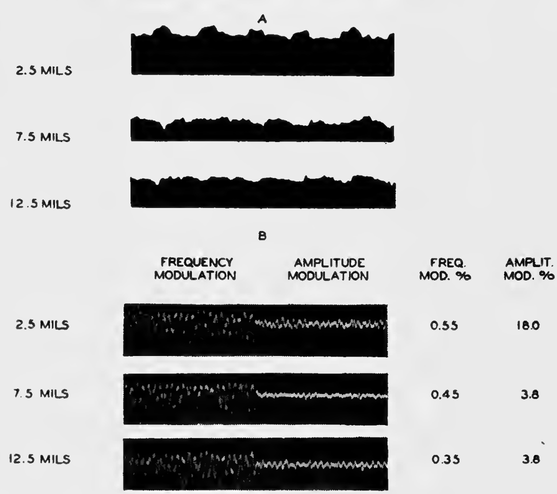


FIG. 9. (*Upper*) (*A*) Microphotometer record of transmission in unmodulated sound negative without sprocket holes near sound-track.

(*B*) Oscillograms of frequency and amplitude modulations from negative without sprocket holes near sound-track. Film modulated 3000 cps.

FIG. 10. (*Lower*) (*A*) Microphotometer record of transmission in unmodulated sound print with sprocket holes near sound-track made from negative without sprocket holes.

(*B*) Oscillograms of frequency and amplitude modulation from print with sprocket holes near sound-track made from negative without sprocket holes. Film modulated 3000 cps.

irregular one attributable without doubt to the random distribution of the silver grains in the film.

The curves of Fig. 8 show the relation between frequency modulation and the distance from the edge of sprocket holes of the center of the 5-mil scanning zone, for both the negative and the print made from it at another laboratory. Taking the negative first, it will be noted that the flutter varies from 0.54 per cent for the 5-mil zone

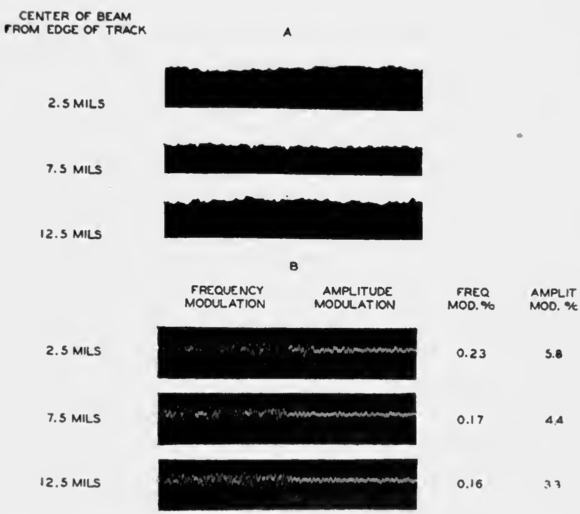


FIG. 11. (*A*) Microphotometer record of transmission in unmodulated sound print without sprocket holes near sound-track made from negative without sprocket holes.

(*B*) Oscillograms of frequency and amplitude modulation from print without sprocket holes near sound-track made from negative without sprocket holes. Film modulated 3000 cps.

adjacent to the sprocket holes, to 0.05 per cent when the zone is moved in 100 mils. Similarly the values for the print range from 0.9 to 0.1 per cent. The usual width of sound-track scanned in reproducing is approximately 80 mils, and the center of this zone is 54 mils removed from the sprocket-hole edge. Accordingly, vertical lines were drawn upon the graph marking the boundaries of the usual scanning area, and the intercepted areas lying beneath the negative and the positive curves were measured with a planimeter. The areas were then divided by the 80-mil base line, and the resulting ordinates gave the average frequency modulation to be expected from these films. These values correspond very closely to the measured values obtained, respectively, for the negative and positive, and are shown upon the graph.

This illustrates very clearly that when frequency modulation or flutter is measured in the standard manner, the magnitude of the quantity measured may be attributed in part to the development and in part to the recording or printing mechanism, as well as in part to random modulation. Thus, in the case under study, it is found that in the negative track at a distance of 100 mils from the sound-track edge, the flutter is reduced to a value of 0.05 per cent. Hence the recorder used in this test might be said to be essentially free of 96-cycle flutter, because if flutter had been introduced by the machine it would have extended the entire width of the track. In the case of the print, flutter is higher throughout the region studied, reaching an apparent residual value of 0.10 or 0.05 per cent higher than the negative. This indicates that but little 96-cycle flutter is introduced in printing, and the rise in residual flutter may be attributed to other causes.

35-MM. FILM WITH ONE SET OF PERFORATIONS

In order to determine more definitely the part played by the sprocket holes in producing the results analyzed above, the possibility was suggested of obtaining 35-mm. film having perforations along one side only. Accordingly the Eastman Kodak Company very generously supplied 1000 feet of both sound negative and positive emulsions so perforated. In order to make the tests the teeth on the sound-track side were removed from the sprockets of the recorder to accommodate the negative stock during recording; and in order to make a print from the negative, the teeth were ground off one side of the sprockets of a standard printer and prints were made on film having (*a*) one set of perforations, (*b*) having two sets of perforations.

The results obtained from the negative are shown in Fig. 9, both microphotometer and flutter set results being given. It will be noted that no 96-cycle frequency or amplitude modulation is in evidence. The results obtained from the prints are shown in Figs. 10 and 11, the top curves in Fig. 10 being microphotographs from the print having sprocket holes. These show some evidence of 96-cycle amplitude modulation. Incidentally, the same curves show how relatively unimportant this effect is in a print made from a negative from which the effect was absent. In the lower part of Fig. 10 are the oscillograms of flutter measurements made from the 3000-cycle modulated print. Here frequency modulation is very pronounced. In Fig. 11 are given the graphs of the print that had no sprocket holes near the sound-track, showing the total absence of both amplitude and frequency modulation. The fact that the print having sprocket holes, but made from a negative without sprocket holes adjacent to the sound-track area, shows decided evidence of frequency modulation but little of amplitude modulation, while the other print having no sprocket holes made from the same negatives shows the absence of both modulations, points to the possibility that frequency modulation induced by the development process may be attributed to differential shrinkage of the film in the areas between and opposite sprocket holes. We have for some time past had experimental evidence, in another connection, to indicate that frequency modulation, to the extent of 0.25 to 0.5 per cent, may be introduced by improperly drying negatives, and that properly hardening the film before drying very greatly reduces the hazard of distortion from this cause.

The cause of amplitude modulation may be directly attributed to the passage of the sprocket holes through the developing solution. This is verified by the fact that when film without sprocket holes is used the phenomenon disappears.

REFERENCES

[1] CRABTREE, J., AND WADDELL, J. H.: "Directional Effects in Sound-Film Processing—II," *J. Soc. Mot. Pict. Eng.*, **XXI** (Nov., 1933), No. 5, p. 351.

[2] SCOVILLE, R. R.: "A Portable Flutter-Measuring Instrument," *J. Soc. Mot. Pict. Eng.*, **XXV** (Nov., 1935), No. 5, p. 416.

[3] SHEA, T. E., CURTIS, A. M., AND RUMPEL, C. H.: "The Rapid-Record Oscillograph in Sound Picture Studies," *J. Soc. Mot. Pict. Eng.* **XVIII** (Jan., 1932), No. 1, p. 39.

MODERN THEATER LOUD SPEAKERS AND THEIR DEVELOPMENT*

C. FLANNAGAN,** R. WOLF,** AND W. C. JONES†

***Summary.**—Although many of the basic ideas involved in the operation of present-day loud speakers were conceived during the early stages of the development of the telephone, it was not until the advent of the vacuum tube amplifier that these principles were applied to the design of structures capable of delivering sufficient acoustical power to be audible throughout a room or auditorium. Having reached this stage, however, the developments that culminated in the sound reproducing systems employed with present-day sound pictures came in rapid succession. These developments have embraced all phases of loud speaker design, with the result that systems are now available that convert from 25 to 50 per cent of the electrical input into acoustical output, and maintain conversion efficiencies of this order of magnitude over a frequency range of 50 to 10,000 cps. These systems are so designed as to be capable of reproducing the recorded sound at intensities that not only greatly enhance the dramatic effect of the presentation in the theater, but also open entirely new fields in recording. All these improvements have been attained with a reduction in distortion and improved fidelity of the reproduced sound. The directional properties of the loud speakers also have been markedly improved, with the result that the better quality of reproduction achieved is available throughout the entire seating area and the undesirable beam effects previously experienced have been eliminated.*

Almost without exception the basic ideas underlying the operation of the loud speaker were conceived during the early stages of development of electrical transmission of speech. For example, the magnetic circuit used in the motor elements of many of the first commercial loud speakers was employed also by Bell in his demonstration models. In this circuit the polarizing field in the air-gaps between fixed pole-pieces and a movable magnetic diaphragm is modulated by the field set up by the voice currents. Although it possesses such desirable characteristics as simplicity and cheapness, this magnetic circuit is poorly adapted to loud speakers designed to deliver large amounts of acoustical power, owing to the fact that the diaphragm represents

* Received January 18, 1937; presented at the Fall, 1936, Meeting at Rochester, N. Y.

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

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

a compromise between the magnetic characteristics required at high efficiencies and the mechanical properties necessary for good response. Furthermore, a certain amount of distortion in the form of a double-frequency component is always present in the output. Although this is a relatively unimportant factor at low output intensities, it rapidly assumes a position of importance as the output level is increased.

Means for correcting these limitations were proposed at an early date. As early as 1880 the suggestion was made that the performance of the telephone receiver could be improved by the use of the balanced-armature type of magnetic circuit.[1] Other disclosures along this line were made in rapid succession, with the result that by 1890 structures such as that shown in Fig. 1, were proposed embodying practically all the basic features of the balanced-armature type of magnetic circuit which has found such extensive use in loud speakers.[2] In addition to being inherently more efficient than the simple form of magnetic circuit previously discussed, this circuit possesses also the desirable characteristics of materially reducing the double-frequency component in the output and enabling the designer to achieve high magnetic efficiency without adding unduly to the effective mass of the moving element. The output at low frequencies, however, is limited by the non-linear distortion that occurs with large displacements of the armature and the noise introduced if the armature strikes the pole faces. The stiffness required to assure stable mid-center adjustment of the armature in the air-gaps introduces sufficient reactance in most commercial structures of this type to place a definite limitation upon the low-frequency response. The problem of attaining good response at the higher frequencies is complicated by the fact that the electrical impedance has a large reactive component that often causes appreciable transition losses at these frequencies.

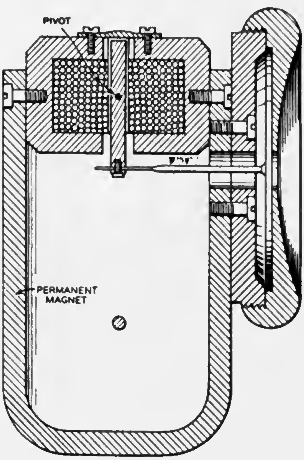


FIG. 1. Capps' balanced armature receiver structure.

As early as 1877 the suggestion was made that the static force on the diaphragm of the magnetic type of receiver could be eliminated and its performance improved by making the diaphragm of non-magnetic material and attaching to it a driving coil arranged to vibrate freely in a transverse magnetic field (Fig. 2).[3] In addition to covering the essential features of the moving-coil type of motor element, this suggestion also included a flared diaphragm having an edge of low stiffness. Obviously, this disclosure incorporated many of the structural features that have played an important role in modern loud speaker development, for in a well designed motor of the moving-coil type the useful driving force is substantially pro-

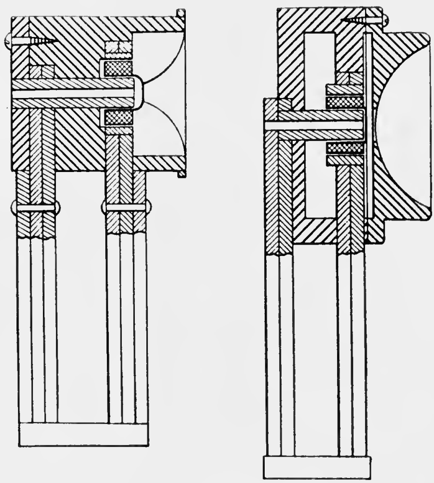


FIG. 2. Moving-coil receiver introduced in 1877.

portional to the voice current in the coil, even at large amplitudes, thus eliminating the double-frequency distortion inherent in the magnetic type and making possible the high acoustic outputs required of present-day loud speakers without magnetic overloading and distortion. Furthermore, the elimination of the steady force developed by the polarizing field, and the associated problems of stable air-gap adjustment, make it possible to reduce materially the stiffness reactance of diaphragm structure, and hence to effect a marked improvement in the response at low frequencies. In addition, the electrical impedance varies substantially less over the frequency range of interest than it does in the case of the moving-armature type of motor element.

The problem of transmitting the vibrational energy of a solid body, such as a diaphragm, to air is an old one, and in many respects a difficult one. It is of interest that the early efforts to solve this problem involved the same basic means as are employed today. A direct radiator of large area was made by Gray as early as 1877,

FIG. 3. Direct radiator, invented by Gray.

Fig. 3.[4] Conical and flared horns were employed in the first telephone instruments (Fig. 4).[5] No doubt some of the early horns had rates of taper that aided in the transfer of the mechanical energy of the diaphragm to the surrounding air. However, horns designed to incorporate an exponential rate of taper appear to be of more recent origin.[6] Exponential horns have been investigated theoretically and experimentally by Webster and others.[7]

Although the instruments described in the preceding paragraphs incorporated many of the basic features of present-day loud speaking telephones, no source of electrical power large enough to enable them to develop sufficient sound to fill a room or auditorium was available. Attempts were made to solve this problem with mechanical amplifiers, but it was not until the development of the vacuum tube amplifier that these principles were applied extensively to uses other than telephone receivers, in which case it was necessary to develop only enough sound to be audible in the space enclosed between the diaphragm and the ear. With the advent of vacuum tube power amplifiers, the field of application of the loud speaker was rapidly extended. Typical examples of this advance are the equipment that was installed along the Victory Way in 1918, at the presidential conventions of the two major political parties in 1920, at the inauguration of President Harding in 1921, and at Arlington on Armistice Day of the same year.[8] The motor elements of the loud speakers during this period were for the most part of the balanced-armature type. Several different types of horns were employed. Included among these were straight horns having an exponential taper. In certain cases the horns were folded to conserve space.

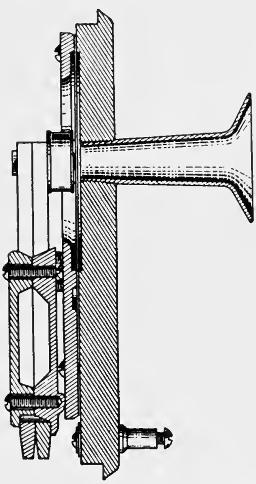


FIG. 4. Early telephone employing flared horn.

With this background of experience in loud speaker design and application to draw upon, the developments that made possible the high-grade acoustical reproduction that accompanied the first showing of sound pictures at the Warner Theater in New York in August, 1926, came in rapid succession. It is with these and subsequent developments in theater loud speakers that this paper is primarily concerned.

The advances that have been made in the performance of present-day loud speakers have been principally along five lines, namely:

(*1*) The increase in the efficiency of the loud speaker as an electroäcoustical transducer, which has resulted not only in outstanding reductions in the power losses of the loud speaker itself, but also has materially reduced the amplifier capacity required for a given sound intensity in the theater.

(*2*) The increase in power-carrying capacity, which has made possible loudness ranges that were hitherto impracticable and which not only enhanced the dramatic possibilities of sound reproduction in theaters but opened new opportunities for improvement in recording.

(3) The extension of the frequency range, both at the high and low ends, which has resulted in outstanding improvements in the quality and naturalness of reproduction.

(4) The substantial reduction in non-linear distortion, which has materially increased the fidelity of the reproduced sound.

(5) The improvements in the directive properties of loud speaker units, which have aided greatly in attaining uniform results throughout the theater.

In discussing these advances it is convenient to divide the loud speakers into two classes; namely, those in which the entire frequency range is transmitted by one unit, and those in which the electrical output from the amplifier is distributed between two or more units by means of dividing networks.

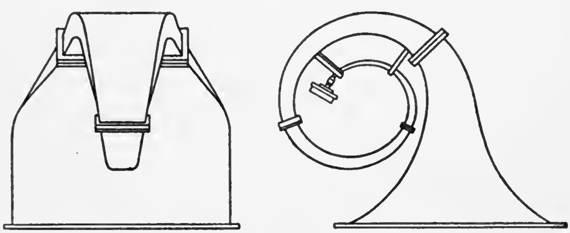


FIG. 5. Exponential horn equipped with moving-coil receiver.

Single-Unit Loud Speakers.—The loud speakers employed in the first showing of sound pictures at the Warner Theater are typical examples of the single-unit type. In this installation it was possible to obtain for the first time efficiencies as high as 25 per cent over a wide frequency range, and to operate at much higher output levels than had previously been feasible. It was also possible to attain this increase of efficiency and higher output level with a substantial reduction in non-linear distortion.

The loud speakers employed in this installation were of the horn type, and consisted of a moving-coil receiver unit and an exponential horn so designed as to conserve the space behind the motion picture screen (Fig. 5). Multiple throats permitting the use of either two or four units on one horn were also provided. The important structural features of the receiver unit are shown in Fig. 6. Although the unit has been described in detail in an earlier publication[9] several of the more important structural features will be reviewed here inasmuch as they represent advances in loud speaker construction typical of the recent trends in design.

It is convenient for purposes of analysis to look upon the loud speaker as an electroäcoustical transducer drawing power from an electrical circuit and delivering it to an acoustical load. The electrical and acoustical terminal conditions are therefore fixed within

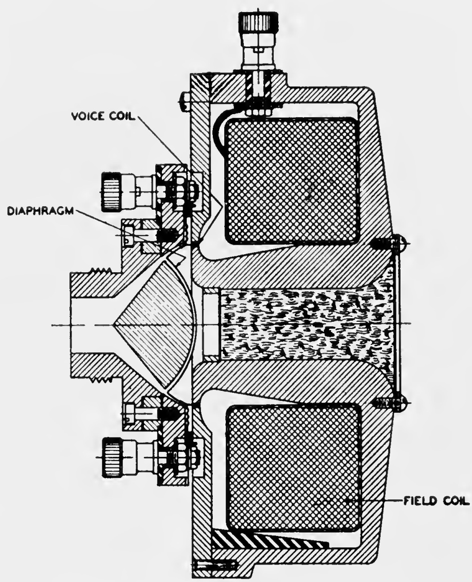


FIG. 6. Sectional diagram showing the diaphragm, air chamber, and throat construction of the *555* type receiver.

rather narrow limits by the electrical impedance of the associated amplifier and the acoustical impedance of the space in which the loud speaker is to operate. Achieving high conversion efficiency over a wide frequency range is therefore primarily a matter of designing the component parts of the structure so as to minimize internal losses within this range and, so far as possible, to eliminate transition losses due to impedance unbalances. Many of the problems involved in obtaining an efficient flow of power from an electrical source to an acoustical load have been discussed in previous publications,[10] and hence need not be taken up in detail here. However, high magnetic efficiency, low effective vibrating mass and stiffness, and efficient radiation play such important parts in accomplishing this result, that the means by which this objective was attained in the moving-coil unit and horn previously mentioned will be discussed briefly. Owing to the limitations imposed by available magnetic materials, the permissible size and weight of the magnetic structure, cost, *etc.*, the principal problem involved in loud speaker design usually is that

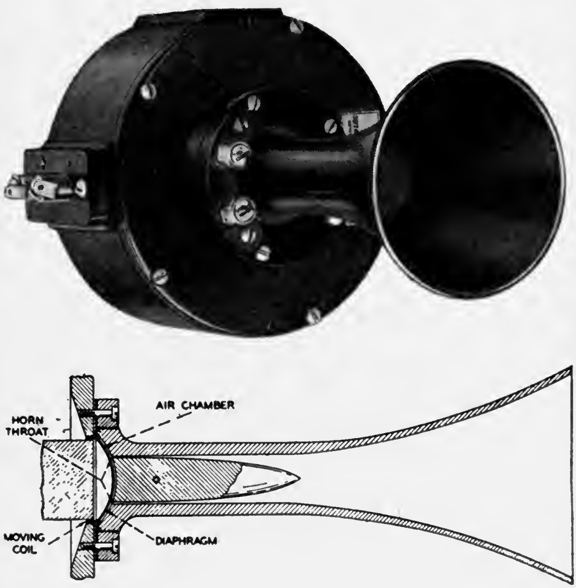


FIG. 7. High-frequency loud speaker used in 3-way system; including sectional diagram showing the diaphragm, air chamber, and horn construction.

of approaching the ideal as closely as these limitations will permit. The design of the magnetic structure of the loud speaker in question is, however, not only such that it meets the requirements imposed by commercial production, but provides a high force-factor, which contributes materially to the high overall efficiency that has been attained.

In structures of the horn type it is usually necessary to couple the diaphragm to the throat of the horn by means of an air chamber, in order to avoid large transition losses. Most loud speakers having the conventional form of coupling chamber fail to reproduce the higher frequencies at the same intensity as the lower ones, due to the fact that changes in pressure developed at different points on the surface of the diaphragm do not reach the throat of the horn in proper phase. This effect has been reduced in the design in question by adopting an annular throat opening so located between the center and the periphery of the diaphragm that disturbances originat-

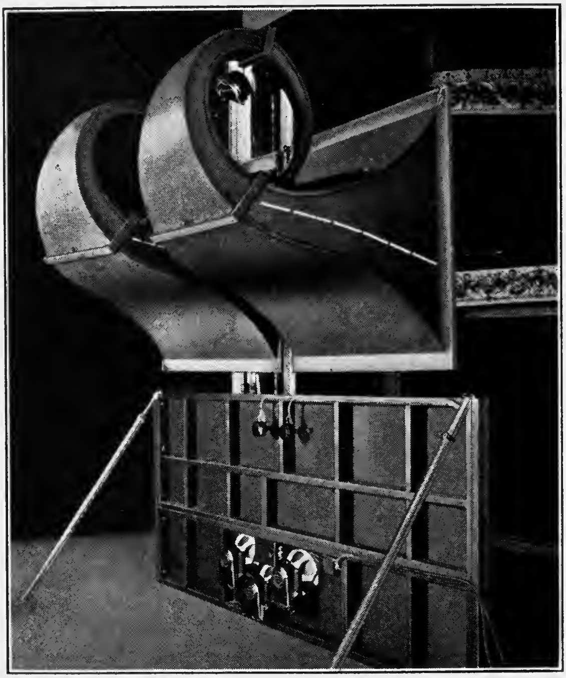


FIG. 8. Typical 3-way loud speaker installation.

ing at the inner and outer portions arrive approximately in phase even up to comparatively high frequencies. With this type of construction it is possible to use a fairly large diaphragm and deliver large amounts of power without an appreciable sacrifice in efficiency either at the high or the low frequencies.

By using thin duralumin sheet and forming it into two reëntrant spherical surfaces, it was possible to produce a diaphragm not only of low effective mass but one that when driven at a point near its edge, vibrated substantially as a piston over a wider frequency range than was previously possible. Both these features reacted upon the response at the higher frequencies and aided materially in improving the efficiency of conversion at these frequencies.

The driving coil was made of aluminum ribbon wound on edge

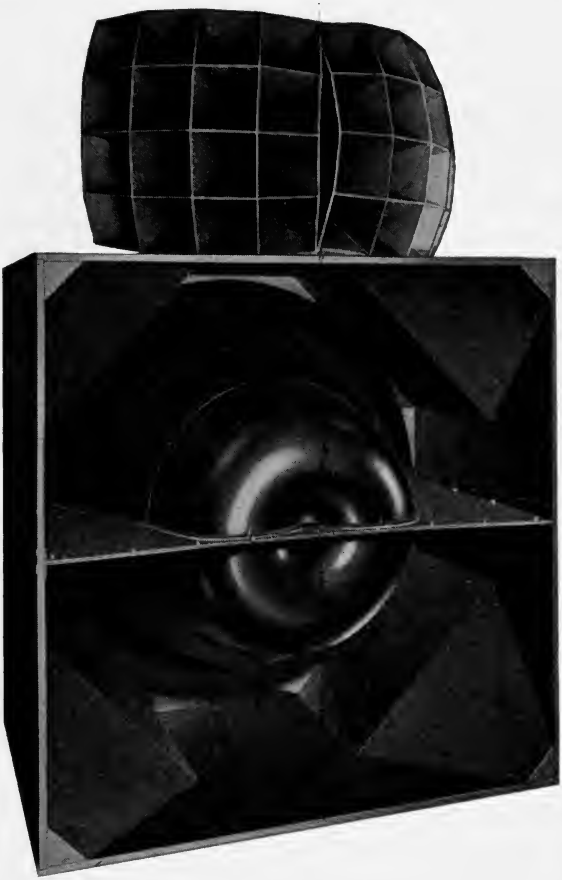


FIG. 9. Experimental 2-way horn system.

and held together with a thin layer of varnish which served also as insulation between the turns. This form of construction provided a compact coil having a high ratio of active conductor to total space occupied in the air-gap, and permitted operation at higher temperatures than had previously been tolerable. Moreover, it aided materially in obtaining high magnetic coupling, and, because of its small mass, was a contributing factor in improving the efficiency of the structure at the higher frequencies.

As was pointed out in the discussion of various types of motor elements, one of the outstanding advantages of the moving-coil type is the low stiffness obtainable. Two features of this receiver unit aided in attaining this result: namely, a low-stiffness diaphragm edge and a hollow center pole-piece which reduced the stiffness of the cavity between the center pole-piece and the diaphragm. Tube resonance in the pole-piece was prevented by a filling of sound absorbing material.

In addition to having a well designed motor element, it is essential that the radiator be an efficient one. In other words, it should be so designed as to represent a constant load on the diaphragm throughout the frequency range it is desired to transmit. The impedances of horns approach constant resistance as the frequency rises, but this condition is attained most rapidly when the cross-sectional area varies exponentially with distance along the axis. A unique feature of such a horn is that its transmission range is inherently limited at the low-frequency end. An infinite horn of this type would suppress the frequencies below this limiting value and transmit freely the frequencies above. The closeness with which a finite horn approximates these characteristics depends upon the efficiency with which the mouth radiates energy to the surrounding air. The mouth of the horn should, therefore, be of such dimensions that it will radiate freely waves of the lowest frequency in the desired range, and the conduit portion should be capable of freely transmitting all frequencies that the mouth will radiate. It is this property of the rate of taper, that all frequencies in the range of efficient radiation of the mouth opening are freely transmitted, that differentiates the horns of recent design from the earlier types mentioned in the first part of this paper.[10]

A large number of these single-unit loud speakers have been installed in theaters since their initial introduction in 1926 and have given excellent service. Many of these instruments have never been replaced by units of later design and are still in daily use.

Multiple-Unit Loud Speakers.—While it has proved feasible as a result of careful design to extend markedly the frequency and volume ranges of the loud speakers of the single-unit type, the fact that the entire frequency range must be covered by one unit imposes important design limitations. In general, a diaphragm designed for efficient radiation of low frequencies has too high a mass to be best suited for use at high frequencies. In addition, the problem of radiation at the high frequencies is further complicated by the tendency of a diaphragm large enough to meet the low-frequency requirements to change its mode of vibration and no longer act as a piston as the frequency is increased. Furthermore, a diaphragm designed to radiate the high frequencies efficiently is not best suited mechanically to develop the large amounts of acoustical power required at the lower frequencies without serious distortion and possible mechanical failure.

Considerations such as these led first to the development of a moving-coil loud speaker of the horn type having vibrational characteristics permitting efficient radiation at the higher audible frequencies.[11] A model of this speaker is shown in Fig. 7, with a sectional sketch showing the internal construction. The diaphragm was made of duralumin drawn into a hemispherical dome at the center. A voice-coil of aluminum ribbon was attached at the edge of the dome portion. The horn was tapered exponentially and terminated in an annular throat, to minimize high-frequency interference in the cavity in the front of the diaphragm. The mechanical and acoustical constants of the various portions of the structure were so chosen as to result in efficient radiation at frequencies as high as 12,000 cps. with substantially uniform response at all frequencies between 3000 and 12,000 cps. This speaker was used as an adjunct to speakers of the single-unit type, and resulted both in a substantial increase in the frequency range and in a marked improvement in the distribution of the high-frequency sounds.

Three-Way System.—The design of loud speakers especially suitable to radiate the low frequencies was next undertaken with such success that three-band systems became especially attractive and eventually led to the commercialization by Electrical Research Products, Inc., of the wide-range system.[12] In this system the output from the amplifier is distributed between three loud speakers by means of dividing networks. The first unit covers the range up to 300 cps., the second from 300 to 3000, and the third from 3000 cps. up (Fig. 8).

In this system the horn-type moving-coil loud speaker described in connection with the single-unit system was retained as the mid-range unit. This not only made it possible to increase materially the maximum output level of this unit without adding to the distortion, but also had the practical advantage that it made the maximum use of existing equipment when extending the range of a system already in operation. The high-frequency unit was the one described above, and was used both singly and in multiple for increasing the power and the capacity.

The low-frequency unit originally consisted of a short horn having an exponential taper and three dynamic loud speakers having conically shaped paper diaphragms. It was found, however, that better response at the lowest frequencies could be attained by using a large, flat baffle. This baffle was of rigid construction, and was so braced that the resonance frequencies of the various areas were not alike. This construction proved to have a decided advantage in that the low frequencies were reproduced with noticeably less distortion.

It was found by experience that the positioning of the units, particularly the high-frequency units, had an important reaction upon the quality obtained with the system. In setting up such a system it was necessary to adjust the position of the high-frequency unit until a location giving the most pleasing quality was found.[12] This process is often referred to as "phasing," and when properly carried out resulted in a marked reduction in distortion, especially in connection with the reproduction of sounds of the impact type.

It has been stated that poor directional characteristics[13] constitute one of the principal limitations of the present theater installations. A solution of this problem was found during the development of the loud speakers used in connection with the reproduction of speech and music in auditory perspective. One of these loud speakers is shown in Fig. 9, and consists of a large-diaphragm moving-coil unit with a folded horn for reproducing the frequencies up to approximately 300 cps., and a multi-throat moving-coil unit with a cellular type of horn for reproducing the frequencies above 300 cps.[13] The first public demonstration of a system employing these loud speakers was given in April, 1933, when the music of the Philadelphia Orchestra, playing in the Academy of Music, Philadelphia, was reproduced stereophonically in Constitution Hall, Washington, D. C.

It is a well known fact that the sound from the conventional type of tapered horn is projected through a relatively large area at the lower frequencies, but that as the frequency is increased the distribution becomes less and less uniform until at the frequencies where the wavelength is small as compared with the mouth opening, the output of the horn is concentrated in a narrow beam along the axis. Concentration of the high frequencies in theater reproduction results in a situation in which if a proper balance between high and low frequencies is attained on the axis of the horn, the sound in the regions to either side tends to be deficient in high frequencies and is characterized as "boomy." Conversely, if the high and low frequencies are balanced at a location off the beam, an excess of high frequencies on the axis of the horn results. Obviously, this situation would be much improved if the radiation from the horn were not spherical but were confined to a solid angle such that the undesirable

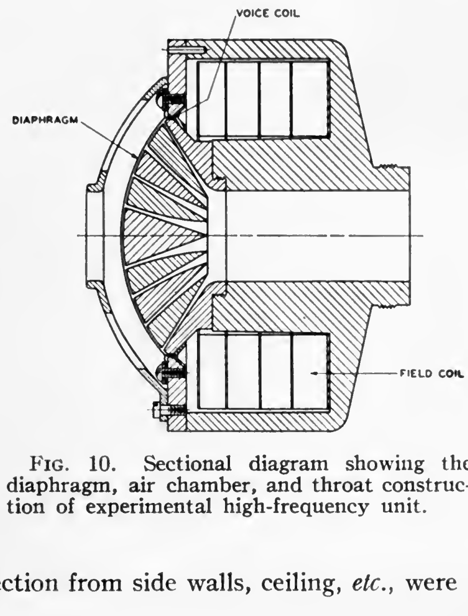


FIG. 10. Sectional diagram showing the diaphragm, air chamber, and throat construction of experimental high-frequency unit.

effects of reflection from side walls, ceiling, *etc.*, were kept to a minimum.

This was accomplished in the auditory perspective system by adopting a multi-cellular type of horn composed of a number of separate channels, each having substantially an exponential rate of taper. The narrow ends of the channels were brought together with their axes parallel and were terminated in a single tube which, in turn, was connected to the receiver unit. Sound from the unit travels down this tube and divides among the channels. For frequencies of which the wavelengths are large compared with the mouth opening, a substantially spherical wave results. As the frequency is increased the sound tends to concentrate more and more upon the axis of each channel. This is permissible, provided the construction of the horn is such that the sound coming from the individual channels is normal to a spherical wave-front.

The receiver unit employed with the multi-cellular horn is shown in Fig. 10. As in the case of the motor elements of the single-unit loud speaker and the high-frequency unit of the three-way system previously described, this unit is of the moving-coil type, and has a formed diaphragm of thin duralumin and a voice-coil of aluminum

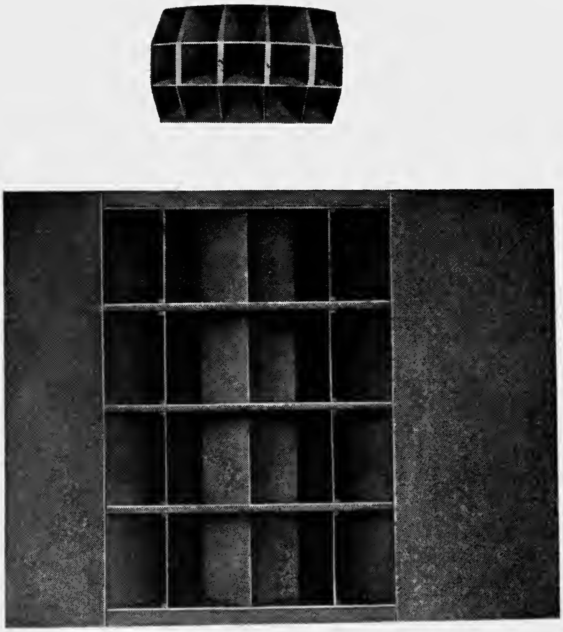


FIG. 11. Diphonic loud speaker system.

ribbon. The throat is also annular but three openings instead of one are provided in order to increase the frequency range.

Diphonic Loud Speaker.—While the wide range system represented a marked improvement from the standpoints of frequency and volume ranges, it was not fully adequate in several respects. The distribution of sound in the seating area was not materially improved, owing to the fact that the same mid-range loud speakers were employed. Furthermore, there was still sufficient distortion due to transients, frequency modulation, and nonlinear effects under certain conditions to be disturbing to the critical listener.

These deficiencies are partly, but by no means entirely due to the loud speakers. Therefore, improvement in the other parts of the sound system was necessary in order to effect a distinct advance in reproduced sound. Advances in the component parts have been made, and the combination of equipment embodying these advances is now know as the Mirrophonic System. The loud speaker of this system has been termed "Diphonic," and is shown in Fig. 11.

The Diphonic loud speaker is a two-way loud speaker in which the output from the amplifier is distributed between the two units by means of a dividing network that introduces approximately 12

FIG. 12. Multicellular horn equipped with two high-frequency units.

decibels of attenuation per octave above and below the cross-over point of 300 cps.

The high-frequency unit and horn are shown in Fig. 12. The receiver unit is a commercial form of the one used in the Philadelphia–Washington demonstration previously mentioned. The physical form of the multi-cellular horn has, however, been changed somewhat, without deviating from the basic design considerations mentioned above. The original horn was driven by one receiver; most of the commercial horns are driven by two units. This is accomplished by using a *Y*-type throat, and permits the use of the horn in theaters requiring more power than can be handled by one driving unit. For smaller theaters, requiring less power, a casting is provided that permits the use of a single unit. It will be noted that the space between the horn cells is open in the commercial unit but closed in the experimental unit. In the experimental unit the space between the horn cells was acoustically deadened by cotton waste packing, which represented about 30 per cent of the weight of the combined horn and unit. The commercial horn eliminated the waste packing by including the deadening medium in the material of the individual cell. These changes are the results of experimental data obtained in a long series of tests and have accomplished a simplification of the design, reduction in weight, and further improvement in the distribution characteristics of the horn. The high-frequency unit now employed in the Diphonic loud speaker gives a substantially uniform distribution of sound with respect to both volume and frequency over an angle of 90 degrees, and has been used satisfactorily over considerably wider angles. Where a critical listener could detect a certain amount of beam effect even in the best wide-range installation, this effect is practically unnoticeable in the Mirrophonic system, with the result that "boominess" is avoided and the intelligibility as well as the naturalness of dialog is greatly improved.

The low-frequency unit also shows marked improvement over the low-frequency speakers previously used commercially. As with the case of the high-frequency unit, this device is based upon extensive experimental data obtained in a variety of tests. Here the problem is one of maintaining minimum physical depth with high translation efficiency. To accomplish this it is desirable to utilize a large driving area. Consequently, a system employing four dynamic speakers of the cone type was adopted. Each of these cone units is about 16 inches in diameter and is coupled to the base of a shallow cavity surrounded by a rigid baffle. The parts forming the cavity and baffle are so rugged that spurious sound radiation due to mechanical vibration of the baffle is prevented. Conventional data were used to determine the general cavity dimensions, but preliminary models indicated conclusively that considerable departure from theoretical views was necessary in order to produce a coupling device free from resonance effects causing a prolongation of certain tones beyond their natural duration, thus masking succeeding tones and impairing the quality.

During the development of the Diphonic loud speaker the construction of test models was guided by listening tests as well as acoustic measurements. Subsequently to the attainment of satisfactory response from the standpoint of frequency characteristic and efficiency, a tendency toward "beaminess" of the high-frequency radiation of the low-frequency unit was observed. This was corrected by the addition of vanes that effectively distributed these sounds over a horizontal angle comparable to that covered by the high-frequency horn previously described.

In addition to the wider frequency range, reduced distortion and better directional properties previously mentioned, the improved efficiency of both units has definitely increased the volume range.

The Diphonic loud speaker requires a minimum of space on the stage; can be quickly dismantled if required; and the technic followed in its installation is considerably simpler than that required by some of the older equipment.

REFERENCES

[1] WATSON, T. A.: U. S. Pat. No. 266,567; filed April 17, 1880, issued October 24, 1882.

[2] CAPPS, F. L.: U. S. Pat. No. 441,396; filed April 7, 1890, issued November 25, 1890.

[3] SIEMENS & HALSKE: German Pat. No. 2355; December 14, 1877. SIEMENS: Brit. Pat. No. 4685; February 1, 1878. CUTTRISS AND REDDING: U. S. Pat. No. 242,816; June 14, 1881.

[4] PRESCOTT, G. B.: "Bell's Electric Speaking Telephone," *D. Appleton & Co.* (New York), 1884, p. 458.

[5] *Ibid.*, p. 441.

[6] TOURNAYRE AND TOURNAYRE: French Pat. No. 463,660; submitted October 15, 1913, published March 2, 1914.

[7] WEBSTER, A. G.: "Acoustical Impedance and Theory of Horns and Phonograph," *Proc. Nat. Acad. Sci.*, **5** (1919), No. 6, p. 275.

[8] GREEN, I. W., AND MAXFIELD, J. P.: "Public Address Systems," *Bell Syst. Tech. J.*, **2** (April, 1923), No. 2, p. 113.

[9] WENTE, E. C., AND THURAS, A. L.: "High-Efficiency Receiver of Large Power Capacity," *Bell Syst. Tech. J.*, **7** (Jan., 1928), No. 1, p. 140.

[10] MAXFIELD, J. P., AND HARRISON, H. C.: "Methods of High-Quality Recording and Reproducing Music and Speech Based on Telephone Research," *Bell Syst. Tech. J.*, **5** (July, 1926), No. 3, p. 493. HARRISON, H. C.: U. S. Pat. No. 1,730,425; October 8, 1929.

[11] BOSTWICK, L. G.: "An Efficient Loud Speaker at the Higher Audible Frequencies," *J. Acoust. Soc. Amer.*, **2** (Oct., 1930), No. 2, p. 242.

[12] MAXFIELD, J. P., AND FLANNAGAN, C.: "Wide-Range Reproduction in Theaters," *J. Soc. Mot. Pict. Eng.*, **XXVI** (Jan., 1936), No. 1, p. 67.

[13] WENTE, E. C., AND THURAS, A. L.: "Symposium on Wire Transmission of Symphonic Music and Its Reproduction in Auditory Perspective—Loud Speakers and Microphones," *Bell Syst. Tech. J.*, **13** (April, 1934), No. 2, p. 259.

DISCUSSION

MR. KELLOGG: In practically all these loud speaking systems in which one speaker handles the low frequencies and the other the high, there is a difference in the time at which the sound from the two sources reaches the listener, corresponding to four to six or eight feet of travel, since the high-frequency unit is placed nearer the front of the horn of the low-frequency speaker. Has any definite conclusion been reached as to the effect of the difference in the time of arrival of the two components?

MR. JONES: The effect is referred to in theater reproduction as "phasing." It plays a very important part, particularly with the impact type of sound. It is a design feature that I did not have time to discuss; however, it is important in arranging a loud speaker system, particularly one involving a large number of units of different horn lengths, that the diaphragms be so located relatively to the face of the unit as a whole as to correct the effect that you have in mind.

This is usually done in the case of multi-unit systems by adjustment in the theater. It is possible, however, if the units have horn lengths essentially equal, to take care of the major portion of the effect in the initial assembly.

MR. COOK: Loud speakers are generally mechanical circuits having series-connected elements at their fundamental resonance frequency. This frequency is usually either below or near the lower limit of their frequency response. In addition, these devices are seldom critically damped at this resonance frequency. In such circuits any applied impulse would create an oscillatory transient that would not die out immediately upon removing the applied force.

There have been many examples of loud speakers, the transients of which have a duration of as much as half a second. Practically any musical composition would have notes changing from one tone to another in time intervals of this order, at the same time being preceded by transients having relatively steep wavefronts.

It would seem probable that completely faithful reproduction would be impossible under such conditions, for while reproducing a desired tone, another that had occurred at some previous time might still be present. Have you any information as to how serious that has been, and whether any marked improvements in that regard have been made or are likely in the near future?

MR. JONES: Speakers such as the ones I described represent an improvement in that respect. I feel quite confident that in the future we may expect greater improvements from the standpoint of transient characteristics.

MR. CRABTREE: What is the power capacity of the units especially the large units?

MR. JONES: The objective in present-day reproducing systems for theaters is to develop about 25 or 30 watts of sound power. Measurements made on orchestral instruments show that maximum power occurs in the region of 250 to 500 cps., and is of the order of ten watts. A system that has an output capacity of 25 to 30 watts is capable of delivering from two to three times the maximum power of a sizeable orchestra.

With good conversion efficiency, that is, of the order of 50 per cent, this means that the electrical input levels can be very materially reduced in obtaining the 25 to 30 watts, and hence the amplifier problem is very much simplified. There is a fair factor of safety over that. I should say that it is not unreasonable to expect 100 per cent overload to be carried for a very short time.

RESEARCH COUNCIL SPECIFICATIONS FOR A STANDARD SYNCHRONIZING SYSTEM FOR CAMERAS*

Summary.—*In July, 1936, the project of adopting a standard synchronizing system for cameras was suggested to the Research Council of the Academy of Motion Picture Arts & Sciences for the purpose of eliminating confusion on stages resulting from the use of clap-sticks and other visual-auditory synchronizing devices, to derive from the system the advantages of adopting uniform methods in all studios, and to achieve such uniformity among cameras as will allow using the cameras in all studios without altering the synchronizing equipment. Specifications of the standard synchronizing system are given for cameras of several makes.*

SUBJECT

These specifications describe the combination and application of existing and/or modified commercial equipment to a system to synchronize the camera with the sound recording equipment by fogging the film inside the camera after the equipment is in motion and has reached operating speed.

These specifications are designed to cover the simple fundamentals of a synchronizing system, and may be elaborated upon in any way provided the fundamental dimensions and units of equipment are retained within the system.

The Research Council drawing entitled *Units of the Research Council Standard Synchronizing System for Cameras* (Fig. 1) shall be considered a part of these specifications.

The drawings entitled "Application of the Standard Synchronizing System for Cameras to the Mitchell *NC* Camera" (Fig. 1), "Application of the Standard Synchronizing System for Cameras to the Standard Mitchell Camera" (Fig. 2), and "Application of the Standard Synchronizing System for Cameras to the DeBrie Super-Parvo Camera" (Fig. 3) shall not be considered a part of these specifications but are presented only to assist in the application of the standard to actual studio practice.

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* Reprinted from the *Technical Bulletin* of the Academy of Motion Picture Arts & Sciences, December 31, 1936; effective January 1, 1937.

STANDARD UNITS

The individual items of which this standard system consists have been so chosen that either an argon vapor lamp and socket or a filament-type switchboard lamp and socket may be used interchange-

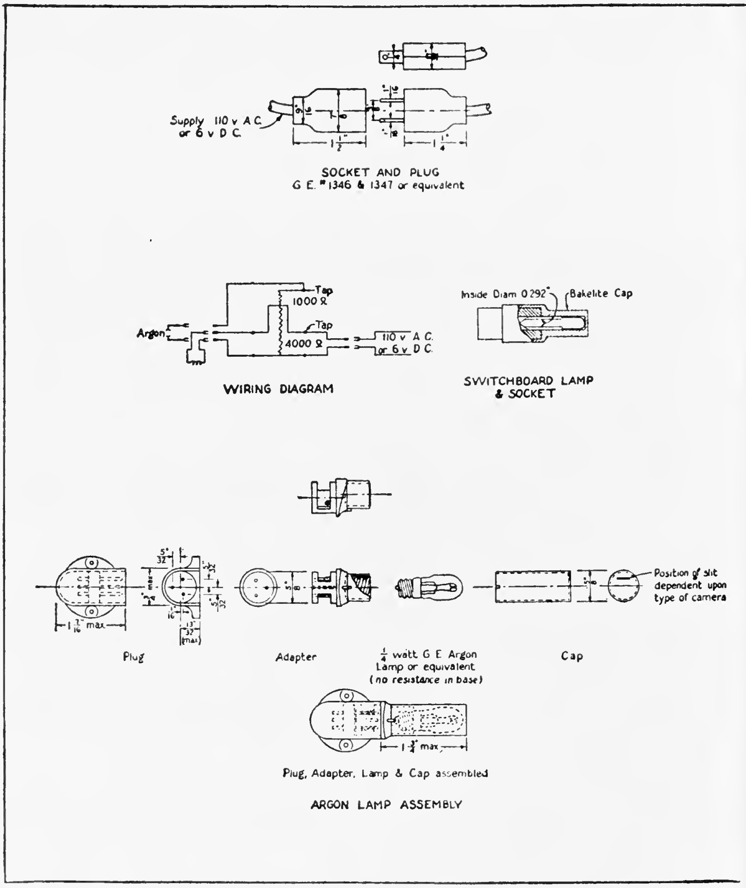


FIG. 1. Units of the Research Council standard synchronizing system for cameras (October 26, 1936).

ably in any camera and/or any camera equipped with this standard synchronizing system may be connected into any studio power supply system with proper electrical characteristics, to provide a standard synchronizing mark upon the film.

In addition, the individual items included in this system have been chosen of dimensions and type which are inexpensive and commercially available (in some cases with slight modifications).

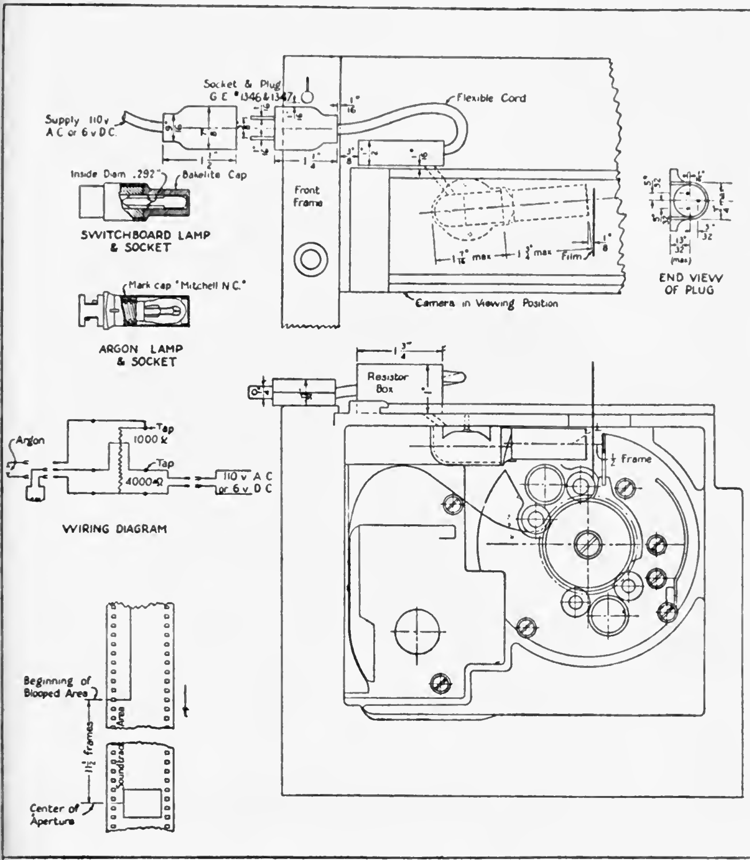


FIG. 2. Application of the Research Council standard synchronizing system to the Mitchell *NC* Camera (October 26, 1936).

THE SYSTEM

The Standard Synchronizing System for Cameras shall consist of: (*1*) a standard plug of dimensions shown in Fig. 1 and into which either an argon vapor lamp or a filament-type switchboard lamp with an appropriate socket will fit interchangeably, mounted inside the camera in such a position as to throw a beam of light upon the film, positioned at a fixed distance from the center of the aperture; (*2*) external resistors of sufficient size and connected as shown in Fig. 1, to provide the proper current for either the argon vapor or

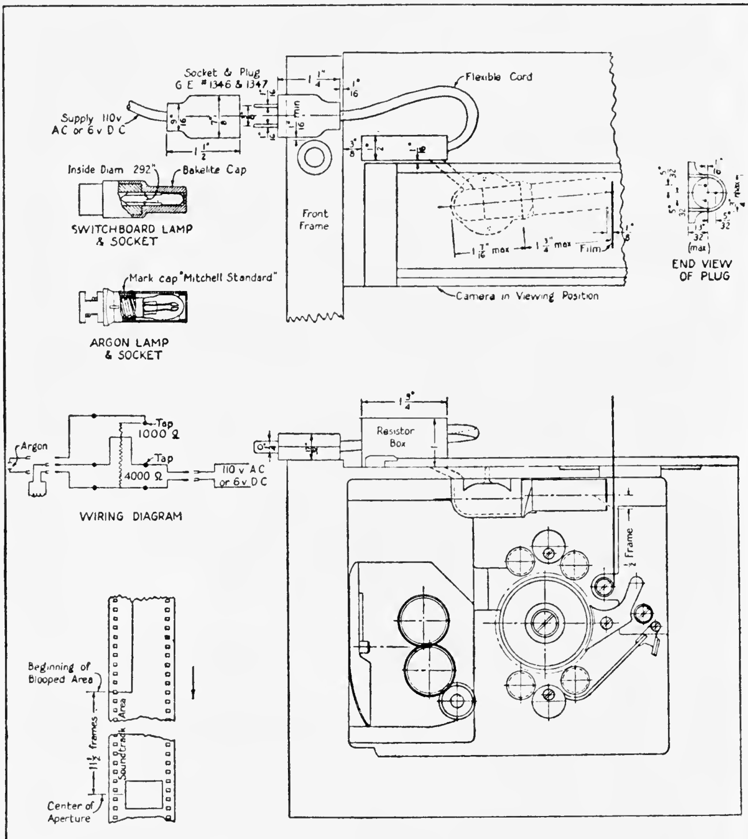


FIG. 3. Application of the Research Council standard synchronizing system to the Mitchell standard camera (October 26, 1936).

filament-type switchboard lamp; (*3*) a standard General Electric *1346* (or equivalent) plug and an associated General Electric *1347* (or equivalent) socket through which the synchronizing lamps may be connected to either a 110-volt a-c. (for the argon vapor lamp) or a 6-volt d-c. (for the filament-type lamp) current supply.

DIMENSIONS

The socket, into which an argon vapor or filament-type switchboard lamp will fit interchangeably shall be of fundamental dimensions shown in Fig. 1, and shall be so located that there will be a

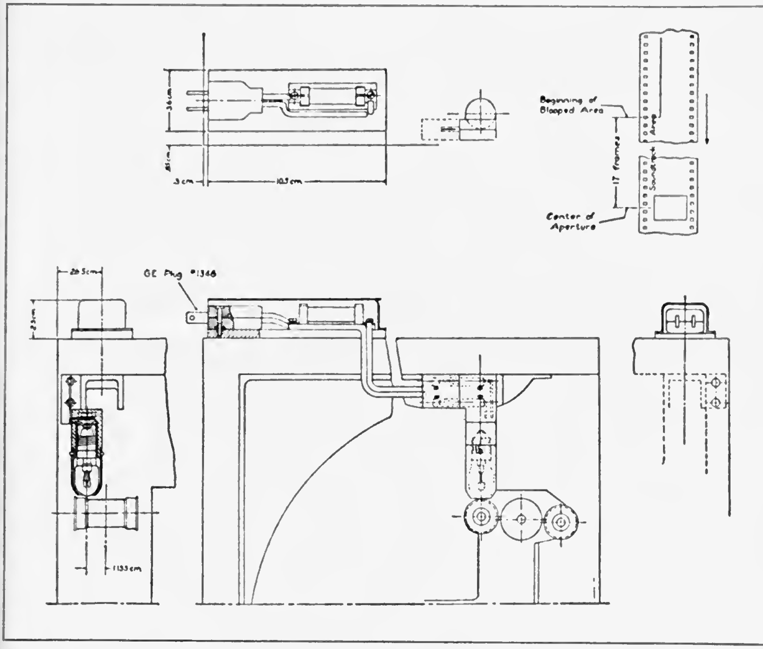


FIG. 4. Application of the Research Council standard synchronizing system to the DeBrie super-parvo camera (December 17, 1936).

clearance of not more than $^3/_{16}$ or less than $^1/_{16}$ inch between the end of the lamp-and-socket assembly and the film.

The outside plug (General Electric No. *1346*, or equivalent) shall have a maximum length of $1^1/_4$ inches, width of $^7/_8$ inch, and a height of $^{17}/_{32}$ inch, with plugging elements $^1/_{16}$ by $^1/_4$ inch in vertical dimensions, located $^3/_8$ inch from center to center.

The outside socket (General Electric No. *1347*, or equivalent) shall have a maximum length of $1^1/_2$ inches, width of $^7/_8$ inch, and height of $^{17}/_{32}$ inch, with sockets of suitable dimensions into which the lugs of the above plug will fit.

MOUNTING

The synchronizing lamp socket shall be so mounted within the camera that a beam of light will be projected upon the film covering the sound-track area and extending into the picture area.

The synchronizing lamp socket shall be so mounted within the camera that a beam of light will be projected upon the film covering the sound-track area and extending into the picture area.

The lamp and socket assembly shall be so positioned that the synchronizing mark shall be located at a point exactly $11^1/_2$ frames from the center of the camera aperture in the Mitchell *NC* and the Mitchell Standard cameras, and at a point exactly 17 frames from the center of the camera aperture in the DeBrie Super-Parvo cameras.

Note.—Although not included as part of these specifications, it is suggested that an outline of film loop be etched upon the camera wall to indicate the exact length of film with which the camera is to be threaded in order to position the synchronizing mark accurately.

To conduct the studies in the project described above, S. J. Twining was appointed by the Academy Sound Recording Committee to investigate the current status of camera synchronizing methods, both with reference to studio-owned as well as commercially owned cameras available by rental to the producing companies.

A consulting committee, consisting in general of the studio camera, laboratory, and cine-technical department heads, was appointed to determine the various units of the system that would best meet the various requirements of the industry. This committee consisted of:

J. ARNOLD	F. FLACK	J. M. NICKOLAUS
F. S. CAMPBELL	F. GAGE	E. OSTER
G. CRANE	G. LABUE	W. G. ROBINSON
W. EGLINTON	M. LESHING	W. RUDOLPH
H. ENSIGN	C. LINDBLOOM	A. TONDREAU
G. FISCHER	E. B. MCGREAL	R. WILKINSON

A Sub-Committee consisting of W. C. Miller, H. G. Tasker, S. J. Twining, and Gordon S. Mitchell, Manager of the Research Council, represented the Sound Recording Committee in the discussions of the projects with the camera and laboratory groups.

The Chairman of the Research Council is William Koenig; Sound Recording Committee, E. H. Hansen; Sub-Committee on Standardization of Synchronizing Systems for Cameras, S. J. Twining.

TRANSMISSION OF SOUND AND VIBRATION IN BUILDINGS*

ERWIN MEYER**

Summary.—*A description of studies made at the Institut für Schwingungforschung, Berlin, in the transmission of sound and vibration in buildings, with particular reference to the analogies between the properties of sound insulating structures and electrical networks. Some of the problems treated deal with the air-borne transmission of sound through multiple walls; the propagation of sound in building materials, and the physical properties of insulating materials for structure-borne sound; and electrical apparatus for measuring vibrations in buildings.*

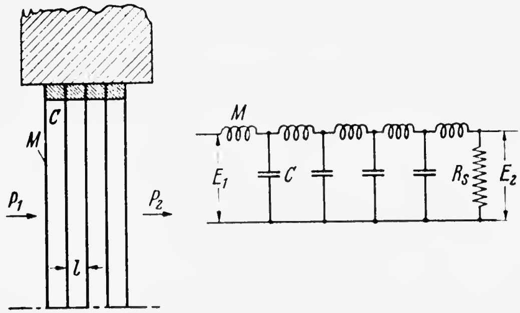
As is known, a distinction is made between air-borne and structure-borne sound. Transitions between these two classes of transmission occur very often and cause many difficulties in sound and vibration insulation; on the other hand, the various mutual relations between them and the analogies to corresponding electric questions are very interesting. There are so many problems of this sort that only a few especially treated in this Institute will be selected: air-borne transmission through multiple walls; sound propagation in building materials, and physical properties of insulating materials for structure-borne sound; and electrical apparatus for measuring vibrations in buildings.

MULTIPLE WALLS

From the measurements of Berger in 1911 it is known that the sound insulation of a single wall depends almost entirely upon its mass. This is quite right, if the lowest natural period of the wall is several octaves under the used frequency range and if the damping is not too small. This law can be theoretically demonstrated, and is also confirmed by experiments. For the usual building materials and partition walls of ordinary dimensions the previous assumptions are not completely fulfilled; thicker and heavier walls especially have higher and less damped natural periods; therefore we do not get the

* Received October 10, 1936.
** Institut für Schwingungforschung, Berlin.

theoretically expected weight-insulation curve of single walls. The weight curve has a very important meaning, but is only empirical. For the theory of multiple walls we assume that a section of the multiple wall is physically like a mass. Fig. 1 shows the electrical analogue of



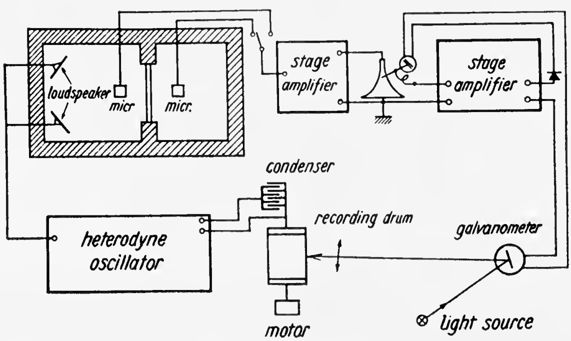


FIG. 1. (*Upper.*) Multiple wall (scheme and electrical analogy).

FIG. 2. (*Lower.*) Automatic apparatus for recording sound transmission.

the multiple wall. The mechanical-acoustical behavior resembles that of a low-pass filter. The cut-off frequency is

$$n_0 = \frac{c}{\pi}\sqrt{\frac{p}{ml}}$$

where m is the mass (g/cm²) of the single wall, l the thickness (cm) of the air space, p the air density (g/cm³), and c the sound velocity (cm/sec). The arrangement for measuring the sound transmission of such a wall is shown in Fig. 2. The multiple wall under test separates two empty rooms having large reverberation times, so that we have in each room a diffuse sound field. First, the sound density in

FIG. 3. Sound insulation curve: sound pressure (*a*) in transmitter room; (*b*) receiver room.

the loud speaker room is recorded with a logarithmic valve-voltmeter; then the density in the second room. The entire procedure is then repeated. An original photographic record of a wall is shown in Fig. 3.

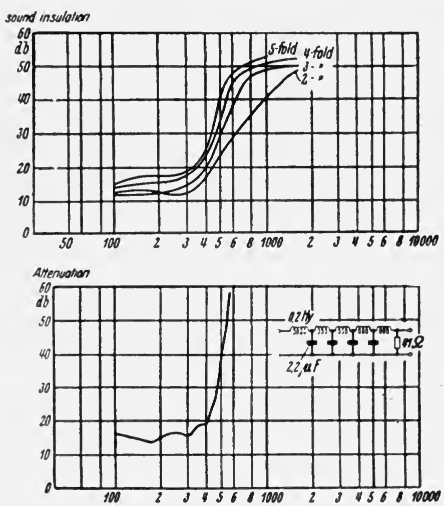


FIG. 4. Multiple wooden wall with space damping; electrical low-pass filter.

A series of experiments done by this method showed that triple, quadruple, quintuple, *etc.*, walls have cut-off frequencies almost in agreement w'th the formula above. Still another effect known from the principles of propagation of electric currents in filters was present: the phase velocity of a tone is less when its frequency approaches the cut-off frequency. An impulse is thus dispersed into its frequency components, and it makes a great impression upon an observer when hand clapping in front of the wall is heard as the sound *oo-e* behind

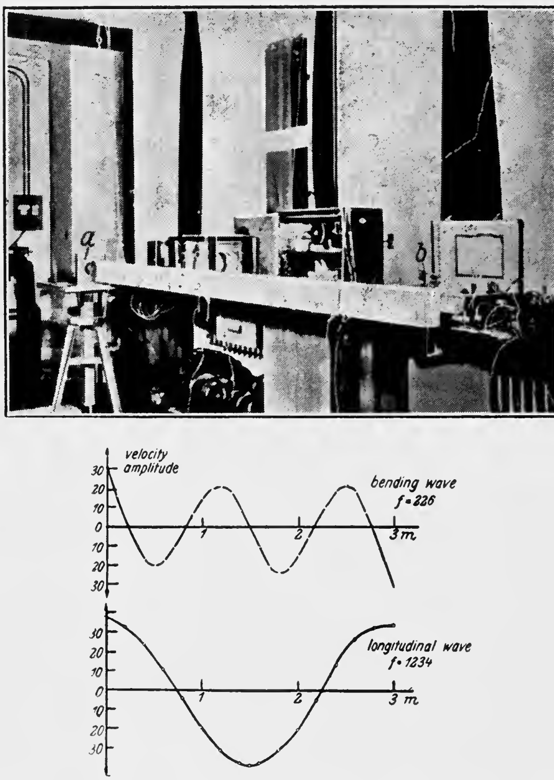
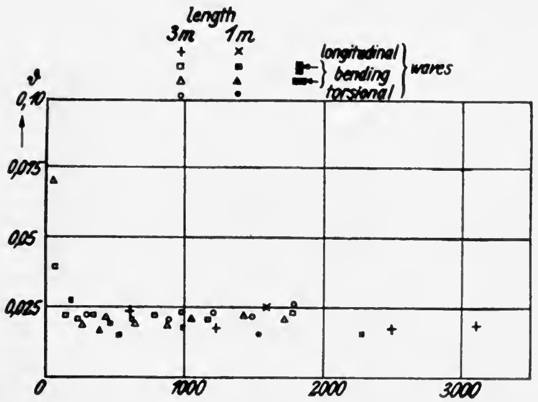


FIG. 5. (*Upper*) Concrete rod with driving apparatus (*a*) and pick-up (*b*); (*lower*) distribution of amplitudes.

the wall; the low frequencies arrive first, as can be demonstrated by an oscillogram. But all measurements made on multiple walls showed one difference between the corresponding mechanical and the electrical low-pass filters. An electrical filter has a large transmission loss beyond the cut-off frequency; the corresponding mechanical filter shows only a slow increase of attenuation, the reason being that the air cushion between two sectional walls does not represent a real stiffness. The cushion is, in fact, quasi-stationary in the thickness dimension; however, the dimensions parallel to the wall are greater than or at least comparable to the wavelength of the tones.



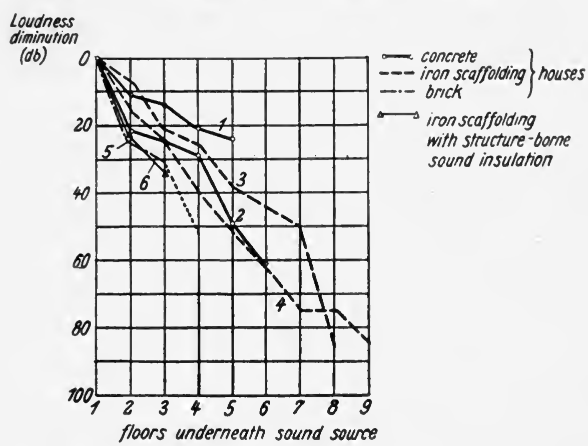


FIG. 6. (*Upper.*) Decrements of concrete rod.
FIG. 7. (*Lower.*) Propagation of structure-borne sound in buildings.

The diffuse incidence of sound creates a pressure gradient parallel to the walls, and in order to avoid resonances in this direction the air spaces between the walls must be damped by inserting porous absorption materials. It is sufficient to fix these materials at the boundaries. For a multiple-wall construction of this kind (wooden plates, $m = 0.2$ g/cm^2, $l = 3$ cm, $n_0 = 480$ cps.) the results are shown in Fig. 4.

On the right side of the figure is drawn for comparison the attenuation curve of a low-pass filter the exact electrical analogy of the wall. The quintuple wall corresponds to a network having four sections. The curves are very similar except at the higher insulation values,

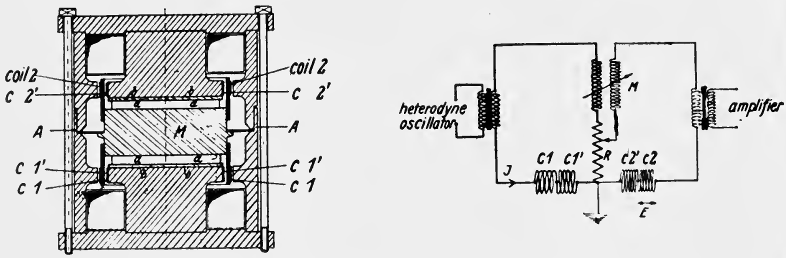


FIG. 8. Mechanical impedance meter; section and electrical circuit.

where they are lowered in the mechanical case by secondary influences. If side-damping is applied to the air spaces, making the thickness equal to half a wavelength, air-space resonances in the thickness direction are distinctly obtained. If side-damping is not used, these resonances can not be found. To avoid them the entire air

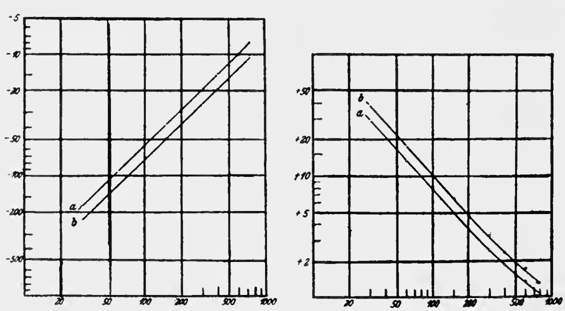


FIG. 9. Reactance (*left*) and resistance (*right*) curves for cork-rubber-cork combination (ordinates × 10 g/sec. mechanical ohms).

space must be damped, but in the most cases the air space is small in comparison with the wavelength. Multiple walls manufactured according to these principles with a cut-off frequency lower than 100 cps. insulate surprisingly well, giving 20 db. more attenuation than a single wall of the same weight. The formula given above for the cut-off frequency shows that for good insulation it is necessary to lower this frequency, which can be done by using heavier sectional walls or thicker air spaces. That means that for good insulation against air-borne sound the requirements are either weight or plenty of space.

The loosest practically possible coupling between two walls is an air space between them. In most cases there must be additional solid connections between the walls, which constitute at the same time sound bridges. We have studied these questions to some extent, and have found, of course, parallels to a telephone line. A short line having continously distributed capacitance and inductance can be inductive or capacitive according to its terminating impedance. In the case of light walls, heavy and elastic sound bridges transmit less than do light bridges of less elasticity. The converse is the fact in the case of heavy walls. In every case we have found that supports with springs and rubber, which are the constructional elements of the floating walls, are the best.

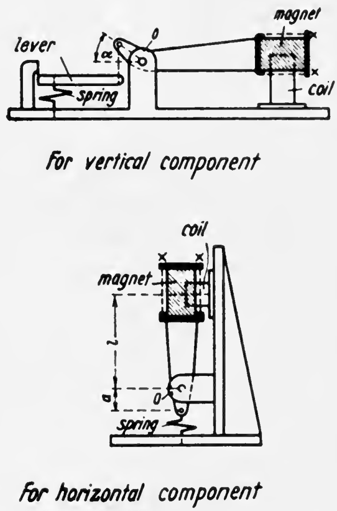


FIG. 10. Electrodynamic vibration meter.

STRUCTURE-BORNE SOUND

Sound bridges lead directly to the question of sound propagation through a building as a whole. First must be considered the attenuation in the building materials themselves, and we must distinguish between the various types of sound waves, *e. g.*, longitudinal, torsional, and transverse or bending waves. The transmission of these sound waves can easily be measured by a resonance method. A bar of the material in question (wood, concrete, brick, stone, iron) is driven at one end by an electrodynamic system of low mechanical resistance (at *a*, Fig. 5). The velocity amplitude is measured by a gramophone pick-up at the other end of the rod (*b*, Fig. 5). In Fig. 5 is shown the curve of velocity amplitude along the rod for a transverse resonance (of the fourth order, to show the characteristic displacement of the ends) and for a longitudinal vibration (of the second order). To get the attenuation of the waves, one has only to measure the resonance curves and to determine the decrement θ. Assuming low damping, the theory shows that the attenuation of the waves in the distance $\lambda/2\pi$ is $\theta/2\pi$ or $\theta/4\pi$, respecitvely, for longitudinal and torsional or transverse waves, respectively. In Fig. 6 are represented the decrements for two concrete bars of different lengths, for the different kinds of waves; the decrements are almost independent of the frequency. This leads to the conclusion that the losses are material losses due to hysteresis.

For a technical survey it is better to express the physical data in decibels per meter. The data differ, of course, for the different pitches and waves, and one can state only the order. To attain an attenuation of 1 decibel the following lengths are required: iron, 25–1000 m.; brick, 8–50 m.; concrete, 5–30; wood, 3–20. No prospect therefore appears of damping the sound waves by pure material losses. Damping can occur only by transition from one building structure to another. In every building there are such transitions which give a more or less sufficient damping. This is illustrated by Fig. 7. In various houses in Berlin, of brick, iron, or concrete structure, the sound propagation in the structure itself has been measured. In Fig. 7 the abscissas represent the number of floors underneath the sound-source, the ordinate the diminution of loudness in decibels. The sound-source (trampling machine) was generally placed at the highest floor. The ordinary brick building has the greatest transmission loss (19 decibels per floor), while concrete and iron have only 8 decibels per floor. By insulating the iron scaffolding with cork plates (Curve *6*, Fig.7) the same values are attained as for the brick houses.

To interrupt the sound propagation in structures we use "sound-soft" materials: namely, materials having low impedance, such as cork, rubber, *etc.* It is important to know the physical properties of these materials. After many experiments an electromechanical resistance meter was constructed for this purpose. Two equal pieces of the material to be tested, separated by a metal disk (Fig. 8), are placed between the poles of two pot-shaped magnets. A coil C_1 is situated in the circular air-gap of the magnet and fixed to the metal disk. A current flowing in this coil exerts a force upon it, and consequently also upon the test pieces.

Similarly, on the other side of the metal plate is another coil. The voltage induced in it measures the velocity amplitude of the metal disk and the test pieces. The test pieces are loaded by inserting metal sheets, if an additional static pressure is desired. To prevent the current coil from influencing the voltage coil, each is divided into

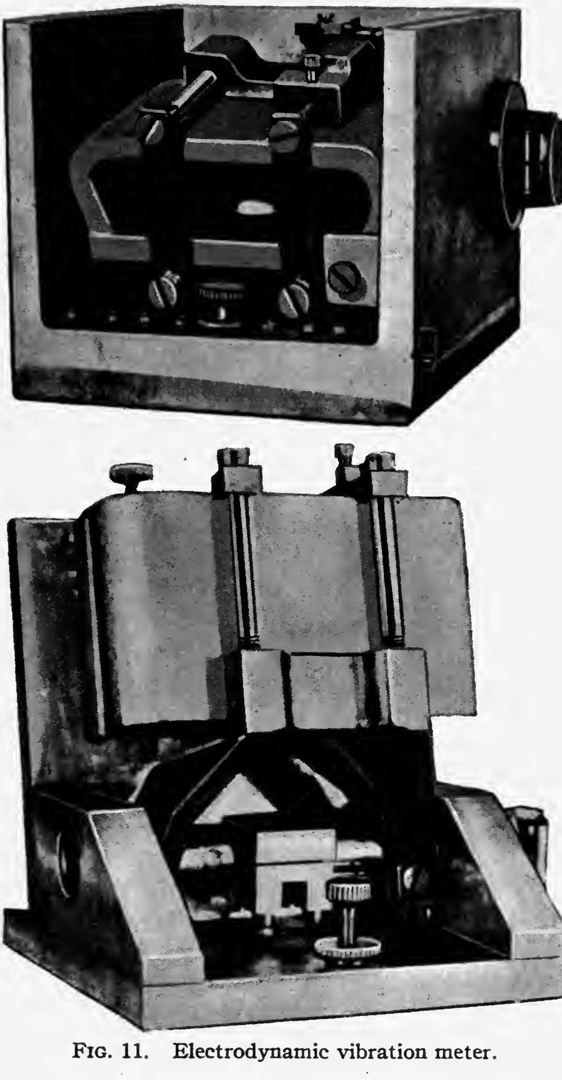


FIG. 11. Electrodynamic vibration meter.

two parts wound in opposite sense, half the winding being fixed and the other half movable. Fig. 8 shows the electrical measuring device; the induced emf. is compensated by a Larsen compensator. If $Z = r + j\omega M$ is the impedance of the compensator, we obtain for the mechanical impedance of the whole system (metal plate and material under test) $W = A_1A_2/Z$. The constant A_1A_2 is determined by means of a known reactance, *e. g.*, by a mass. The mechanical impedance of the system by itself, without test pieces, is measured similarly. The frequency range used is 30–700 cps.

What results are to be expected? For the lower frequencies a material such as cork, felt, rubber, *etc.*, is equivalent to a resistance connected in series with a capacity. The capacity corresponds to a mechanical compliance C, and the electrical resistance to a mechanical resistance B. The mechanical reactance B is thus equal to $-1/\omega C$ and it remains to find the dependence of the resistance R upon the

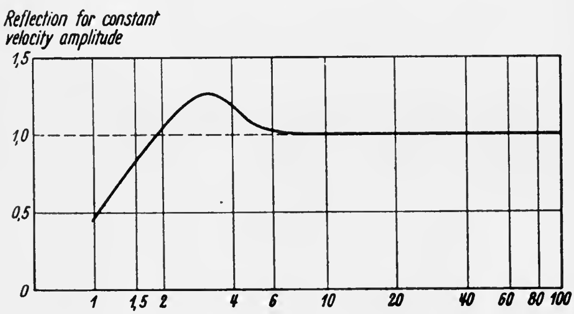


FIG. 12. Response curve of vibration meter.

frequency. If we assume that a certain fraction α of the (potential) input power Bv^2 (v=velocity amplitude) is transformed into the heat Rv^2, it follows that R is proportional to $1/\omega$, because $B = 1/\omega C$ and C itself are constant. These assumptions are, in fact, confirmed by experiment. For cork with a rubber layer, Fig. 9 illustrates the dependence of the reactance and the resistance upon the frequency, the two curves referring to different static pressures. Both have a slope of 45 degrees; which means, for the reactance curve, that the compliance and, therefore, also the elasticity constant, do not change with the frequency. The greater the loading the smaller is the compliance. The resistance curves show that the resistance is inversely proportional to the frequency. Corresponding to the dielectric phase difference of a condenser, a loss factor can be determined for the material, usually termed "absorption factor" (but in another sense, as in room acoustics). Generally the ratio of resistance to impedance will be defined as loss factor. For most materials this number is 10–30 per cent, and does not depend upon the loading. It is also important that all electrical constants be almost independent of the amplitude of the alternating force. Materials such as cork or rubber are used for insulating machines, especially those of variable speed, and for insulating building structures. The values obtained with the apparatus described permit comparison of the materials and selection of the most suitable ones for specific purposes.

ELECTRICAL MEASUREMENT OF VIBRATIONS

Vibrations of buildings belong to the category of structure-borne sounds, except that the frequencies are lower. They lie in the neigh-

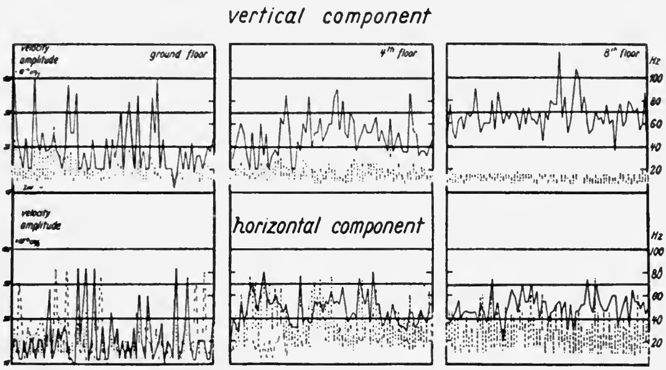


FIG. 13. Vibrations in different floors of a building (solid curves: velocity amplitude, broken curves: frequency range).

borhood of the lower auditory limit. Therefore, the instrument for measuring them must differ somewhat in construction from sound pick-ups, although many electroäcoustical analogies may be made use of without difficulty. In exemplification, the essential features of the new vibration meter constructed at the Institute will be described. As a rule purely mechanical seismometers are used, which measure either the displacement or the acceleration of the ground as functions of their resonance frequencies. One type employs low frequencies and the other high frequencies. Similar principles would apply to acoustics, where, however, we measure the velocity amplitude or the pressure. To determine the velocity amplitude, the vibrations of the mechanical measuring device must be controlled by a resistance, not by a mass or compliance, as is usual. The solution seems to be impossible by purely mechanical means, but it can be done by electromechanical apparatus. Fig.10 shows the principle, Fig.11 the apparatus itself. A pot-shaped magnet serves as a heavy mass, and is supported by a lever. By means of a spring a low resonance frequency of about one cycle per second is obtained. A coil fixed to a base plate, and which vibrates with the ground, dips into the circular air-gap of the magnet. For oscillations of the ground somewhat higher than the resonance frequency of the system, the heavy magnet remains at rest. Consequently, the relative movement between the magnet and the ground is at the same time a measure of the absolute velocity of the ground. The emf. in the coil thus determines the velocity of the ground, at least within the frequency range 1.5–100 cps. The response curve (Fig. 12; with amplifier) is obtained by means of an oscillation desk consisting of a plate and a spring of variable length, the desk being made to oscillate by an electromechanical feedback device. The amplitude of the desk with which the calibration is performed is read with a microscope.

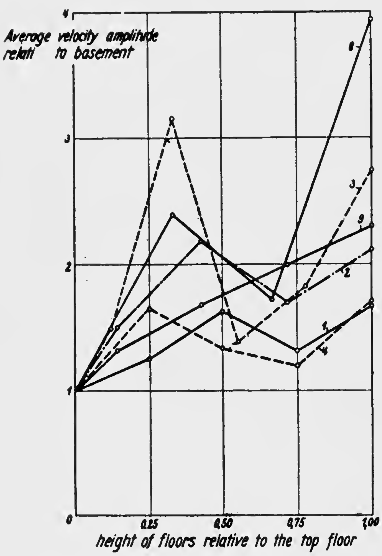


FIG. 14. General distribution of vibrations in buildings (1–9) of different height; horizontal component.

There are three measuring systems, one for the vertical movement, two for the horizontal motions. The emf. of the system is amplified and its average value is measured, with a time-constant of 0.2 second. In this manner the intensity of the vibrations is determined. For measuring the frequency, the output of the amplifier drives a polarized relay, which establishes alternately a condenser charging and discharging circuit. The discharge current indicates the frequency of the vibrations, or rather, in the presence of several frequencies, the frequency range. In such manner the amplitude and frequency (average values) of vibrations of a building, caused by the traffic in the streets, for instance, are determined. With the apparatus described about ten thousand single measurements have been made in Berlin in various buildings. Fig. 13 is an example of these measurements. The abscissas represent the time (about 1/4 hour), the ordinates the velocity amplitude (full-line) or the frequency range (dashed-line). Both the vertical and the horizontal components increase with the height of the floor. It is very remarkable, and has been observed in many buildings, that the frequency range in the vertical component is filtered out. In the uppermost floor only a small range of frequencies is found: namely, the resonance periods of the ceilings, whatever the spectrum of the traffic vibrations may be. The building is a mechanical wave-filter in the vertical direction; but this effect has never been observed in the horizontal. Moreover, for the horizontal velocity component the form of the vibrations was very similar in all buildings. Fig.14 represents a series of measurements in various buildings of different heights; the abscissa is the height relative to the uppermost floor, and the ordinate gives the relative amplitudes, also referred to the value at the highest floor. It is seen that horizontal vibrations of two types are present, the fundamental (building as a whole) and the second harmonic (one node). It is very surprising that this knowledge can be obtained by a statistical excitation such as represented by traffic.

In the foregoing only a few examples have been selected to show the relations between mechanics and acoustics in building vibrations; but they show clearly that not only all the measuring devices, but also the methods of treating the problems, have been helped much by electrical engineering. It seems quite necessary to make electrical analogies. Only by very exact physical investigation of the individual factors can it be hoped to accomplish a survey of the complex propagation of sound and vibration in buildings.

THE USE OF VISUAL EQUIPMENT IN ELEMENTARY AND SECONDARY SCHOOLS*

C. M. KOON**

Summary.—*Encouraged by a grant from the American Council on Education, the United States Office of Education launched the National Visual Instruction Survey in January, 1936, to determine (1) the nature of the visual and auditory equipment owned by elementary and secondary schools in the United States, (2) the extent of its use, and (3) ways in which national agencies can facilitate the use of visual and auditory aids for instructional purposes. The author of this article directed the survey, and Mr. Allen W. Noble assisted him. Reports were received from approximately 9000 school systems covering 95 per cent of all cities with a population of 5000 or more, and a fair percentage of the rural school districts. The paper summarizes the results of the survey.*

Dr. John W. Studebaker, U. S. Commissioner of Education, is of the very definite opinion that schools need audio-visual aids if they are to be efficient and up to date. Yet, the recently complicated National Visual Instruction Survey conducted by the Office of Education disclosed the fact that, of the 82,000 schools covered by the survey, representing a total enrollment of some 17,000,000 pupils, only 50,012 units of radio and visual projection equipment were reported as being owned by these schools. The schools and school systems covered by the survey were mainly located in urban centers.

The survey was conducted for the purpose of determining, *first*, the frequency of use of the various audio-visual aids in each school or school system reporting; *second*, to secure a list of all audio-visual equipment owned by each school or school system; and, *third*, to arrive at an analysis of the problems met in the administration of a program of audio-visual education.

It is estimated that the 33,000,000 persons enrolled in America's public and private schools spend about 198,000,000 hours *per day* in school, as compared with 195,000,000 hours *per week* spent in our

* Received January 19, 1937; presented at the Fall, 1936, Meeting at Rochester, N. Y.

** Office of Education, U. S. Dept. of the Interior, Washington, D. C.

theaters. Yet a breakdown of the equipment owned as disclosed by the national survey reveals that throughout the schools covered there are but 9304 motion picture projectors, of which only 793 are equipped for sound; 11,500 radio receiving sets; and 941 central sound systems. There are some 280,000 elementary and secondary schools in the United States—more than eighteen times the number of film theaters and more than 438 times the number of broadcasting stations.

It would appear from this that while mechanical improvements in the commercial entertainment field march steadily forward, the use

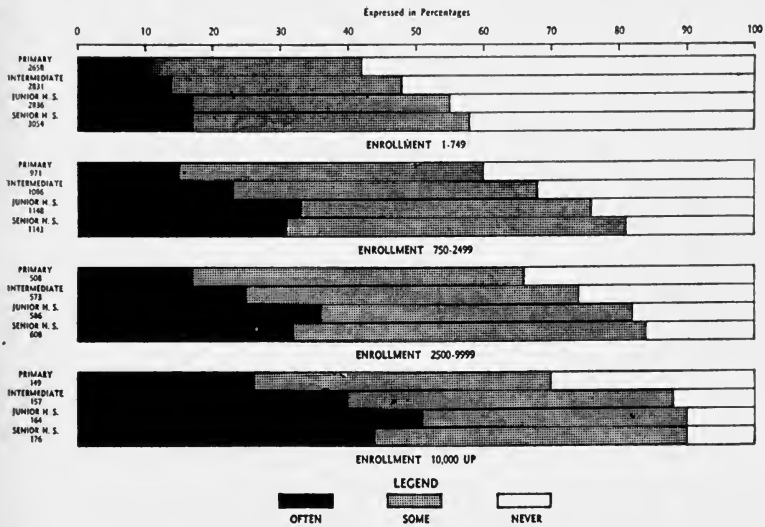


FIG. 1. Extent to which motion pictures are used in elementary and secondary schools.

of these improvements, so necessary for better transmission of modern educational ideas in a modern way, lags far behind in our Nation's schools. Obviously, audio-visual education can not expect to make much headway with less than one unit of equipment per school. Mechanical and non-mechanical aids to teaching technic for the intellectual development of the young people of this country is of vital importance. Present-day social problems arising out of the complexities of our times will be effectively solved only if the teacher is given every aid created by the mind of man to combat them.

The survey brought to light one very significant point. Almost *half* of the schools reporting *were not electrically serviced to accommodate* *mechanical visual equipment.* In spite of this fact, two-thirds of the school systems reported that they make some use of visual equipment in their teaching.

A glance through the total inventory of mechanical visual aids shown as being owned by the schools circularized is revealing, to say the least. The equipment in Table I was listed as owned by the schools reporting:

TABLE I

Total Equipment Owned by Schools

17,040	Lantern-slide projectors
3,007	Still-film attachments
2,733	Slide-film projectors
2,073	Micro-slide projectors
2,720	Opaque projectors
6,074	16-mm. silent motion picture projectors
458	16-mm. sound motion picture projectors
3,230	35-mm. silent motion picture projectors
335	35-mm. sound motion picture projectors
11,501	Radio receiving sets
841	Centralized radio-sound systems.

Using *owned* equipment as a basis for calculations, the startling inadequacy of audio-visual equipment in the Nation's schools is emphasized by dividing this list by the approximate total of more than 81,000 schools from which it was derived:

TABLE II

Equipment Owned per School

0.210	Lantern-slide projectors
0.037	Still-film attachments
0.034	Slide-film projectors
0.026	Micro-slide projectors
0.034	Opaque projectors
0.075	16-mm. silent motion picture projectors
0.00565	16-mm. sound motion picture projectors
0.040	35-mm. silent motion picture projectors
0.004	35-mm. sound motion picture projectors
0.142	Radio receiving sets
0.0104	Centralized radio-sound systems

Mathematical limitations forbid further calculations to determine the fraction of unit of equipment per 17,000,000 children served by these schools.

These figures are, of course, extreme. In addition to the *owned* equipment many pieces of apparatus were reported as *rented* or *borrowed.* Many radio sets, for instance, installed in schools are the personal property of teachers and students; many of them belong to student clubs. Other equipment actually in the school may be the property of persons who leave them there for demonstration purposes.

In addition to mechanical devices, non-mechanical aids such as objects, models, and specimens; wall maps; charts and graphs;

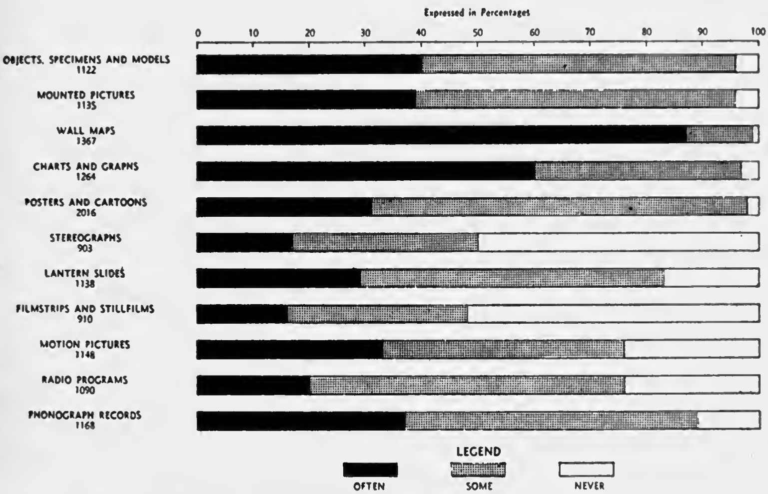


FIG. 2. Extent of use of all audio-visual aids in junior high schools of 750–2499 enrollment group.

mounted pictures; posters; cartoons; and stereographs were shown as being in wide use by the survey. All kinds of aids in this category showed strong resemblance in their relative frequency of use. First, being inexpensive and for the most part easy to obtain their use is more widespread and more frequent than mechanical aids. Second, the extent to which they are used progresses in direct proportion to the size of the school system using them. In this group, however, the extent of use of such aids ranged from the almost universal use of wall maps to the comparatively limited use of stereographs.

Mechanical audio-visual aids, which include motion pictures, lantern-slides, slide-films, radio programs, and phonograph records are, quite understandably, not employed as widely in education as are the simpler non-mechanical aids. However, the survey brought to light a rapid rate of growth in the school employment of both radio programs and motion pictures. In the larger systems, a greater and more uniform use of all audio-visual aids was reported.

Lumping together mechanical and non-mechanical aids, it is interesting to analyze the frequency of use, as reported by the survey, of all the various aids in the different pupil groupings. For instance, the use of wall maps shows first place in use from the smaller schools through the largest. The use of charts and graphs comes second in the smaller institutions until the 2500 or more level is reached, beyond which posters and cartoons rank second, charts and graphs third. Fourth place went to mounted pictures throughout the various levels. Likewise, objects, specimens, and models were uniformly fifth in rank. Next in order of use came phonograph records.

The use of radio programs shows wide variation among the various enrollment levels. In the smallest schools, that is, those serving from one to 750 students, the use of radio ranks seventh. In the next level (750 through 2499) radio instruction falls to ninth place. In schools serving from 2500 to 10,000, radio is next to last in frequency of use, and in the largest schools it ranks last.

While the use of radio, ranking seventh in the smallest schools, is but fifteen per cent, its frequency of use in the largest schools, where it ranks last, is twenty-two per cent. Thus it will be seen that while radio appears to drop as the pupil level increases, actually it is more widely used in larger schools although other audio-visual aids outrank it in frequency of use.

The use of motion pictures ranks eighth in all enrollment levels. Next in the smallest schools is the use of lantern-slides, although this device ranks seventh from the 750-student level up. Similarly, stereographs show next to last in the two lower levels, while their use ranks ninth in the upper brackets. Least of the visual aids to be used are slide-films and still films, with the exception of the largest schools, where this method outranks radio programs by a fraction of a per cent.

Table III shows the frequency of use of the various audio-visual aids among the different enrollment levels.

A still further analysis of the data shows an increasing rate of use of the various audio-visual aids as the grade levels advance until the senior high school is reached. In the main, senior high schools do not make as much use of audio-visual aids as do the junior high schools. Table IV, for motion pictures, illustrates this point.

While the foregoing percentages of frequency are rather gratifying in view of the low percentage of unit of equipment per school, the survey forces one to the unavoidable conclusion that our schools,

TABLE III

Analysis of Frequency of Use of Various Audio-Visual Aids in Education
(Per Cent)

Pupils Enrolled →	Under 750		750–2499		2500–9999		Over 10,000	
Reported as Using →	Often	Some	Often	Some	Often	Some	Often	Some
Wall maps	69	26	76	20	76	19	80	16
Charts and graphs	52	42	56	38	56	39	64	32
Posters and cartoons	50	45	45	52	58	39	61	38
Mounted pictures	43	49	47	48	50	45	61	38
Objects, specimens, *etc.*	37	55	43	52	46	48	59	40
Phonograph records	34	45	42	48	44	47	54	43
Lantern slides	11	36	26	50	29	54	48	41
Motion pictures	15	36	26	46	28	49	41	47
Radio programs	15	47	18	51	18	57	23	61
Stereographs	10	24	17	32	19	43	25	47
Slide-films and stillfilms	5	20	13	29	13	37	23	44

both public and private, are poorly equipped to get the ultimate results attainable through a more widespread use of mechanical and non-mechanical means of graphically and entertainingly impressing upon the mind of the student vital facts in the study of science, geography, history, social science, health, English, nature, commerce,

TABLE IV

Use of Motion Pictures on the Different Grade Levels
(Per Cent)

Pupils Enrolled →	Under 750		750–2499		2500–9999		Over 10,000	
Reported as Using →	Often	Some	Often	Some	Often	Some	Often	Some
Primary (Grades 1, 2, 3)	11	31	15	45	17	49	26	54
Intermediate (Gr. 4, 5, 6)	14	34	23	45	25	49	40	48
Junior high (Gr. 7, 8, 9)	17	38	33	43	36	46	51	39
Senior high (Gr. 10, 11, 12)	17	41	31	50	32	52	44	46
Average use all grades	15	36	26	46	28	49	41	47

and industry; indeed, practically all subjects included in the school curriculum.

The question—why are not these important audio-visual aids to teaching technic in more widespread use in the schools and school systems throughout the United States?—logically frames itself in the mind of anyone studying the findings of the survey. It is interesting, then, and important to explore the reasons given by those in charge in the various school units as to why audio-visual equipment has been so slow in getting a foothold in our schools.

The greatest handicap reported was lack of sufficient budgetary provision for the work. Next was the fact that the schools were unable to get the proper aids in the classroom when needed most. Third greatest difficulty was the declaration that the teachers were insufficiently trained in the use of visual aids. The fourth complaint was that the available aids fail to cover the course of study adequately. Fifth was a lack of understanding of the value of visual aids. The

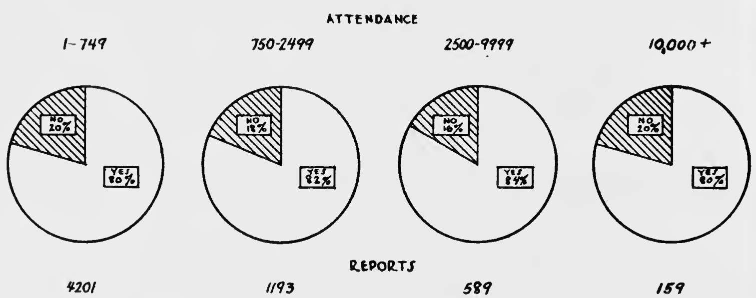


Fig. 3. Schools encouraging attendance at selected motion pictures.

sixth difficulty recorded was the lack of information on sources of desirable films and other aids.

A space was left open in the questionnaire so that city and county public school superintendents and principals of private high schools might express any other difficulties not specifically mentioned in the questionnaire. In the survey's compilation of reasons given here it is interesting to note that many superintendents and directors wrote that they were personally in favor of the use of visual aids, and that their faculty was reasonably trained in the use of such equipment, but that they were unable to convince the school board and others in charge of fiscal policies of the merits to be found in the use of visual aids. This can be termed lack of understanding of the value of such aids, and materially affected the budgetary provisions.

In an effort to determine what means might be set up to offset these difficulties, the survey listed several suggestions in the questionnaire. By far the greatest interest was centered upon the formulation of some plan whereby equipment could be purchased with the assistance of some Federal agency. By this was not meant merely to purchase the equipment at reduced costs or on time payments, but that there was a need of assurance that the equipment so purchased would be standard as to quality and size, in order that films could be obtained for it. With the development of a Federal purchase plan, such as the Electrical Home and Farm Authority is now formulating, it will be possible to have the equipment inspected and certified by the

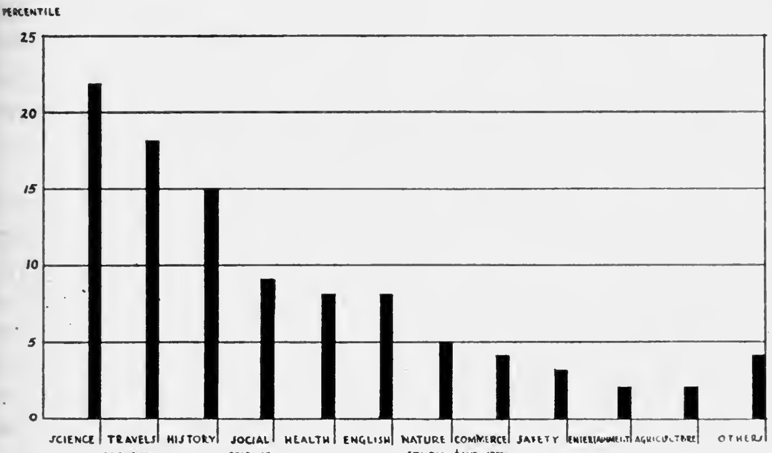


FIG. 4. Relative volume of usage of educational films by subjects (17,228 listings).

Bureau of Standards, which will do much, the survey believes, to offset some of the prejudices recorded.

Many instances were disclosed where obsolete and odd-sized equipment had been sold to schools and school boards. Very little use can be made of this equipment.

Demonstration lessons in the schools by visual instruction experts received the second heaviest vote. Next came the expression of a need for lesson plans to aid in the correlation of visual aids with the course of study. Ranking fourth was the need for additional motion pictures *produced for instructional purposes*. Next in order of favor was the establishment of visual instruction centers where courses could be offered. On this point there seemed to be a difference of opinion as to the most expedient manner of bridging this gap, as many of the teachers in the schools have had little or no training in the use of visual aids.

Three courses are open in this connection. First, that the teacher be required to attend a university or college and obtain such training. Several states already require this of new teachers, but the main problem lies in training those who have completed the requirements imposed prior to this time and who are now teaching. The second alternative is to require the teacher to take a course in the use of visual aids from an extension division of one of the many universities offering such courses. The third means of training the present staff is to employ supervising teachers of visual instruction whose duty will be to work with the teachers and show them how to select the films, slides, *etc.*, to be used by the entire school. Several school systems have reported that the latter course seemed the most expedient and flexible, and reported the successful use of this means.

The next development desired by those in the field, the survey revealed, was the establishment of some group or groups to give expert evaluation of educational films and other visual aids. Many superintendents and directors of visual education reported that they were too frequently disappointed in the contents of the films, and that the descriptions supplied were inadequate and often misleading. It is interesting to note that almost without exception the entire platform of the proposed American Film Institute was approved by the respondents in the National Visual Survey.

Following the logical *why* as to the scarcity of audio-visual equipment throughout the schools at the present time, comes the even more logical *what is to be done both by educators and producers of equipment to overcome this deficiency?*

In general, it may be said that the most important need in the development and extension of the use of visual aids in education is more coöperation and better understanding between motion picture and other visual-aid producers and manufacturers, on the one hand, and educators and socially minded groups, on the other. The former need to become more fully aware that this vast potential market must be developed by long-time planning on a sound economic basis. The latter need to appreciate more fully the importance of the technical, professional, and business ability of people in the industry, and the fact that both must work together on a public spirited but sound economic basis. More specifically, the following suggestions are made for the further development of the field of visual education:

(*1*) Further improvements in the 16-mm. projector to make it even easier to operate and essentially "fool-proof."

(2) More uniformly good reductions from 35- to 16-mm. prints.

(*3*) The Society of Motion Picture Engineers vigorously discourage attempts to sell schools freak and impracticable types of visual aids, as well as splendid types of aids that get out of order easily.

(*4*) The Society of Motion Picture Engineers to work out minimum performance standards for 16-mm. projectors intended to show either silent or sound films in semi-dark rooms.

(*5*) The further development of deferred payment plans for major units of visual equipment. Perhaps the Federal Government should participate in somewhat the same way as it has in encouraging farmers to purchase electrical farm and home equipment in the Tennessee Valley Authority and Rural Electrification projects.

(*6*) A more efficient distribution system for educational films and equipment.

(7) Closer coöperation between industry and educators in determining the content and treatment of subjects in new films and other forms of visualization.

(*8*) More teacher-training courses in the technic of teaching with motion pictures and other visual aids, as well as more courses in photoplay appreciation.

(*9*) A vigorous publicity campaign of a high order, reaching all the 9000 key people listed in the new *National Visual Education Directory** just issued by the American Council on Education, Washington, D. C.

DISCUSSION

MR. MITCHELL: Some of you recognize that the trend recently has been toward definite recognition of motion picture applications in teaching. A number of teachers have been reluctant to use motion pictures, particularly sound pictures, because they rather felt that it eliminated the personal touch, or perhaps tended to eliminate the teacher entirely.

Enough experience has been accumulated under carefully controlled conditions to prove beyond question to even the most skeptical that the use of sound motion pictures shows educational results far in advance of any other medium. They have been tested under such conditions that no argument remains. They have been recognized officially by Government departments, by the President, and by a Council sponsored and patroned by Mrs. Roosevelt, the President's mother.

Such official recognition naturally has an effect upon school officials who are politically minded. It is fortunate that we have reached this stage, and those close to the field have recognized how very rapidly it is progressing.

* Copies of the *National Visual Education Directory* listing the addresses of 9000 visual leaders in local school systems and the equipment owned, may be purchased from The American Council on Education, Washington, D. C.

ORGANIZATION AND WORK OF THE FILM LIBRARY OF THE MUSEUM OF MODERN ART*

JOHN E. ABBOTT**

Summary.—*Until last year no organization existed for preserving films of outstanding merit or for arranging for their distribution and study by those interested in film as living art and in its history and development. A grant from the Rockefeller Foundation and private gifts permitted the Museum of Modern Art to establish such a Film Library in June, 1935, under the presidency of John Hay Whitney, with Will H. Hays, Chairman of the Advisory Committee.*

The functions of the Film Library are to trace, obtain, and preserve important films, American and foreign; to edit and assemble such films into programs for educational and non-commercial exhibition; to arrange notes and critical appraisals of them; to assemble a library of books and data on the films; and otherwise to make available information concerning their artistic, dramatic, and historical aspects to all who may be seriously interested. The series for 1936 consists of (1) The Development of Narrative (1895–1911); (2) The Rise of the American Film (1912–17); (3) D. W. Griffith (Intolerance); (4) The German Influence; (5) The Talkies.

Although the film has been with us for nearly half a century now, until last year no organization existed anywhere for preserving motion pictures of particular merit or interest. People could read and talk about pictures of the past, such as Sarah Bernhardt's *Queen Elizabeth*, which Mr. Zukor brought over from France and by doing so established the feature film; but people could not see *Queen Elizabeth;* nor, for that matter, could they have a look at *The Jazz Singer*, which had an even more overwhelming influence upon the course of the film's history. It was necessary for us to depend upon our memories, our very inadequate and inaccurate memories of the film, if we wanted to form an estimate of the changes, the advances that have occurred since Al Jolson's mammy song rang the knell of the silent pictures.

That it would be highly desirable to preserve outstanding films had been generally agreed by everyone but that it was practicable seemed highly doubtful. It hardly lay within the scope of the film

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* Presented at the Spring, 1936, Meeting at Chicago, Ill.

** *Directort,* Museum of Modern Art Film Library, New York, N. Y.

industry itself to tackle the job: for one thing, it would be an expensive task, and one without appropriate financial returns. What is more to the point, however, is that no man, or body of men, can look both forward and backward at the same time. The energies and talents of the industry are necessarily canalized into today's and tomorrow's activities; a quite different set of energies and talents are needed for the backward perspective, for the collecting or librarian's habit. Also, as it is notorious that artists are often the worst judges of their own work, it was to be suspected that the creative ability of the film industry as a whole would be inadequate for selecting from its vast output what among that output had been the most memorable and best worth preserving.

The first attempt to form a library of excellent films seems to have been made in Denver, Colorado, in 1922, by George William Eggers, the Director of the Denver Art Museum. Later attempts to revive meritorious films followed in many large cities all over the world, but seldom endured for long. After all, prints wear out, and receipts from occasional revivals hardly justify making new prints. Only one or two especially famous films continued to pop up from time to time. All the rest of the huge output of the industry vanished once its relatively brief period of box-office productivity was ended. The probabilities were, therefore, that all the films, bad and good, made since the beginnings of the industry, must continue to lie forever unseen in their various vaults and warehouses. In the course of time they would deteriorate and eventually perish; therefore, to future generations the nature of films of the past would continue to be a matter of legend, conjecture, and mystery. In other words, the film was condemned to enjoy only a transitory life—even the best films were condemned to enjoy only a momentary space in the sun and thereafter to become revered memories like the very famous plays of the *commedia dell'arte* about which, actually, so little is known although so much is said. It seemed a great pity.

Now, if anything were to be done to create a museum of the film, it did seem obvious that a singularly appropriate institution to undertake the work was the Museum of Modern Art, in New York. Founded in 1929 it has energetically concerned itself with contemporary art in all its aspects, from architecture to photography, from painting to typography. And since the foundation of the Museum of Modern Art, the director and the trustees had always planned a department of films. Yet, before the Museum of Modern Art could approach the task, three things were needed. One was to ascertain whether there existed a serious interest in the film as living art. Another need was money, to create and maintain a film library; and the third was the coöperation of the film industry.

Inquiry proved that colleges and museums all over the country were anxious for material to make possible a serious study of the film. Thereupon, a scheme for the creation and operation of a film library was drawn up such as would enable the motion picture to be studied just as, for example, mediaeval sculpture or contemporary drama is studied. A grant from the Rockefeller Foundation and certain gifts of money from private individuals provided the necessary funds to start work. The Museum of Modern Art Film Library came into existence in June, 1935. Its officers are John Hay Whitney, *President;* Edward M. M. Warburg, *Treasurer;* and John E. Abbott, *Vice-President.* The last named was appointed *Director,* and Iris Barry, *Curator.* Later, an advisory committee was formed with the following members:

Will H. Hays, *Chairman*
Jules Brulatour
Stanton Griffis, a trustee of Cornell University
Dr. Irwin Panofsky, Professor of Fine Arts at the Institute for Advanced Studies at Princeton, N. J.
Dr. David H. Stevens, Director for the Humanities of the Rockefeller Foundation
Irving Thalberg

The Film Library then set to work. There was no precedent for what it hoped to do. Its plans were:

(*1*) To compile and annotate a card index of all films of interest or merit of all kinds produced since 1895, both American and foreign.

(*2*) To trace, secure, and preserve the important films of each period since 1893.

(*3*) To edit and assemble these films into programs for exhibitions in New York and throughout the country by colleges, museums, and local cultural organizations.

(*4*) To compose program notes on each exhibition, which would include a critical appraisal of the films and would aid the student in appreciation of the medium.

(*5*) To assemble a library of books and periodicals on the film, and other historical and critical material including the vast amount of unrecorded data still in the minds of men who developed the film. If the history of the formative period is to be preserved, it was necessary to obtain this information at once; otherwise, it would be irrecoverably lost at the death of these men.

(*6*) To assemble and catalog a collection of film "stills."

(*7*) To preserve and circulate the musical scores originally issued with the silent films, and to arrange musical scores when the original has been lost (sheet music or phonograph records) to be circulated with the silent programs when needed.

(*8*) To act as a clearing house for information on all aspects of the film, and to maintain contacts with all interested groups, both in America and abroad.

(*9*) To make available sources of technical information to amateur makers of film.

(*10*) To publish a bulletin containing articles and illustrations for furthering the appreciation and study of the motion picture and to make known the Film Library's activities.

We immediately approached the film industry in this country, first, through Motion Picture Producers & Distributors of America, Inc., and then, individually, the executive heads of producing companies. What we asked of them was, of course, the use of certain films they owned. The Film Library was in a position to pay the cost of restoring negatives, prints, and circulation. There were innumerable difficulties to be ironed out, such, for instance, as the complications arising in the case of a film that has been remade by a firm other than the one that originally produced it. And, of course, the conditions under which the Film Library would circulate films had to be defined and agreed upon. Despite the obvious legal and technical difficulties, once our objects were made clear the fullest coöperation was forthcoming, and in almost every case the films we asked for have been made available to us. Also, early in the Library's existence we were fortunate in acquiring the collection of early films and other material that the late Jean A. LeRoy had amassed.

Our first series of films for circulation was released in January, 1936, under the title of a "Short Survey of the Film in America from 1895 to 1932." It was planned as a first-year course, or survey, which would provide a groundwork for a more voluminous series in the following year. It was composed almost exclusively of American films, not only because of the predominant part this country holds in the film field, but also because historically the native film has been on the whole much less seriously considered and appreciated than it deserves. The idea seemed to have become prevalent that foreign films were art, but hardly the domestic film. This was a point of view that seemed untenable. This preliminary series of films consisted of five programs, each, roughly of two hours' duration, issued one a month. The first program was entitled *The Development of Narrative,* and covered the years 1895 to 1911, beginning with the Edison Company's brief but business-like *Execution of Mary Queen of Scots* and ending with Sarah Bernhardt in *Queen Elizabeth.* It also included the two deservedly famous items, *A Trip to the Moon* and *The Great Train Robbery.*

The second program, called *The Rise of the American Film,* included early films by D. W. Griffith and Mack Sennett, and an early Western from the Ince studio, with Wm. S. Hart; it concluded with the celebrated "vamp" film *A Fool There Was.* The third program was devoted entirely to D. W. Griffith's *Intolerance.* The fourth program was called *The German Influence* and included the late F. W. Murnau's first American-made picture, *Sunrise.* The last program traced the development of the talking film, and included two scenes from *The Jazz Singer*—one of them, of course, being the one in which Jolson sings his mammy song—and the whole of *All Quiet on the Western Front.* Last item on this program, and in the series, is *Steamboat Willie,* the first Mickey Mouse release.

Where, one may ask, were these films shown? It would be tedious to give a list of the exhibiting institutions; but so far they have been fifty in number, and include eleven colleges, twelve universities, fifteen museums, two art schools, and ten adult cultural organizations, located in twenty states.

Each program is prefaced by a rolling title of fact and comment, and other titles giving the necessary historical data preface each single film. Scores for piano have been arranged as accompaniments for all the silent programs, and the music is sent out in advance to give time for rehearsal. But what we feel is the most important feature of the programs, except for the films themselves, is that carefully written printed program notes are also provided for each member of all the audiences seeing the films we circulate. These program notes are intended, on the one hand, to convey information about the history of the motion picture, and, on the other hand, to help students both to gain a thorough grasp of its development and to arrive at a more analytical and more detached attitude to the film generally than is possible when films are shown currently for entertainment only.

I think there is little question that anyone who has seen the five programs I have briefly described has now a good grounding in the history of the art and has acquired a totally new respect for, and a much profounder understanding of, the medium as a whole. Those of us at the Film Library have to admit that we have gained a great deal ourselves. Considerable misinformation about films has accumulated over a period of time, and this was inevitable so long as what we knew about them was largely hearsay and recollection. It is quite an experience to review the history of the film again. For instance, how often has it been said that D. W. Griffith invented the close-up? Actually one very early film, the famous John C. Rice-May Irwin Kiss, turns out to have been taken entirely in close-up—in 1896. That knowledge makes it even more interesting to see, when we come to D. W. Griffith's early films, that while he did not invent the close-up, he most definitely discovered how to *use* it. And then, again, it is commonly believed that the moving camera, tracking shots, came in with the German films after the War. But in our third program in Griffith's *Intolerance* there are startlingly effective and long-sustained tracking shots, where the camera swings across the great outer courtyard of a Babylonian palace and is then moved slowly forward.

There is a real thrill, comparable, I suppose, to the thrill with which an Egyptologist uncovers a new burial chamber on the Nile, in being able now, for the first time, actually to trace the innumerable influences, packed into an unbelievably short span of years, that have produced the films we see today. It gives a real sense of satisfaction to be able to trace a clear line of descent from the old Max Linder comedies, through the Keystone comedies to the work of René Clair; or gradually to see the connection between the technic that Porter hit upon in *The Great Train Robbery* being carried a stage further in the extraordinarily free cutting of *Intolerance;* and then, scientifically analyzed and applied, to see the same technic applied to the much later Russian films. We believe that being able to review and study the history and development of film technic, to view the medium in perspective, will prove to be a tremendous benefit to future technicians of the film.

Our work has only begun; many of our difficulties still lie before us. We have been much encouraged by the response of the academic world to our activities, and by the generous coöperation of the old-timers and the newcomers in the industry itself. We most urgently need the help, the criticism, and the encouragement of all who belong to the industry in our effort to preserve the outstanding films of the past, to make their development understood, and to create a consciousness of tradition and history within the art of the film.

(A reel of three subjects chosen from the first series of films assembled by the Film Library was projected at the close of the paper.)

The following represents typical material supplied with the films when they are distributed:

A SHORT SURVEY OF THE FILM IN AMERICA CIRCULATED BY THE MUSEUM OF MODERN ART FILM LIBRARY

PROGRAM I

The Development of Narrative: 1895–1911

The Execution of Mary Queen of Scots *1895*

(Produced by The Edison Co. Directed by William Heiss. Cast: Unknown.)

Once people had overcome their amazement that the moving picture really moved, the new invention was appreciated because it could *record* the present—topical views of Fifth Avenue or a French railway station were much enjoyed—and because it could *recreate* the past. This ruthless little Edison film was made for the peep-show, or kinetoscope. After 1896, films were commonly shown on screens.

Wash Day Troubles *1896*

(Directed by Edmund Kuhn. Cast: Mrs. Edmund Kuhn and others.)

The film could do more than record and recreate: it could invent new stories. Comic incidents like this were improvised from the earliest days, and developed later into slapstick comedy.

It was after the period now under review that the American film developed its own characteristic expression. During the early years foreign films contributed much to the repertory of the cinema in America. Trick films and historical films from France, spectacles from Italy and melodramas from England were widely shown.

A Trip to the Moon *1902*

(Produced and directed by George Méliès. Story, design, scenery, effects by George Méliès. Cast: George Méliès, dancers from the Théâtre du Chatelet, acrobats from the Folies Bergères.)

Méliès made hundreds of films between 1896 and 1914. His experience as an illusionist and magician helped him to exploit the camera's resources, so that he quickly hit upon stop-motion photography for magical transformations and disappearances, used a close-up as early as 1896, and made the first film by artificial light. His influence can be traced in innumerable films but most markedly in French advance-guard work like Cocteau's *The Blood of a Poet.*

Clearly, Méliès regarded the film literally as a series of tableaux vivants, though he achieved a continuity by overprinting the end of each scene on the beginning of the next. As in most early narrative films, the scenery is disposed and the characters move horizontally as on a stage in view of an audience.

The beautiful painted backcloths, movable scenery, and stylized props Méliès himself designed, and executed in grisaille: he was an enthusiastic student of Prud'hon, Delacroix, and other Romantic painters. Méliès notably developed screen narrative by ransacking literature for stories to tell and by telling them in his own energetic and imaginative manner.

A Trip to the Moon was made when most films were only three minutes long. It displays the richness of Méliès' invention and humor: his zooming close-up of the face of the moon is masterly and the whole film is charmingly unrealistic and gay.

This print is incomplete: there should be thirty instead of the present twenty-five tableaux. Scenes of rejoicing when the explorers return to port are missing at the end.

The Great Train Robbery *1903*

(Produced by The Edison Co. Directed by Edwin S. Porter. Cast: George Barnes, "Bronco Billy" Anderson, A. C. Abadie, Marie Murray, and others.)

This short story in cinematography created a sensation upon its appearance and has become a classic of the screen. The whole feeling of the film is definitely cinematic, movement is employed toward and away from the camera, as well as horizontally in front of it. Once or twice the camera is even swung to follow the action. The sudden close-up with which the picture ends could, according to the original Edison catalog, be inserted either at the end or the beginning as desired.

The story is told falteringly and the continuity is crude, yet already here is a feeling for the interplay and assembly of short shots which D. W. Griffith afterward mastered and the Russians have since developed into modern montage. Porter had hit upon the principle of film editing.

Its style is mixed. In the chase scenes there is not a trace of the theatrical: the dance-hall has a stage backdrop with painted stove and lamp; in the station-master's office a horizontal stage-set looks onto the great outdoors.

When issued, the film was printed on tinted celluloid—yellow for the dance-hall, bluish green for the woods. Since tinted stock is seldom used today, it has not proved practicable to match the color of the original.

Faust *c1905*

(Produced by Pathé. Director and cast: Unknown.)

This is not the *Faust* that Méliès made, but another version. The last half of the film is missing. Like so many of the early French pictures it was issued either plain or hand-colored: the coloring cost extra, and was done in bright stained-glass or stereopticon hues.

It is interesting to note how, in an effort to let the audience know what the actors were thinking, "visions" were used as here when the tapestry on the wall gives place to Marguerite's memory of her meeting with Faust.

Queen Elizabeth **1911**

(Directed by Louis Mercanton. Acquired through the courtesy of Paramount. Cast: Sarah Bernhardt, Lou Tellegen and others.)

"This is my one chance of immortality," Sarah Bernhardt said when first asked to act for the screen. The ability of the film to bring eminent persons of the day before the widest public has preserved for us here a ghostly souvenir of the theatrical past. It was Adolph Zukor who acquired this French picture and distributed it here as the first of the "Famous Plays with Famous Players" with which the career of the firm we now know as Paramount was begun. "Presented by Daniel Frohman," it made its first appearance at the Lyceum Theater, July 12, 1912. The story of the film's introduction to and subsequent career in this country is well told in Will Irwin's *The House That Shadows Built* (Doubleday Doran, 1925).

Queen Elizabeth is a photographed play rather than drama conceived in terms of the cinema. There is, nevertheless, a distinct shock to the spectator when at the conclusion, the star takes a curtain, for on the screen the player has hardly ever stepped out of his role. (A recent exception occurred in *Escapade*, with William Powell and Luise Rainer.) It is noticeable that the acting, which is for the most part decidedly statuesque, at times becomes painstakingly pantomimic, especially in the scenes between the Queen and the Countess of Nottingham. Long subtitles are also employed throughout, each of which describes carefully the action about to take place.

Sarah Bernhardt's prestige surpassed that of any player now living: she could do no wrong, and the fact that she had consented to act for the films did much to diminish prejudice against the movies. The success of this film and of the Italian spectacle *Quo Vadis* helped to establish the longer feature.

DISCUSSION

MR. CRABTREE: Do I understand that you are obtaining the negatives of these films? If so, what steps are being taken to store them so as to assure their perpetuation?

MR. ABBOTT: To date we have in our possession only certain very old negatives, which have been acquired from various sources. We are in touch with others concerning additional early films. We plan to build a vault that will be constructed according to the opinions of the best authorities; for the preservation of negatives only, not positives. We hope to have arrangements ready within the next eighteen months.

MR. CRABTREE: I think that if you follow what is being done in the Archives Building at Washington you will be getting the best information obtainable, since both the Film Preservation Committee of our Society, the Bureau of Standards, and the various film manufacturers are closely coöperating with the Archives personnel.

MR. ABBOTT: If any members of the Society have bits of information or old documents that they feel would be of interest, we would appreciate their sending them to us. If they wish them back, we will photograph and return them. We hope to accumulate as much data as possible, and then see what can be done toward rearranging them into some straight-line history of the development of the film. Any documentation would be of the utmost interest and assistance to us.

MR. CRABTREE: Do you speak of films or literature?

MR. ABBOTT: Literature as well as films, but primarily histories of certain reports, findings of investigations, and all sorts of printed documents that have been extremely difficult to locate.

MR. TASKER: Including, I suppose, newspaper reports and records?

MR. ABBOTT: Including everything. It may interest you to know that already our library contains the largest collection of film books, magazines, and papers on the subject in existence. It is available for inspection by all who are interested in motion pictures.

MR. CRABTREE: What is the fee charged for lending the films?

MR. ABBOTT: On sending them out, we charge a fee to the college or university, which, at the present time, is about thirty-five per cent of the actual cost of preparation. The deficit is made up through an educational grant from the Rockefeller Foundation.

On any one series, a five-months' program including all the program notes for each member of the audience, and full musical score, the charge is $125. That comprises, in the first series, between 50 and 60 reels, plus the program notes, music, and lecture material.

MR. CRABTREE: Are single films available, or only the series?

MR. ABBOTT: In some instances single films have been rented if the institution has already used the entire series as a background for study. If they want supplementary instruction in one subject, such as the study of the technic of Mack Sennett or the development of action or narration in the Westerns, we send additional films for their undergraduate classroom work. Naturally, we are not in favor of releasing single films, but would rather have them in a program formulated to show some specific expression. We have no intention of going into the distributing business for revival films. Also, the films are not available to groups other than established educational institutions or museums, and they are to be shown only to persons who are accredited members of that organization. They can not be booked by a commercial theater.

MR. RICHARDSON: What has finally been determined as to the stability of the film; how long will an image last?

MR. ABBOTT: Certain experts who are interested in what we are doing have been coöperating with us on that problem. We had an unknown negative of 1897, which was printed perfectly. On the other hand, we have had negatives of 1930 and 31 that had to be restored before they could be printed. It is very difficult to make a definite answer concerning the life of any negative.

MR. RICHARDSON: If I may say this further, I have had photographs in my files for more than 50 years. Some of them are very badly faded while others are in perfect condition. Isn't it extremely likely that the same thing will be true of motion pictures and that the life depends upon the methods and the thoroughness with which they are washed?

MR. CRABTREE: The stability depends upon many factors, including the nature of the film, the degree of washing, and the time, temperature, and humidity of storage.

A NEON-TUBE OSCILLOSCOPE FOR THE PROJECTION ROOM*

F. H. RICHARDSON** AND T. P. HOVER†

Summary.—*After a brief discussion of the matter of suitable instruments and tools for the projectionist, for adjusting and maintaining his equipment, a neon-tube oscilloscope for investigating defects in the sound reproduction is described. By means of this instrument the presence of noises and other defects in reproduction due to maladjustment of the equipment can be detected, and the means of eliminating these distortions indicated.*

The general construction of the instrument and some of its applications are described.

The advent of sound brought about many changes in motion picture-sound projection. Perhaps the most noticeable change is in the type of tools and maintenance equipment required in the modern projection room. True, some of the silent picture "operators" who boasted of twenty years' experience with one pair of plyers and a screwdriver as a tool kit had finally risen to the heights of an added hammer and perhaps even a wrench; but the projectionist of today who is able to take proper care of modern equipment, and make necessary emergency repairs, must have many tools and even some precision instruments.

Unfortunately, as matters now stand, the projectionists who receive the highest wages usually need the fewer tools, because most of the larger theaters paying such wages now engage maintenance service, and necessary repairs are made either by engineers or by factory representatives.

On the other hand, in the smaller theaters, where the wages are lowest, the projectionists usually must do their own maintenance work and be able to take care of almost every kind of emergency

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** New York, N. Y.

† Ohio Theater, Lima, Ohio.

repair. These men in many cases find the outlay required for proper tool equipment beyond their means, and most theater managements fail or refuse to provide proper tools. Lack of adequate tools can not, therefore, be wholly blamed upon the projectionist. Having inadequate means, he finds available an assortment of tools that are questionable and very often offered at fanciful prices. This great industry should see to it that tools of really good quality are supplied to those who are required to take care of its splendid equipment, and supplied at reasonable prices.

One instrument in particular, that many projectionists would like to have available, is a good tube-tester and combination voltmeter and ammeter. It has been only very recently that we have been able to purchase reasonably accurate equipment of this sort for less than a month's salary. The alternative has in many instances been the construction of tools and test equipment by projectionists themselves, or by groups organized for the purpose.

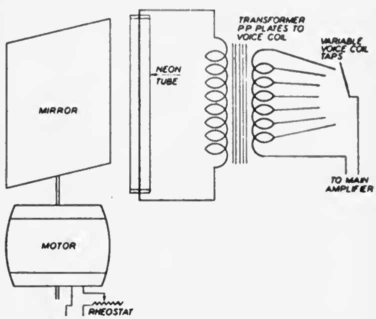

FIG. 1. Diagram of neon-tube oscilloscope.

About the time the cathode-ray oscilloscope came into practical use many projectionists realized that such an instrument would be of great value in the projection room, but the cost acted as an effective deterrent to its general use. After considering the problem, the authors came to the conclusion that it would be quite possible to devise an instrument that would provide at least a reasonably accurate record of sound phenomena and be easy to construct, simple to operate, and reasonable in price.

The first experiments were with a crystal-controlled oscillating mirror, which projected a more or less accurate picture of the sound-wave, but the plan was abandoned because of the mechanical and optical difficulties involved. Experiments with various kinds of recording lamps showed excellent response to the audio signal, but the light emission was too feeble for successful scanning or analyzing. Finally a neon-tube volume indicator was chosen, after many trials of tubes of various kinds and characteristics. The instrument has been put into production at a very low price. It can be successfully used by the projectionist who is willing to apply himself to the study of matters he must understand in any event if he hopes to give efficient results in the projection room. If the projectionist wishes to construct one himself, he can do so for about two and a half dollars, with a little ingenuity. The instrument is stable in operation, and with reasonable care will last indefinitely. Fig. 1 is a diagram of the arrangement.

A tube of the neon type has recently been placed upon the market by a radio parts manufacturer that is adaptable to this instrument. There also is a mirror which may be attached to a motor shaft and used for scanning the neon discharge. The other important parts of the instrument are a variable-speed motor, with control, and a transformer that will step up the amplifier output to approximately 250 volts. An independent amplifier may be used, or the regular amplifier of the theater sound system will prove satisfactory.

FIG. 2. Commercial unit.

Although the tube may be operated directly from the output tubes of the amplifier, a matching transformer is much more satisfactory. It should be of the universal type originally employed for coupling push-pull output tubes to variable voice-coil taps. As the load on the tube is less than ten milliamperes, almost any size of transformer will serve.

This instrument, properly handled, enables one to inspect the output of the sound system, and facilitates the precise setting of the exciter lamps, a procedure that is not too well understood by a large percentage of projectionists. If the setting is incorrect, jagged lines appear upon the mirror when the projector is running without film, due to the vibration of the exciter lamp filament, which modulates the light-beam and produces a characteristic noise oscillogram. Proper setting of the lamp smooths this out and assures the best possible results.

Tube microphonics show up instantly as jagged lines in the oscillogram when the tube is touched or gently vibrated. If slight noise is indicated, and the tubes and other equipment are apparently in good condition, one may suspect a noisy photoelectric cell, which conclusion may be immediately checked by replacing the cell.

Loose elements in the optical system are more common than is suspected. They may be checked by opening the gain control or the fader wide, and tapping the various elements with a hammer made of a rubber eraser attached to a stick. Poor joints or connections in wiring circuits may also be discovered in the same way, and are usually identified by bright and jagged noise patterns in the oscillogram.

FIG. 3. Home-made unit.

The instrument has been found extremely helpful in setting up the bevel gear that drives the micarta gear on the constant-speed shaft of the Western Electric reproducer. A test prod was made by placing a long steel needle in a Western Electric *2A* reproducer connected to the regular sound system amplifier. The oscilloscope was connected to the output of the amplifier, and a sensitive vibration detector was thus provided. The needle was held against the center of the constant-speed shaft and also on the bracket of the *708A* drive. When the gear was too loose the backlash registered upon the oscilloscope mirror; when too tight, the gear chatter appeared in the form of a distinctive noise oscillogram. Both show up as parasitic wave-forms that follow and in some cases overshadow the wave-form registered for proper gear operation.

The test prod will find many such uses in the projection room where slight adjustments and closer checking will effect great improvement in reducing both gear noise and wear.

A contact type of microphone or pick-up may be substituted for the Western Electric *2A*, for studying floor and structural vibration in projection rooms. Frequently a small wedge properly inserted beneath the projector or the motor-generator will effect wonders in quieting the operation of the machines.

DISCUSSION

MR. HOVER: I believe that the present system of servicing leaves much to be desired. It is not entirely the fault of the companies furnishing the service; there are union regulations that prevent it from being as successful as it might be. That is the reason why I have personally advocated that the projectionist himself do his part.

The average projectionist is a bit "touchy." On the other hand, he has a certain pride in his work, and within him feels a certain amount of resentment. I believe that resentment was aroused when sound first came in. The attitude of the service men who first went into the field was responsible for it. The attitude was "I am the authority." They ignored the common courtesies to the men with whom they worked. The situation has changed, we all know, but the feeling still persists, and the average projectionist is just a bit doubtful about the service men.

Regardless of the amount of equipment that the engineer may bring in, the projectionist would rather use a dollar meter or its equivalent for testing, and use his own brains in applying the meter, than to use one hundred dollars worth of equipment that the engineer brings with him. That is the spirit that exists.

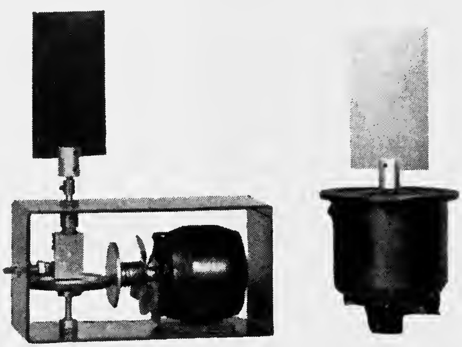

FIG. 4. Mirror and motor assembly.

While I am not in a position to state facts and figures, I feel that servicing is not covering the theaters that need it. The ones that need it are the little theaters, the "shooting galleries," as we call them. After all, they support the industry to a large extent. Recently I heard it said that considerable original thought, so far as projection is concerned, originates in those theaters because the men are on their own; if they can not make inferior equipment work, then the results suffer. If developing a little idea such as this instrument will help them, I believe it deserves the attention of the engineers. After all, the projectionist has considerable to say as to whether the picture is going to be a failure or a success.

MR. WOLF: Then I take it, Mr. Hover, that you advocate that each projectionist service his own equipment?

MR. HOVER: Not at all. The projectionist should get all the help he can from the service men. But, I do not believe that he should be permitted to lean upon the service men and depend upon them for the thought and initiative that he requires for his own job.

NEW MOTION PICTURE APPARATUS

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

NEW RECORDING EQUIPMENT*

D. CANADY**

When designing sound-film recording equipment for use in foreign countries, for small studios and free-lance cameramen, the limitations imposed by the intended use of the equipment must be taken into account. Power lines of various voltages and frequencies, the lack of skilled technicians, and laboratory facilities for processing sound-film are factors that must be carefully considered.

Much has been said and written during the past few years regarding the relative merits of the various methods of recording sound upon film. The methods can be roughly divided into two classes: the variable light-source and the constant light-source. The former appears in the glow-lamp system, and the latter in the systems employing the ribbon light-valve and the galvanometer. All such systems are capable of recording sound of excellent quality.

Next to selecting the recorder itself, the most important item is the light-modulating device. Due to its great simplicity and excellent recording qualities, the glow-lamp is ideally suited to the small producer because of several reasons: (*1*) it contains no moving parts, and therefore requires no delicate adjustments; (*2*) it is free from harmonic distortion (harmonics introduced in the other systems become serious with increasing frequency); (*3*) with fixed slit dimensions, glow-lamps are capable of recording frequencies beyond the audible limit; (*4*) from an economy standpoint the glow-lamp is preferable to other types since no additional apparatus is required to keep it in working order.

Glow-lamp recording requires that the exposure be confined to the lower portion of the H&D curve and is known as toe recording. Toe recording possesses certain advantages not found in other methods; some of which are mentioned below:

(*1*) No special developer is required for the sound negative or positive. One bath serves for both negative and positive as well as for picture prints.

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** Canady Sound Appliance Co., Cleveland, Ohio.

(*2*) For the same recording level, toe-recording gives approximately 6 db. more volume in reproduction than the methods using the straight-line portion of the H&D curve.

(*3*) Toe recorded negatives can be reproduced as easily as positives. This is an important item when only one print is to be made, as for re-recording, producing incidental music for titles, *etc.*

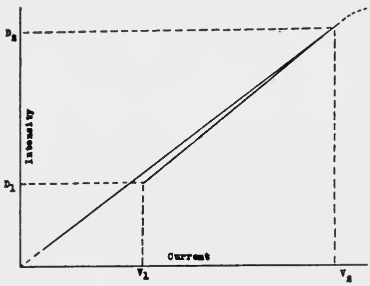

FIG. 1. Characteristic curve of glow-lamp.

(*4*) Toe recording is less affected by slight variations of gamma. A transmission of 45 to 50 per cent is satisfactory for both negative and positive.

(*5*) In practice, toe recording has the same modulating range and overload point as other methods.

Theoretically, straight-line recording is superior for noise reduction, but unless up-to-date processing methods are available and the recording equipment is operated by skilled technicians, the toe method will give equal results.

Recording Lamps.—In recent months marked improvement has been made in recording lamps. Present lamps operate at comparatively low voltage and are

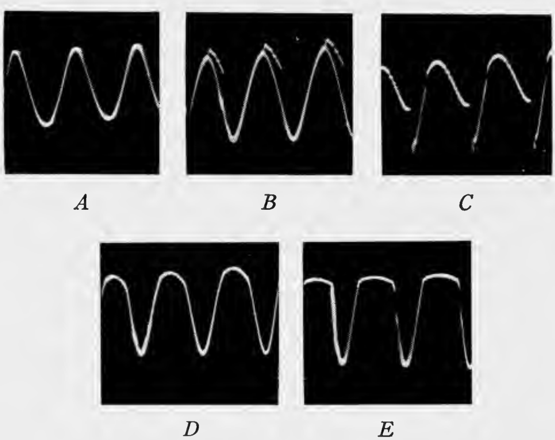

FIG. 2. (*A*) 1000-cycle oscillogram of 3-element lamp with the third electrode disconnected; (*B* and *C*) modulated to the point at which extinction begins; (*D*) resistor reduced to 0.05 megohm; (*E*) series resistor shorted, producing bad distortion.

quite uniform. Sufficient exposure for toe recording is easily obtained with lamps operating at 250 volts and approximately 10 ma. They will withstand considerable overload without damage or "smoking up" on the end. A patent has recently been granted[1] on an improved type of lamp that delivers sufficient light for straight-line recording.

A feature of the present lamp is its suitability for use in noise-reduction circuits. Lamps drawing 10 ma. at 250 volts can be reduced to 1 ma. at 200 volts before extinction begins. The spectrum of the emitted light matches very closely the sensitivity spectrum of positive recording stock.

It is well known[2] that light produced by a gas-filled lamp varies in intensity

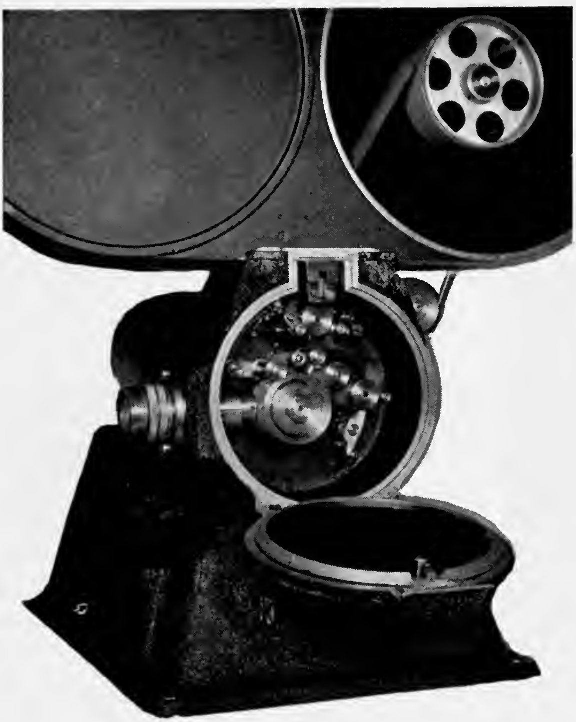

FIG. 3. The new sound-film recorder.

according to the current applied to the electrodes. The time-delay is so small that oscillations of the order of one millionth of a second can be faithfully followed.

The intensity is a function of the applied current, as indicated in Fig. 1. Increasing the polarizing voltage from zero, the lamp does not light until a certain value, V_1, has been attained, producing an intensity of D_1. From that point the intensity is a linear function of the current up to a value V_2, when the relation ceases to be linear.

If the current is then decreased from the value V_2, a new curve results. The descending curve almost coincides with the ascending curve, but remains slightly above it. As the descending curve passes the ignition point V_1, the lamp is not extinguished at once, but the intensity continues to decrease steadily almost to zero. In order to avoid distortion, it is necessary to limit the operation of the lamp between the values V_1 and V_2.

Three-Element Recording Lamps.—It has been stated[3] that by adding a third element to the two-element lamp, a wider modulation range can be obtained without distortion due to the ionization-maintaining current flowing through the third electrode at all times. It has been common practice to connect the additional electrode to the high-voltage supply through a resistance of one or two megohms. Neglecting the lamp resistance, a 2-megohm resistor in series with a 300-volt supply allows only 0.00015 ampere as the steady ionizing current. Recent investigation has shown that when sufficient current flows through the third electrode to enable it to function as a maintaining element, the wave-form is distorted in proportion to the current flowing through this element.

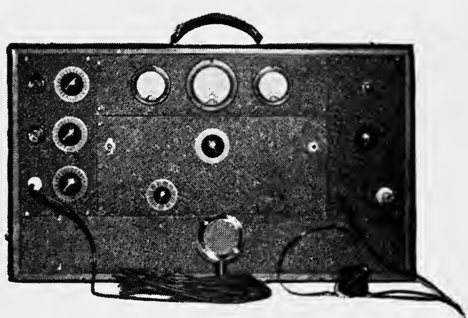

FIG. 4. Recording amplifier.

A 1000-cycle oscillogram of a three-element lamp operating as a two-element lamp with the third element disconnected is shown at *A* in Fig. 2. *B* and *C* (Fig. 2) are oscillograms of the lamp modulated to the point where extinction begins. Connecting the third electrode to the 300-volt polarizing voltage through a 1-megohm resistor had no effect upon the wave-forms *B* and *C*. When the resistor was reduced to 0.05 megohm, the wave *D* resulted. *E* shows a badly distorted wave caused by completely shorting out the series resistor. It is apparent that the introduction of a third electrode introduces distortion by cutting off the peaks, and reduces the modulation range of the glow-lamp instead of increasing it.

Noise-Reduction Unit.—High standards set by the industry demand that the light falling upon the unexposed film during recording be reduced to a low value during periods of no modulation, for which purpose an auxiliary unit has been provided. Design considerations indicate the necessity of keeping the light intensity within limits not exceeding the straight portion of the H&D curve. Circuit design prevents the exposure from dropping below fixed limits, and excessive volume will not increase the exposure beyond the straight portion of the curve due to saturation of control unit. Patent has been applied for on certain improvements incorporated in this unit, and additional details can not be given at this time.

Recording Lamp Polarizing Voltage Supply.—In the past, the polarizing voltage required by recording lamps has been largely furnished by heavy-duty radio *B* batteries. Difficulties experienced in obtaining replacement batteries in foreign countries and out of the way places has led to the development of a small rectifier unit supplying a maximum of 500 volts directly from a 6- or 12-volt storage battery. Rectifier units for operation on 110–220 volts a-c. are available for studio use. The hum level is reduced to a low value by thorough filtering, and no trouble has been experienced from this cause.

New Sound-Film Recorder.—A new recorder possessing unusual constancy of speed is shown in Fig. 3. The recorder proper is of cast aluminum, and a ribbed base of generous proportions minimizes the vibration of the driving motors operating on low-frequency power lines.

Three flywheels, in addition to a non-resonant sprocket filter, maintain the film speed constant. A heavy flywheel is located upon the shaft of the recording drum, one of slightly smaller dimensions is used upon the shaft of the driving motor, and a third upon the drive sprocket shaft.

An unusually large "wrap" around the recording drum allows full advantage to be taken of the stabilizing effect of the large flywheel. Accurately cut gears of special pitch are used throughout, and contribute largely to the quietness of the machine. By using "silenced" magazines, the recorder can be used in close proximity to microphones when occasion arises. Provision has been made for using glow-lamps or any other type of modulator. Ample room has been provided in the base for meters, receptacles, switches, *etc.*

Recording Amplifier.—A semi-portable recording amplifier mounted in an oak carrying-case having removable metal panels is shown in Fig. 4. Three mixing controls with their associated input receptacles are mounted upon the left panel. The top panel includes a filament voltmeter, calibrated volume indicator, and a milliammeter. The amplifier is located behind the center panel, which is instantly removable for replacing tubes, *etc.* Plate-circuit jacks are provided in the amplifier chassis for testing purposes. Output controls are mounted upon the panel at the right, and plate-supply batteries are stored in a compartment behind the bottom panel. The amplifier furnishes sufficient amplification so that low-level microphones may be used direct without the need of preamplifiers.

This form of construction possesses several advantages: (*1*) less trouble is likely to develop when all the components are rigidly mounted together in one case; (*2*) less time is consumed in setting up the equipment, and delays often caused by bad connections in plugs and cables are eliminated; (*3*) less chance of hum pick-up due to the short leads and thorough shielding.

Another amplifier of extremely light weight is housed in an aluminum case. Weight has been reduced to a minimum through the use of new light-weight transformers and condensers. Amplifiers for studio use are furnished for standard rack mounting, and operate on batteries or local power supply.

REFERENCES

[1] U. S. Patent No. 2,038,825.

[2] MOREAU-HANOT, M.: "Photométrie des Lumieres Brèves ou Variables," *Revue d' Optique Théorique et Instrumentale* (Paris), Chapt. XI, p. 106 (1934).

[3] BRAMAN, V. T.: "Glow-Lamp Sound-on-Film Recording," *Electronics*, **2** (June, 1931), No. 6, p. 679.

A NEW REEL-END ALARM*

D. CANADY AND V. A. WELMAN**

As the duties of the projectionist in a modern motion picture theater become more numerous and exacting, and as the quantity and intricacy of the equipment intrusted to his care is continually increased, some positive, unfailing means of announcing to him the impending finish of the reel he is showing upon the screen becomes absolutely necessary.

Without some such signal, tests, adjustments, repairs to equipment, or other work of immediate necessity must often be neglected in order to devote the last few minutes of a nine- or ten-minute reel to watching for the end, or, as an alternative, doing his other tasks and taking a chance on catching the change-over when the time comes.

Even in the silent days, when the operation was simpler, there was a general demand for some such signal, the earliest, perhaps, being a coin wound into the reel of film fifty or a hundred feet from the end. When the film unrolled to the proper point the coin would drop and the resulting clatter would provide the signal.

The most common device, both of the silent days and at the present time, is an arm pivoted near the edge of the magazine, bearing upon its free end a roller which rests on the film as it unwinds. When the core of film is no longer large enough to support it the roller drops with a bang, sounding a warning.

Thousands of this type of reel-end alarm are in use, and these thousands in constant daily use have caused and are causing an immense amount of film damage. It is no use to argue that with proper care it need not damage the film, or that if properly designed no damage will result. The proof of the matter may be had by dropping into any second-run theater in the country and watching the wavy scratch down the center of almost every reel.

Since the roller rides upon the emulsion side of the film, which, in first-run houses is usually fairly "green," this type of alarm is particularly dangerous in those houses.

This type of reel-end alarm has the further disadvantage that it must be manu-

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** Canady Sound Appliance Co., Cleveland, Ohio.

ally reset each time a reel is threaded in the projector. The human factor is thereby introduced, which is especially likely to fail during periods of difficulty with other parts of the projection room equipment, just at the times when the reel-end alarm is of most importance.

The requirements for a successful reel-end alarm are:

(*1*) It should accurately and positively announce the approach of the end of the reel, a predetermined distance from the end.

(*2*) It should not damage the film in any way.

(*3*) It should be automatic in action, requiring no act on the part of the projectionist to place it in operation.

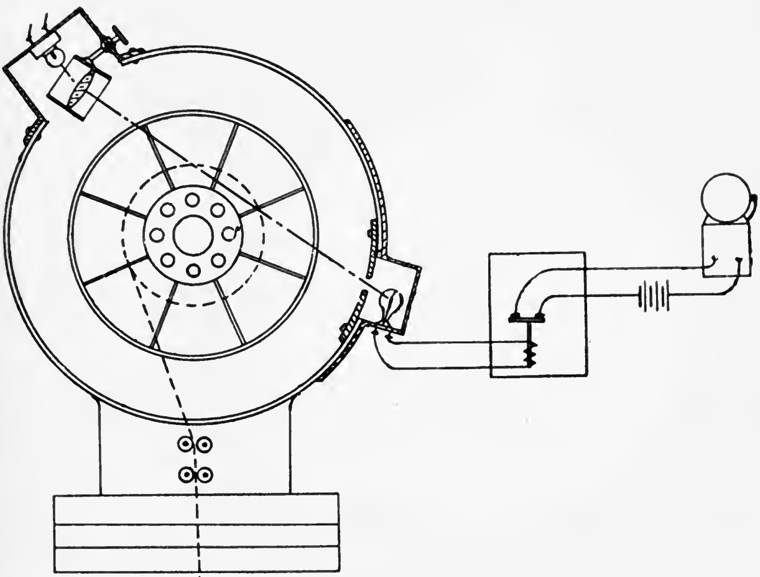

FIG. 1. Schematic arrangement of reel-end alarm.

(*4*) It should be rugged, and easy to install and maintain. These requirements are fulfilled in the alarm described here. Experimental samples were constructed and used about five years ago. The patent was applied for in 1932 and was recently issued as No. 1,982,133. The principle employed is that of uncovering a beam of light so that the light will fall upon a light-sensitive cell when the film unwinds to a predetermined point, a principle well known now and applied to many uses during the past year, but something of a mystery at the time the first models of this reel-end alarm were constructed.

The patent drawing (Figs. 1 and 2) is self explanatory, although in actual application many variations are possible as to light-source, lens, adjustment, type of light-sensitive cell, and relay and signalling device. The apparatus consists essentially of a light-source and a focusing and adjusting device, in a case attached to the upper magazine; and a light-sensitive cell to receive the beam of light after it has passed the core of the reel of film. The light-sensitive cell is connected to a suitable relay, either vacuum-tube or magnetic, which operates a signal consisting of lights, buzzer, or electric bell. A one-stroke bell is perhaps the best signal. The power for the circuit is derived from the commercial power lines, no batteries being required.

As can be seen from Fig. 1, when the reel of film has been reduced to a predetermined size, the beam of light is no longer interrupted but proceeds to the light-sensitive cell. Perhaps the most compact and most easily installed arrangement is to house the light-source, a copper-oxide cell, relay, and bell with their necessary associated parts in one metal box, mounted directly upon the magazine, returning the beam of light from the exciter lamp to the photoelectric cell stationed along-

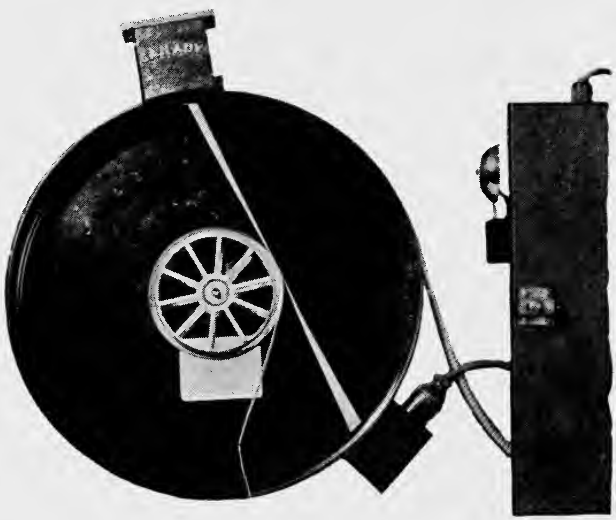

FIG. 2. Photograph of installation.

side it by means of a glass or metal mirror attached to the magazine upon the opposite side of the reel. Such an installation would require a minimum of changes in the magazine, the only outside electrical connection being a rubber- or metal-covered cord to the framing-light circuit or other convenient lighting circuit.

DISCUSSION

MR. CRABTREE: What is the sensitivity of the reel-end alarm, in terms of film convolutions?

MR. WELMAN: In this experimental set, two or three layers of film.

MR. CRABTREE: Can any projectionist say whether that sensitivity is adequate?

MR. HOVER: I believe that that is more sensitive than the average roller alarm. I checked the roller type some time ago, and found that it will drop, as a rule, anywhere within a length of film of approximately 12 feet one way or the other. Even the most careful and accurate set-up has a certain amount of play in the bracket or arm that holds the rolls, and it is also influenced by whether the film is wound tightly or loosely.

MR. CRABTREE: When the usual black spot appears upon the screen, what tolerance does the projectionist have? In other words, how many seconds may elapse before he throws the change-over switch?

MR. WELMAN: This appliance has nothing to do with change-over. This provides a signal indicating that the change-over dot is soon coming. It is to warn the projectionist to look for the dot.

MR. CRABTREE: Why could it not be used to eliminate the black spot?

MR. WELMAN: It is not accurate enough for that. To eliminate the dot you must hit it within a couple of frames.

MR. TOWNSEND: I used to disapprove reel-end alarms for the reason that I felt it gave the projectionist a chance to nap, or do something other than pay attention to the show. Since I have gone back into the projection room I have used the alarm myself, not so that I can take a nap, but because the alarm has certain advantages, especially in smaller theaters that are now using the Suprex carbons which burn at quite a high rate.

The reel-end alarm provides a very definite time in which to light the arc. The projectionist can gauge the length of carbon, and can use short lengths to advantage. The human factor enters in this way: A projectionist who happens to be of a nervous temperament is likely to strike the arc two or three minutes earlier than is necessary if he merely looks at the amount of film left upon the reel. If he has an alarm that is thoroughly accurate, he will not light up too soon. Another projectionist may strike the arc too late, so as to utilize as much of the carbon as possible. He may change over and find that he has a poor light because of having struck the arc too late.

MR. HOVER: A signal of this type would be greatly appreciated by projectionists who have gone through a fire in the projection room. After such an experience the projectionist will have a strong aversion to opening the magazine door when the machine is running.

The condition actually exists, that because the little ports, or windows, in the magazines are not well lighted, the magazine door is sometimes left open so that the projectionist can watch the film. Every projector should have some kind of device that will indicate the time to light up the arc without having to open the magazine door.

MR. DANIELSON: Is the danger of fire increased by putting an exciter lamp in the upper magazine? What do the fire authorities think of the device?

MR. WELMAN: The lamp is in a separate box, and is blocked off by a glass plate. It is no worse than the light now in the magazines, which the underwriters have approved.

A DEMONSTRATION TRIODE FOR VISUALIZING ELECTRONIC PHENOMENA*

F. E. ELDREDGE AND H. F. DART**

Several discoveries that were later to prove fundamentally important in the design of electronic tubes were made shortly before the turn of the twentieth century. Edison, in 1889, had just invented a practical and commercial electric lamp. In 1895, Roentgen, the German, showed his first x-ray pictures. In 1896, Becquerel, the Frenchman, discovered radioactivity. Two years later, radium was discovered by the Curies in France. From these discoveries arose many new concepts of physics and many developments that later evolved into extremely useful tools.

Starting in 1900, many theories of physics required an electron. Milliken measured the electric charge of the electron and found the value so minute that it is difficult to picture its size. In their book, *Photocells and Their Applications*, Zworkin and Wilson say:

"To realize how small the mass of an electron is, imagine an electron speeding through space at the rate of 100 miles an hour or about 150 feet per second. Let us calculate the force of a blow it would give to an obstacle placed in its path, assuming the electron was brought to a dead stop in one-tenth second. We will find the average force experienced by the obstacle would have the amazingly small value of one hundred-thousand-million-billion-trillionth of a pound, or 1/100,000,000,000,000,000,000,000,000,0001b."

It is interesting to note how quickly the fields of industry and amusement have put the new ideas into practical, every-day use. In fact, one of the amazing characteristics of this age is not only the willingness to accept changes, but the will to utilize the achievements of science and scientific minds.

To be more specific, let us consider the filament of a lamp. It receives heat energy, which causes luminescence. An incidental by-product is the liberation of electrons near this filament. In a lamp, however, they do not serve any direct useful purpose. Placing to one side of a heated filament a piece of metal or a plate, on which a positive voltage is applied, will produce an appreciable flow of current between the heated filament and the plate. A modification of this simple device has considerable importance, for in a proper circuit it will convert alternating into direct current suitable for operating arcs of motion picture equipment, for

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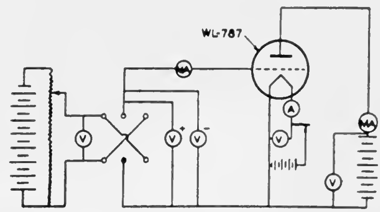
* Received September 17, 1936; presented at the Fall, 1933, Meeting at Rochester, N. Y.

** Special Products Sales Department, Westinghouse Lamp Co., Bloomfield, N. J.

charging storage batteries, for driving trolley cars, and for a host of other similar applications.

Some thirty years ago, Dr. Lee de Forest discovered that a grid, placed between the heated filament and the plate of the tube, exerted a definite control over the passage of electrons from the filament to the plate. The result was the three-electrode tube, which depends for its operation upon the unidirectional flow of electrons from a thermionic cathode to a positive plate, with a grid between the two. A small voltage applied to this grid can oppose or add to the effect of voltage on the plate. In other words, the grid permits controlling the space current flowing between the plate and the cathode.

FIG. 1. The effect of the electrons striking the plate, which is coated with willemite, is seen in luminous bands. The width of these light bands may be varied by changing the voltage of the grid or the plate.



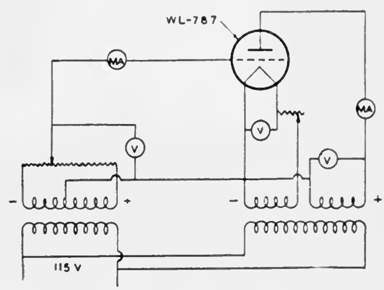


FIG. 2. (*Above*) Circuit for operating the *WL-787* triode on direct current.
FIG. 3. (*Below*) Circuit for operating the *WL-787* triode on alternating current.

The action of the grid may be likened to that of a valve in a water-pipe. A small amount of energy, applied to opening and closing the valve, controls a much larger amount, represented by the water under pressure. The grid is usually operated at a potential negative with respect to the cathode, since then no current is drawn by it, and, consequently, no power, Thus, within a few years a new tool—the electronic tube—has been developed, which has since become indispensable in the fields of communication, manufacturing, amusement, medicine, and many others. Typical examples are the universal use of electronic tubes in radio transmitting and receiving equipment; long-distance telephone lines; the quick response a decade ago of the motion picture industry to add sound to their films, thereby utilizing phototubes, rectifiers, and amplifier tubes; oscillator tubes in short-wave therapy equipment; and now industries of all kinds are using phototubes, amplifiers, high- and low-voltage rectifiers, and grid-glow tubes in the initiation and control of many manu-

FIG. 4. Showing the magnetic effect upon the fluorescent pattern.

facturing processes. There is now a degree of reliability and constancy of characteristics not approached by the tubes of a decade ago.

"SEEING" ELECTRONS BY FLUORESCENCE

The widespread use of electronic tubes in all fields of endeavor has led to the introduction of courses of instruction in electronics in the curricula of many universities, colleges, and technical schools. The Westinghouse Demonstration Triode *WL-787* was developed for use in studying the fundamental principles and operation of the three-electrode tube. It shows visually, in a manner impossible to accomplish in any other way, exactly what takes place when changes are made in the grid and plate voltages of a vacuum tube.

By varying the grid voltage in steps, the effect of changing excitation upon the electron flow from the filament to the plate, and the correlation of this action with fluorescence on the anode, can readily be shown. The controlling effect of the grid upon the electrons radiated by the filament is demonstrated by the fluorescent pattern upon the plate. When greater and greater negative voltage is applied to the grid, the fluorescent strips opposite the openings of the grid become narrower and narrower, until finally they disappear. This condition corresponds to the grid-bias value at which plate current cut-off occurs, and under which condition no electrons will reach the plate.

The grid may be made still more negative, without further apparent change. Such condition corresponds to that existing in an actual triode when the net voltage of the grid is greater than that required to produce plate-current cut-off.

Lessening the negative voltage of the grid will cause the fluorescence to reappear, and the width of the strips will increase as the net voltage is decreased. The fluorescence will be proportional to the rate at which the electrons reach the plate, which is also a measure of the plate current. As the grid becomes positive with respect to the filament, the fluorescent lines become still wider and wider; until, when the grid becomes positive, the fluorescence covers the entire plate with quite uniform intensity.

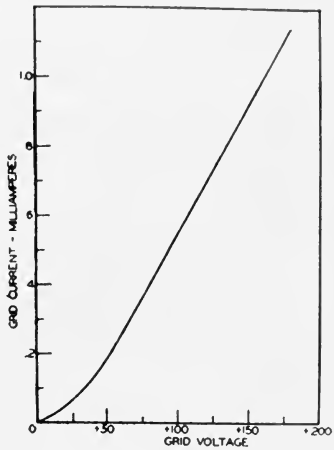


FIG. 5. Average grid characteristic of the *WL-787* triode; characteristics of individual tubes may vary widely from those shown.

EFFECT OF DISTORTION

Distortion in an amplifier may be demonstrated by using a large excitation signal or a wide range of grid voltage. It may thus be shown that the width of the fluorescent bands does not vary in proportion to changes of grid voltage, particularly when the excitation is so great as to cause plate-current cut-off. In the latter case the width of the fluorescent bands will not accurately follow the excitation voltage values, corresponding to the conditions existing in a triode when there is distortion in the ouput.

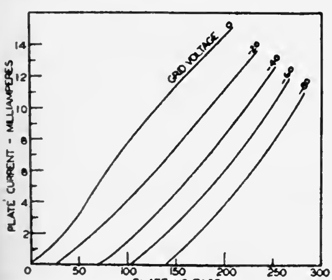


FIG. 6. Average plate characteristic of the *WL-787* triode.

The amplifying effect of the tube may be demonstrated by noting the grid and plate voltages for a certain amount of fluorescence on the plate, and then changing the grid voltage by a few volts, say, 10. It will be found that the plate voltage must be changed by a much greater amount to restore the fluorescent bands to their original width. The ratio of the change of voltage of the plate required to compensate for the change of grid voltage is the amplification factor of the tube.

Another interesting demonstration is to hold a strong magnet near the side of the plate. In addition to showing visually the effect of the magnetic field upon the electrons and their distribution, it is possible under favorable conditions to obtain a representation of the lines of magnetic force.

The filament consists of several parallel oxide-coated wires, all of which are located in one plane, so as to distribute the plate current uniformly. The anode is the usual flat plate mounted parallel to the plane of the filament. The grid is a fairly open and conventional structure mounted between the filament and the plate. A coating of willemite on the side of the plate toward the grid and filament shows a bright greenish fluorescence when bombarded by the electrons emitted by the filament. The glow is pronounced and clearly visible wherever the electrons strike, producing a definite pattern of the grid upon the plate.

TABLE I

Design Data and Ratings of Type WL-787 Triode

	Voltage		Current	
	Normal	Max.	Normal	Max.
Filament	6.0	6.3	1.6 a.	
Plate		300		100 ma.
Grid		±200		50 ma.

Amplification factor	2 (approx.)
Filament	Oxide-coated
Plate size	$3 \times 1^1/_2$ inches (approx.)
Overall height	10 inches
Maximum diameter	$2^5/_8$ inches
Base	4-pin industrial
Socket	Ser. No. 793202

The size and arrangement of the parts have been made such as to render the tube useful in demonstrating the action of the grid in a three-electrode tube. The plate is large enough to permit the action to be visible to everyone in a lecture or classroom of reasonable size. A slight amount of experimentation will show how to handle the tube to demonstrate the desired effects. The tube is practically fool-proof, and will withstand a wide variety of operating conditions. Either alternating current or direct current may be used to heat the filament and to supply voltages for the grid and plate. A tube socket and adjustable sources of voltage are all that are needed to operate the tube, although a few meters will be convenient for making adjustments and readings.

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SPRING, 1937, CONVENTION

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HOLLYWOOD-ROOSEVELT HOTEL

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MAY 24th–28th, INCL.

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Headquarters

Headquarters of the Convention will be the Hollywood-Roosevelt Hotel, where excellent accommodations are assured. A reception suite will be provided for the Ladies' Committee, and an excellent program of entertainment will be arranged for the ladies who attend the Convention.

Special hotel rates, guaranteed to SMPE delegates, European plan, will be as follows:

One person, room and bath	$ 3.50
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	6.00
Parlor suite and bath, 1 person	9.00
Parlor suite and bath, 2 persons	12.00

Room reservation cards will be mailed to the membership of the Society in the near future, and everyone who plans to attend the Convention should return his card to the Hotel promptly in order to be assured of satisfactory accommodations. Special garage rates will be provided for SMPE delegates who motor to the Convention.

Railroad Fares

The dates of the Convention have been chosen in order that delegates may avail themselves of the summer tourists' rates, which go into effect May 15th. The following table lists the railroad fares and Pullman charges:

City	Railroad Fare (round trip)	Pullman (one way)
Washington	$120.75	$20.50
Chicago	86.00	15.75
Boston	132.80	22.25
Detroit	98.30	18.00
New York	126.90	21.75
Rochester	112.50	19.25
Cleveland	101.35	18.00
Philadelphia	122.85	21.00
Pittsburgh	107.10	18.75

The railroad fares given above are for round trips, forty-five day limits. Arrangements may be made with the railroads to take different routes going and coming, if so desired, but once the choice is made it must be adhered to, as changes in the itinerary may be effected only with considerable difficulty and formality. Delegates should consult their local passenger agents as to schedules, rates, and stop-over privileges.

New streamlined trains will be operating from Chicago to Los Angeles and San Francisco, making the trip to Los Angeles in 39 hours. Special fares are levied on these trains.

Technical Sessions

An attractive program of technical papers and presentations is being arranged by the Papers Committee. 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.

Semi-Annual Banquet

The Semi-Annual Banquet of the Society will be held at the Hotel on Wednesday, May 26th. 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.

Inspection Tours and Diversions

Arrangements are under way to visit one or more of the prominent Hollywood studios, and passes will be available to registered members to several Hollywood motion picture theaters. Arrangements may be made for golfing and for special trips to points of interest in and about Hollywood.

Ladies' Program

An especially attractive program for the ladies attending the Convention is being arranged by Mrs. K. F. Morgan and Mrs. P. Mole, *hostesses*, and their Ladies' Committee. A suite will be provided in the Hotel, where the ladies will register and meet for the various events upon their program. Further details will be published in a succeeding issue of the JOURNAL.

Points of Interest

En route: Boulder Dam, Las Vegas, Nevada; and the various National Parks.

Hollywood and vicinity: Beautiful Catalina Island; Zeiss Planetarium; 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 SMPE motion picture exhibit): Mexican village and street, Los Angeles.

TENTATIVE PROGRAM

Monday, May 24th

10:00 a.m. *Blossom Room*
Registration
Society Business
Committee Reports
Technical Papers Program

12:30 p.m. *Florentine Room*
Informal Get-Together Luncheon for members, their families, and guests. Brief addresses by several prominent members of the industry.

2:00 p.m. *Blossom Room*
Technical Papers Program.

8:00 p.m. (To be announced later.)

Tuesday, May 25th

10:00 a.m. *Blossom Room*
Technical Papers Program

2:00 p.m. (To be announced later.)

8:00 p.m. *Blossom Room*
Technical Papers Program

Wednesday, May 26th

10:00 a.m. *Blossom Room*
Technical Papers Program

2:00 p.m. (To be announced later.)

8:00 p.m. *Blossom Room*
Semi-Annual Banquet and Dance of the SMPE; Addresses by eminent members of the industry; dancing and entertainment.

Thursday, May 27th

10:00 a.m.	Open morning
2:00 p.m.	*Blossom Room* Technical Papers Program
8:00 p.m.	*Blossom Room* Technical Papers Program

Friday, May 28th

10:00 a.m.	*Blossom Room* Technical Papers Program
2:00 p.m.	*Blossom Room* Technical Papers Program Open Forum Adjournment of the Convention

NOTE: All technical sessions will be held in the *Blossom Room* of the Hollywood-Roosevelt Hotel. There will be no public exhibit of apparatus anywhere in the Hotel; although members registered in the Hotel will, of course, be privileged to display any equipment they wish in their own rooms.

SOCIETY ANNOUNCEMENTS

PACIFIC COAST SECTION

At a meeting held on January 28th at the auditorium of the Hollywood Chamber of Commerce, a paper by Dr. C. E. K. Mees, *Vice-President* and *Director of Research,* Kodak Research Laboratories, Rochester, N. Y., was presented, entitled, "Interesting Phases in the Historical Development of Photography, Including Recent Progress." As the subject was of wide interest to the industry, the meeting was well attended.

Arrangements are being made by the Board of Managers under the Chairmanship of Mr. K. F. Morgan to conduct a series of interesting meetings each month during the season. Members of the Pacific Coast Section are reminded that the Society has recently established a West Coast office in the Taft Building, at Hollywood Boulevard and Vine St., Hollywood, under the Management of Mr. Walter R. Greene.

MID-WEST SECTION

The regular monthly meeting of the Section was held on February 11th in the review room of Paramount Pictures Distributing Corp., Chicago, Ill. Mr. E. R. Geib, of National Carbon Company, Cleveland, Ohio, presented "The Story of the Carbon Arc," a discourse and demonstration film showing the process of carbon manufacture and the evolution of the carbon arc.

The next meeting of the Section has been scheduled for Thursday, March 11th.

ADMISSIONS COMMITTEE

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

Comi, P. E.
Theater Service & Supply Co.
112 Arlington St.
Boston, Mass.

Crowe, J. W., Jr.
837 W. 36th Place
Los Angeles, Calif.

Daley, T. S.
Imperial Theater
Toronto, Ontario, Canada

Dennison, L. I.
Patterson & Dennison, Inc.
6210 Greenfield Ave.
West Allis, Wis.

Dickerson, A. B.
738 Woodward Building
Washington, D. C.

Haddow, G. K.
Paramount Pictures, Inc.
1501 Broadway
New York, N. Y.

HESTERMAN, W. H.
6137 Addison St.
Chicago, Ill.

JOHNSON, G. A.
Eastman Kodak Co.
Rochester, N. Y.

KAUFMAN, H. C.
Columbia Pictures Corp.
729 Seventh Ave.
New York, N. Y.

LAMSON, F. M.
2901 First Ave., South
Seattle, Washington

LEROY, F. S.
RCA Manufacturing Co., Inc.
Camden, N. J.

RAPAROWITZ, G. A.
1505 Wicker Park Ave.
Chicago, Ill.

RATHMELL, R.
RCA Victor Co. of China
P. O. Box 123
Hongkong, China

REINHOLD, L.
95 Hillcrest St.
Great Kills
Staten Island, N. Y.

REYNOLDS, D. J.
272 Deverill St.
Ludlow, Ky.

SCHEFFY, H.
1279 Lake Ave.
Rochester, N. Y.

SCHOENBERG, M.
1540 Broadway
New York, N. Y.

SKELLY, J. P.
1514 Albany Ave.
Brooklyn, N. Y.

In addition, the following applicants have been admitted by vote of the Board of Governors to the Active grade:

GANSELL, A.
Audio Productions, Inc.
250 W. 57th St.
New York, N. Y.

LOYE, D. P.
Electrical Research Products, Inc.
7046 Hollywood Blvd.
Hollywood, Calif.

ROESSLE, H.
230 West End Ave.
New York, N. Y.

WOOD, C. R., SR.
30–38 29th St.
Astoria, L. I.

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

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See p. 431 for Technical Committees

A REVIEW OF THE QUEST FOR CONSTANT SPEED*

E. W. KELLOGG**

Summary.—*The importance of constant record speed in machines used for reproduction of music was realized by Thomas A. Edison and many other pioneers in sound recording. Crude performance from other standpoints made it hardly worth while for the earlier workers to attempt to obtain extremely high standards of speed constancy.*

The flyball type of phonograph governor came into the picture and has been worked so well that it has not even yet been superseded, although with synchronous motor drives for certain types of equipment the governor is no longer necessary.

Recording sound photographically probably began with the work of Alexander Graham Bell who made records on glass disks; but not until long celluloid films were available and the motion picture thoroughly established did photographic sound recording become a competitor with the disk. As late as 1930, there were many engineers who advocated the disk for sound-picture work. While the same general principle applies to both mechanical and photographic records, the latter involves certain additional problems.

Among the earlier workers in this field, the expedients adopted by C. A. Hoxie and C. L. Heisler, of General Electric Company, deserve recognition. The paper gives brief descriptions and discussions of a number of ingenious arrangements for improving speed constancy that have been employed by various inventors and engineers. Some of these expedients have been applied to record turntables and some to film equipment.

The need of constant speed in any device for recording or reproducing sound was quickly realized in the earliest experiments along these lines. Edison in patent No. 227,679, applied for in 1880, says, "In experimenting with the phonograph I discovered that the reproduction of sound was imperfect if the slightest variation occurred in speed; hence the combination of a cylinder with a very heavy flywheel."

Alexander Graham Bell and Sumner Tainter[1] experimented with various forms of phonographs. One of their early models is on exhibition in the Smithsonian Museum at Washington. The writer

* Presented at the Fall, 1936, Meeting at Rochester, N. Y.; received January 29, 1937.

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

SEE ERRATA – MAY PAGE 579

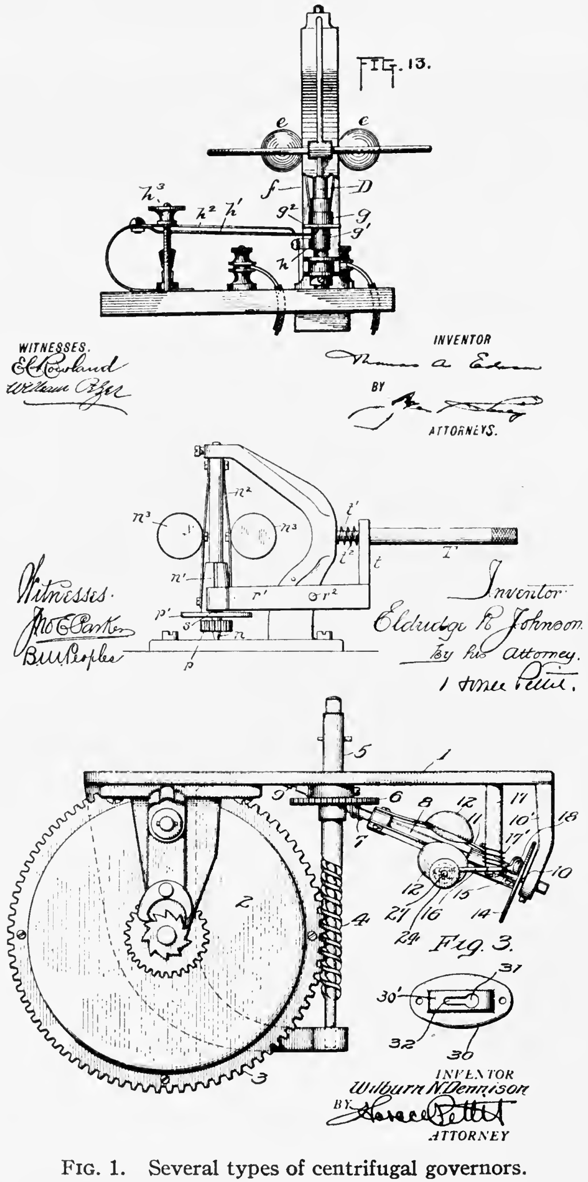

FIG. 1. Several types of centrifugal governors.

had occasion to have a copy made of this machine, which employed a large flywheel, and found that although this and the Edison machine were both driven by hand cranks, it was not difficult with the big flywheels to maintain a speed so nearly constant that fairly creditable reproduction took place.

The fly-ball governor, constructed so as to introduce friction as soon as the speed exceeds a certain value, was employed in some of the earliest phonographs. Fig. 1 shows several forms of phonograph governor. This device worked so well that in one form or another it has remained an essential feature of practically all phonographs until the advent within the past five or six years of phonographs driven by synchronous motors. In an art such as sound recording and reproduction, in which so many factors must be correct to produce a satisfactory overall result, it is not usual to find great refinements introduced in the effort to render one factor perfect so long as there are serious faults of other kinds. For this reason driving systems that today we might regard as short of satisfactory were in general considered good enough, until some of the recent improvements made the shortcomings in the matter of speed more evident. Examples of such advances are electric recording on wax,[2,3] the "orthophonic" phonograph,[2] electric reproduction from disk,[4] improvements in amplifiers and loud speakers,[5,6,7] the development of record materials having lower surface noise,[8] the working out of satisfactory recording on film, and the extension of the frequency range[9] through recent advances in technic. Nevertheless, there were evidently engineers and inventors who, considerably before these improvements came into being, were conscious of forthcomings in the driving systems, and introduced the idea of filtering out irregularities in speed. A French patent No. 10,377, issued to the Fabrica Italiana, Pellicole Parlate, dated June 19, 1909, shows a record turntable driven through a spring, the spring being wound with tape in order to damp out oscillations.

John Constable in a 1918 patent[10] showed a cylindrical record driven through springs, and gives an excellent description of the function of the springs in taking up the vibrations imparted by the driving system. It is possible that these inventors were stimulated to employ filtering systems because they did not have as good governors and gears as could be produced, for their devices did not come into general use until a much later date, and then in greatly modified form. Constant speed in recording or reproduction means not only uniformity of rotation of the record, but avoidance of other relative movements of the record and pick-up device. Thus, the effect of vibration of the pick-up, or record, or both, is the same as if there were changes in rotational speed of corresponding frequency and amplitude. E. H. Amet in a 1917 patent[11] relating to sound motion pictures, shows a very well thought out system for preventing the transmission of vibrations from his picture projector to his phonograph.

APPLICATION OF FILTERS TO TURNTABLES

With the need of lower-speed turntables for sound motion pictures, the difficulties of securing constant speed were greatly multiplied.

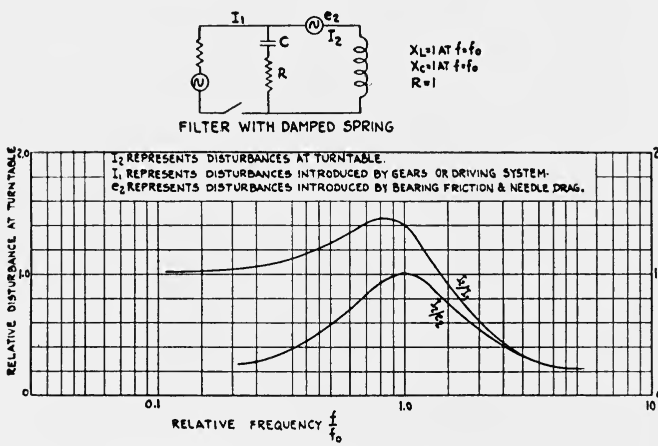

FIG. 2. Characteristics of commercial type of filter.

The difficulties were further increased by the necessity of synchronous operation, which meant geared drive.

Although it is possible to produce gears having a very high order of precision, it is practically impossible to drive any mechanism through gears without the introduction of some vibration of the tooth frequency. As soon as attempts are made to build geared machines in any reasonable numbers and with reasonable manufacturing tolerances, it has almost invariably turned out that complete dependence could not be placed upon the perfect functioning of gears. The errors may be small but they are sufficient to impair sound quality. It is comparatively easy to eliminate the tooth vibrations by driving the turntable, which has considerable moment of inertia, through a flexible element. Such an arrangement is called a mechanical "filter."

Fig. 2 shows the characteristics of a simple filter comprising a single mass and a single elastic element, for example, a turntable driven through a spring. The ordinates show the ratio of amplitude of swing or speed variation of the turntable to that of the driving gear at the other end of the spring. For disturbances of a frequency at which this ratio is greater than unity, the filter does more harm than good. It is evident from Fig. 2, that damping must be provided, since otherwise a bad resonance occurs and persistent oscillations are encountered. Damping may be applied to the spring, or to the turntable. Both systems have been employed, but for the most part the damping has been applied to the spring.

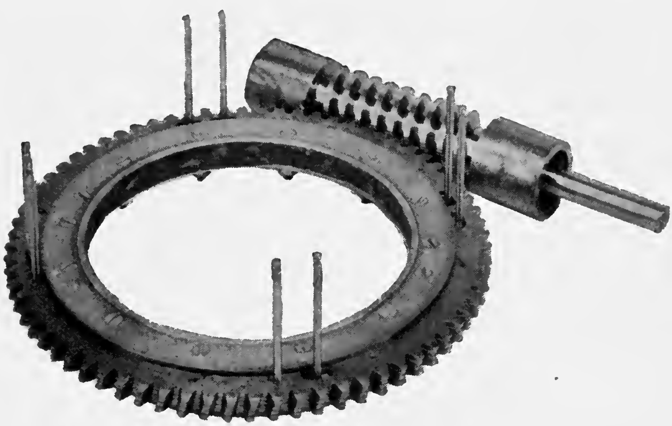

FIG. 3. Laminated worm-gear of Elmer and Blattner.

It will be noted that the filter is of no use except when the frequency of the disturbance is above a certain rate. The successful employment of a filter therefore depends upon avoiding, so far as possible, disturbances of slow periodicity, and then designing the filter so that it will be effective at the lowest frequency that must be expected; which means making the spring flexible enough and the turntable heavy enough. This is often spoken of as giving the filter a "low cut-off frequency." Too often the design has been guessed rather than calculated. H. C. Harrison in U. S. Patent No. 1,847,181 gives a very complete formulation of the requirements.

The lowest disturbing frequency is generally the rotation rate of the slowest gear of the train, and with motor-driven machines this can be the turntable speed. When the turntable speed itself is as low as $33^1/_3$ rpm. (this low speed having been adopted to provide long playing records for sound picture work) filtering presents serious problems. An interesting arrangement for reducing the magnitude of the disturbances to be filtered out, and at the same time increasing the frequency of their recurrence, was described by Elmer and Blattner in 1929.[12] It is assumed in considering the principle of this driving system, that practically all the disturbance of fundamental or turntable frequency will be due to imperfections in indexing the gear on the turntable spindle. Such indexing imperfections are primarily traceable to the master gear in the miller upon which the gear is cut, and there is no way of averaging out these imperfections in the cutting operation. The imperfections in the gear as cut,

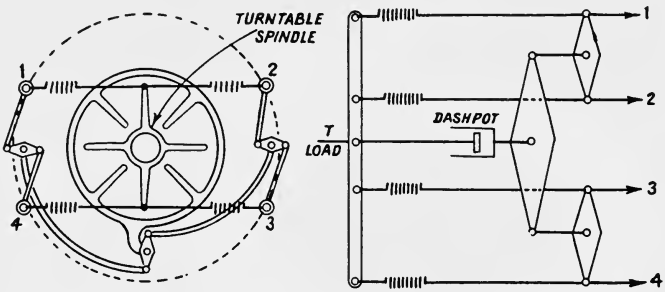

FIG. 4. Diagrams illustrating averaging linkage described by Elmer and Blattner, and straight-line analogue. In actual structure, each gear lamina carried two pins, and equalizing links were in duplicate.

however, can be averaged by the scheme described by Elmer and Blattner. The gear consists of four laminae which are bolted together and milled and hobbed in the usual manner. The four laminae are then separated and each rotated 90 degrees with reference to the adjacent ones. They are mounted in such a way that slight play between layers can occur without excessive friction. This compound gear is driven from a single worm. Fig. 3 shows the compound gear with worm. It will be appreciated that if a certain imperfection in the indexing tends to cause one layer to rotate above average speed, the same effect will not be produced upon the layer that is reversed with respect to the first layer until the gear as a whole has rotated 180 degrees. Thus, although the speed of the individual layers is no more nearly constant than that of a single gear, the average speed of the four layers will be much more nearly constant, and such irregularities as occur in the average speed will repeat themselves four times per revolution.

The system for averaging the speeds of the four laminae is analogous to the action of a whiffletree which provides an equalization of the motions of several horses, as illustrated in Fig. 4. On each lamina are mounted two vertical pins which project through slots in

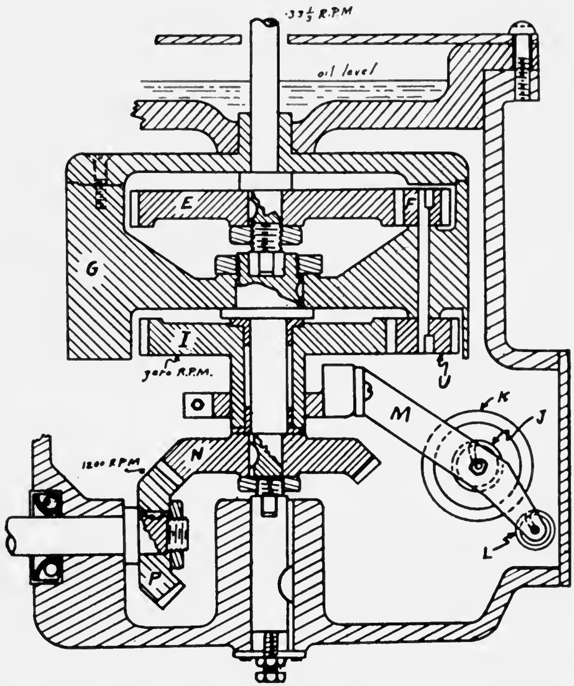

FIG. 5. Planetary turntable drive of A. V. Bedford.

the laminae above, thus providing eight points of attachment for the linkages which equalize the movement. Fig. 4 shows the equalizing linkages in schematic form. The turntable is driven through springs, while an oil dash-pot having radial vanes provides the damping. The dash-pot is driven from the linkage. Thus, filtering is employed in addition to the speed-averaging device just described, which reduces the sources of disturbance that must be filtered out.

Bedford Planetary Drive.—A radically different method of increasing the frequency of repetition of such disturbances as may be due to faulty gears has been employed by A. V. Bedford[13] and is illustrated in Fig. 5. On the turntable spindle is a gear *E*, and below this is a stationary gear *I*, of slightly smaller diameter. Two pinions *F* and *U*, which are coupled together and rotated by a planetary arrangement, engage gears *E* and *I*. Were these gears of the same diameter, no rotation of *E* would result; but since *E* differs in diameter from *I*, each revolution of the pinion-carriage *G* results in a slight rotation of the gear *E*. The diameters are so chosen that the pinions must make about seven revolutions to produce one revolution of the turntable spindle. In the course of this one revolution, all parts of gear *E* have been engaged six times and all parts of gear *I* seven times. In order further to reduce the possibilities of imparting low-frequency disturbances to the turntable, its spindle rotates not in a stationary bearing but in a bearing that rotates with the planetary pinion carriage *G*.

Any torque imparted to the gear *E* reacts upon the gear *I*. Were the latter not restrained it would rotate instead of gear *E*. Instead of providing a rigid anchorage for the stationary gear *I*, it is restrained by means of a spring *L*, and damping is provided by the dash-pot *K*. If the turntable is designed with a reasonable moment of inertia, irregularities in the speed of gear *E* with reference to gear *I*, such as may result from gear imperfections, tend to produce movements of gear *I* rather than speed fluctuations of the turntable gear *E*. Since the moment of inertia associated with gear *I* is quite small, *I* takes up the irregularities, thus providing the filtering upon which reliance is placed to eliminate the comparatively high-frequency disturbances that the planetary drive may introduce.

Brute-Force Methods.—It may seem paradoxical that such elaborate arrangements and complicated constructions as are here described should be necessary in order to provide constant motion when, according to the laws formulated by Isaac Newton, all that is necessary to cause an object to move with uniform velocity is to *let it alone.* Fortunately for disk record work, the power requirements are extremely low, and only such considerations as quick starting, saving of space or weight, or the necessity of exact synchronism, make it necessary to resort to any other expedients than the closest practicable approach to "letting it alone."

The employment of very large moment of inertia is often described as a "brute-force" method, but this approach to the problem is good only when extreme care is exercised at the same time to apply a minimum of forces to the rotating mass. Fig. 6 shows the turntable that comes the nearest to constant speed of any with which the author has had acquaintance. The flywheel is 27 inches in diameter, with a heavy rim. The spindle runs in a carefully made sleeve bearing, and the weight is carried by a steel ball at the bottom. Careful bearing design minimizes the disturbing forces from this source, and the supply of the power through a long thread minimizes disturbing forces from the driving system.

Measurement of Speed Fluctuations.—The testing of turntables for speed constancy has involved even more serious difficulties than the provision of a turntable having a minimum of speed fluctuations.

FIG. 6. Turntable used for reference standard.

Stroboscopic methods become increasingly unsatisfactory as the frequency of the disturbance increases. A better system consists in causing the apparatus under test to generate an electric current, the frequency of which depends upon the speed of running. This alternating current is applied to a circuit that is slightly off tune, and the variations in frequency then appear as variations in voltage which can be measured and recorded.[14] For generating the tone it has not been found altogether satisfactory to cut a record and play it back. Better results have been obtained by means of a carefully constructed magnetic tone-wheel. The problems of measurement of speed fluctuations in turntables is discussed by A. R. Morgan and the writer in a paper published in the journal of the Acoustical Society of America for April, 1936. Using the magnetic tone-wheel on the turntable shown in Fig. 6, we have found it possible to get registrations of as low as 0.1 per cent between the lowest and the highest speeds registered in a period of 6 seconds. The measuring system shows full sensitivity to fluctuations up to 100 per second.

SOUND-FILM SYSTEMS

Photographic recording of sound on film began a good many years ago. The problem of obtaining constant speed does not differ in

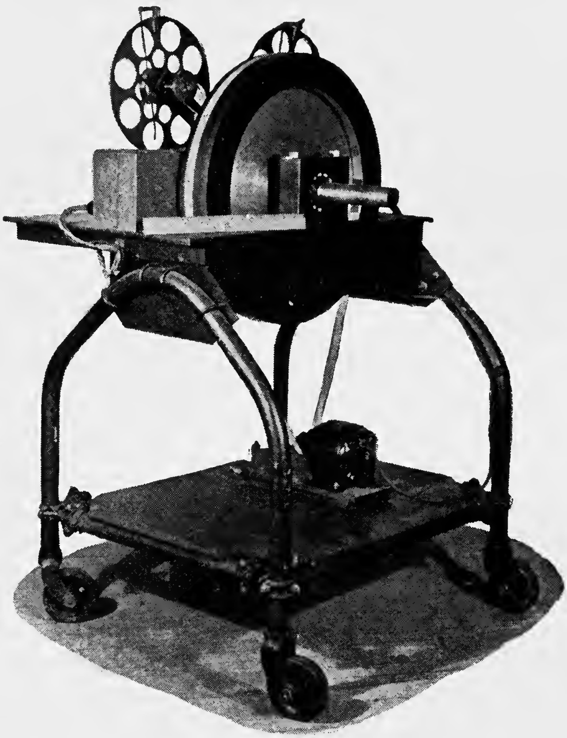

Fig. 7. Example of "brute-force" constant-speed film phonograph.

fundamental principles from that of providing constant speed for disk records, but does present new problems in that the entire record does not move as a unit but is unwound from a supply reel, pulled past the point where a record is made or reproduced, and again wound upon a reel. The motion at the translation point must be protected from irregular pulls due to the reels. An additional difficulty is generally brought in by the requirement that a specified number of sprocket holes must pass per second, regardless of the absolute length of film represented by this number of sprocket holes. In other words, the linear speed for a shrunken film must be less than for a non-shrunken film. Apparent lack of concern for speed constancy upon the part of earlier experimenters in photographic sound recording is probably due to the fact that they had too many worries about other things. That the speed should be constant, however, has always been accepted as an axiom. Machines employing the "brute-force" method of moving a film at constant speed have been of extreme value as laboratory tools. Fig. 7 shows such a machine, known in the RCA Photophone laboratories as the "Grindstone." Such extremes of size and mass are hardly necessary. In general, rotational speeds in film machines can be considerably higher than in disk turntables (for example, 180 to 360 rpm.), and at these speeds flywheels of moderate size are sufficient.

FIG. 8. Sylphon damping arrangement of H. Pfannenstiehl.

Filters on Sprocket Shaft.—In most of the earlier commercial reproducing machines, and in many of the recording machines, the film was moved past the optical system by means of a sprocket; and, practically without exception, the sprocket drive has been filtered. In other words, a flywheel was mounted upon the sprocket shaft, and power was supplied through an elastic connection from a driving gear. As has already been explained, a filter may do more harm than good if it is not adequately damped. The damping has in some cases been applied to the flywheel itself in the form of a viscous brake, and in other designs the elastic connection between the driving gear and the flywheel was damped. Fig. 8 shows a widely used damping arrangement employed in projector sound heads.[15] The two sylphons, or bellows, which are mounted upon the flywheel are completely filled with oil and connected through an adjustable orifice. The mechanism is so arranged that whenever there is relative movement of the flywheel and driving gear, one bellows is stretched and the other is compressed, and oil must flow between them. A device of this form provides very effective damping but must be designed with great care in order that changes in the torque transmitted may not result in appreciable unbalance. All filtered systems with horizontal axes are extremely sensitive to balance.

Inherent Faults in Sprocket Drive.—Although the painful effects of slow speed fluctuations, particularly in the reproduction of music, were early observed, and efforts made to eradicate them, general recognition of the fact that rapid fluctuations of small amplitude can also do serious damage to quality has been extremely tardy. This is perhaps due to the fact that such rapid fluctuations produce radi-

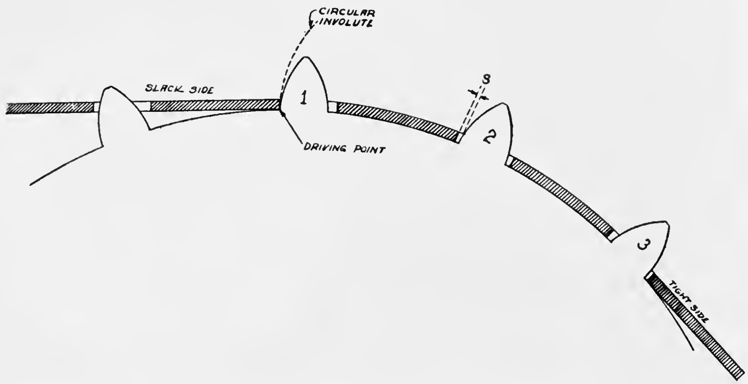

FIG. 9. Common relation between sprocket teeth and perforations.

cally different effects, which were not recognized as being due to speed changes. Moreover, other common faults in recording and reproduction cause impairment of quality so similar to that due to rapid speed variations as to mask the results in comparative tests. The art of sound reproduction may be metaphorically described as "strewn with the wrecks of efforts" to obtain constant speed by means of gears and by means of sprockets. The shortcomings of sprocket drives are made much more serious because the pitch of the film perforations varies with the shrinkage of the film. No matter how the sprocket is designed, there is only one chance in many that the film will really fit the sprocket.[24]

Fig. 9 shows the relation between teeth and sprocket holes when the pitch of the perforation is slightly greater than that of the teeth. It is seen that the tooth on the left is doing the pulling and will continue to do so until the film is stripped off, at which time the film must slip back on the sprocket by a distance *S;* whereupon tooth No. 2 does the pulling. Thus, the film moves at sprocket-tooth speed only for short intervals, interspersed with moments of slipping back. If the sprocket-hole pitch is less than the tooth pitch, there must be a forward adjustment as each new tooth engages, instead of a slipping back. In either case, there is a decided irregularity in film movement, the effect of which is to cause less satisfactory reproduction of high-frequency tones.

Fig. 10 shows what happens to tones of several different frequencies as a result of speed fluctuations at sprocket-hole frequency.[16,17] If a sine wave is recorded and is reproduced by a machine that intro-

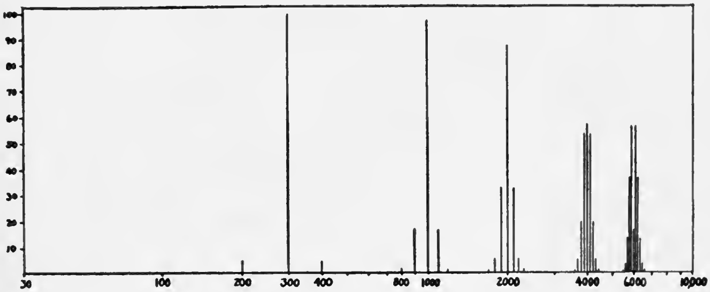

FIG. 10. Effect of film speed modulation upon sine wave recordings of 300, 1000, 2000, 4000, and 6000 cps. (Assumed: speed modulation of 1 mil amplitude at 100 cps.)

duces a variation of 0.001 inch in amplitude approximately 100 times per second, there is little effect upon a 300-cycle tone, although small amounts of 200- and 400-cycle tones are generated. If the recorded frequency is 1000 cps. the magnitude of the 900- and 1100-cycle tones is about 15 per cent of the original. At 2000 cycles the first sideband tones are fully 30 per cent of the original, while additional tones of 1800 and 2200 become appreciable. If the recorded tone is 4000 cps., the sidebands are practically as large as the fundamental, while at 6000 cps. there are four sidebands that exceed the fundamental and two more that are nearly equal to the fundamental. It could hardly be expected that a recorded 6000-cycle note reproduced on such a machine would sound clean and clear, although some semblance of a high-frequency note still results.

Since satisfactory reproduction can not be expected if the film is propelled past the optical system directly by a sprocket, the best machines have employed smooth drums on which the films were supported, dependence being placed upon friction to insure the film's moving with the drum without slipping. Soft-tired rollers pressing the film against the drum have proved satisfactory and make little trouble if properly designed. Various methods of driving the drum have been employed, and among these methods it is regrettable that there have been many attempts to drive the drum by gearing it to the same driving system as the sprocket, without provision for permitting the drum to operate at any other than a fixed speed with

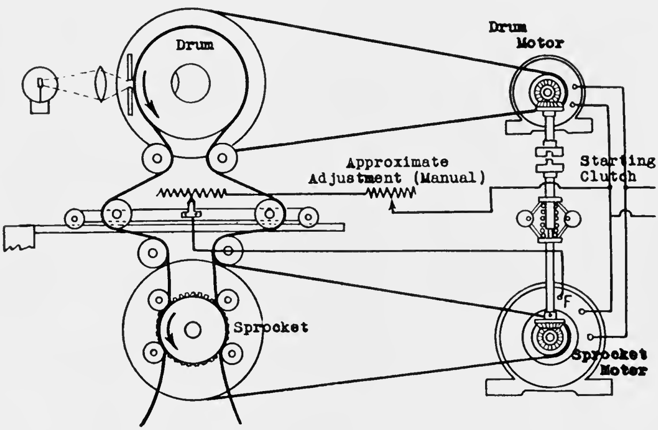

FIG. 11. Electrical drum speed control of C. A. Hoxie.

reference to the sprocket. Such machines may have the appearance of operating as if the drum were performing a useful function, but as a matter of fact, the film must be slowly slipping with reference to the drum surface throughout the operation, and all benefit from the constant-speed drum is thereby sacrificed. The drum must be permitted to select its own speed, depending upon the film shrinkage.

The simplest way to let the drum select its own speed is to drive it by means of the film, which acts as a belt. In applying this principle, dependence has almost always been placed upon a flywheel to provide for uniform rotation of the drum. It would be hard to imagine a simpler system that would eliminate the disturbance due to sprocket teeth. The sprocket tooth disturbance present at the sprocket pulling the film is filtered out because of a certain amount of flexibility in the loop of film between the sprocket and the drum coöperating with the effective mass at the drum due to the flywheel.

The trouble with the simple drum and flywheel system is that it constitutes an undamped filter such as was discussed in connection with Fig. 2. Oscillations are easily set up which persist for a long

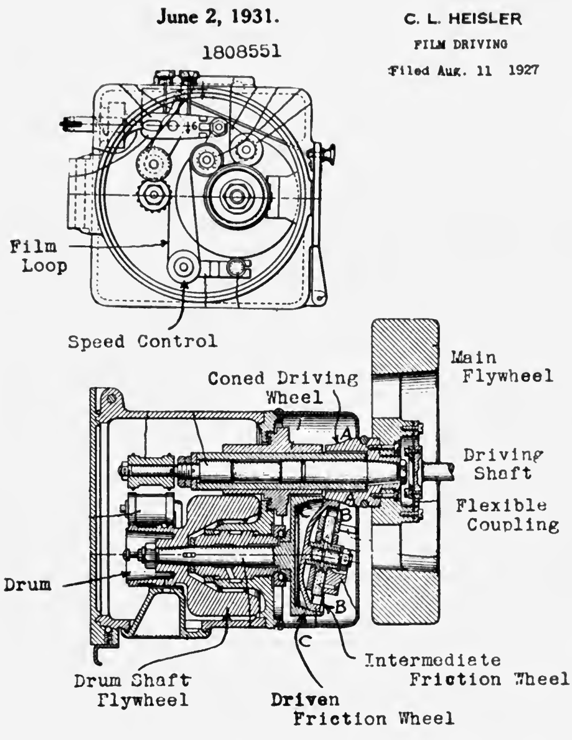

FIG. 12. Mechanical drum speed control or compensator of C. L. Heisler.

time. A small amount of damping is, to be sure, provided by the viscosity of the bearing lubricant; and if through careful construction, or good design, or good luck (or, perhaps, by tedious and painful reconstruction), no disturbance of frequency near the natural frequency of the oscillatory system is introduced, a machine of this type may give creditable performance. A number of other methods of driving the drum at the correct speed have been employed, and some of these are of much interest in view of their ingenuity.

Fig. 11 shows the arrangement of an early laboratory reproducing machine of Charles A. Hoxie, of the General Electric Co. The drum is driven by a separate d-c. motor, the speed of which is controlled through a fine-adjustment rheostat, the position of which is changed by alterations in the lengths of the loops between the sprocket and the drum.[18] This system is not subject to oscillation, since the motor assumes its new speed almost instantly when the rheostat is changed. It is in systems in which the *acceleration* of the drum (rather than its speed) varies in proportion to film loop length, that oscillations are likely to occur.

C. L. Heisler, also of the General Electric Co., designed a recorder that was widely used commercially, using a mechanical method of introducing the fine control of the drum, instead of an electrical method.[19] Fig. 12 shows some of the features of the Heisler machine. The principle is in no wise different from the employment of two oppositely tapered cones, with a belt or friction wheel that can be moved axially to the position at which the speed ratio is correct. Instead, however, of simple conical pulleys, Mr. Heisler employed doubly curved surfaces of revolution, *A* and *C* of Fig. 12, the elements of which were circular arcs. This made it possible to rotate the axis of the intermediate friction wheel *B*, instead of shifting the wheel along its axis. The intermediate friction wheel was mounted much like a gyroscope, except that its axis had only one degree of freedom. On the drum side, the running surface is on the interior of a hollow member *C*. It will be observed that as the axis of the intermediate wheel *B* is rotated in a clockwise direction, its rim is brought into contact with a larger diameter portion of the driving cone *A;* and, on the other side, it runs against a part of the driven member *C* where the diameter of the latter is less. This provides a continuous adjustment of speed. The upper drawing of Fig. 12 shows the loop of film between the sprocket of the drum, engaging a movable idler at the bottom. Changes in the position of the axis of the friction wheel are caused by the lengthening and shortening of this loop of film.

Geared Compensator of C. L. Heisler.—Fig. 13 shows another arrangement by Heisler.[20] A ring-gear, *A*, is mounted on the shaft whose speed is to be controlled, and a slightly larger ring-gear, *B*, is driven at fixed speed from the motor. Two gears *C* and *D*, mounted on a single hub, which the writer has called "creeping gears," mesh with the two ring gears. The creeping gears run on an eccentric hub *E*.

When this hub is permitted to rotate with the rest of the assembly, there is no relative motion of the four gears, and the driving and driven ring-gears rotate at the same speed. Application of a brake, however, to the eccentric hub causes the pair of creeping gears to run around inside the internal gears, and in doing so they cause one to shift slowly with respect to the other.

The smaller the difference between the diameters of the two internal gears, the smaller is the creeping produced by applying the brake to the eccentric hub, and the arrangement may be so designed that the entire difference in speed of the driven shaft produced by applying a brake is only 2 or 3 per cent of the mean speed.

The drawing on the left in Fig. 13 shows the manner in which the

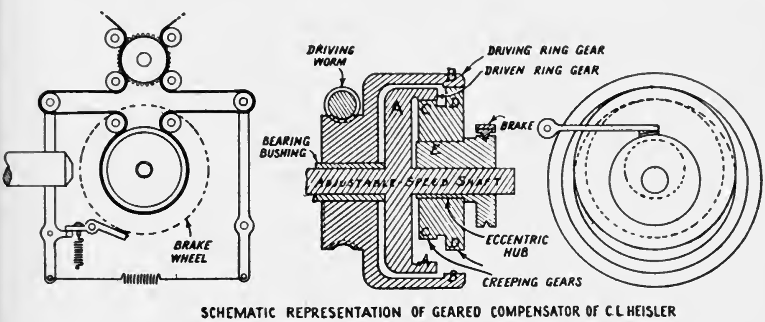

FIG. 13. Geared compensator of C. L. Heisler.

loops of film between the sprocket and the drum control the application of the brake. This drawing shows the arrangement as if the geared compensator were applied to alter the speed of the drum, but in most of the machines that Heisler designed it was not the speed of the drum that was changed but the speed of the rest of the machine, comprising all the sprockets. This is entirely permissible in a projector, which does not have to be synchronized with other machines. Since the geared compensator is a means of controlling average speed, but does so by causing small fluctuations, it is logical to drive the drum directly through gears and a filter from the motor, and to employ the compensator to insure that the sprockets will have the correct average speed to maintain proper film loops. In such a machine it is evident that the film speed in linear feet per minute is the fixed quantity, while the number of sprocket holes per minute will vary, depending upon film shrinkage.

In an alternative construction, the creeping of one gear with respect to another was brought about by an arrangement of worms that rotated with the assembly but did not turn upon their axes unless a brake was applied to a suitably arranged brake-wheel. In practice Heisler found that the action of the brake was such as to cause the brake-wheel to assume an intermediate speed rather than to alternate between full speed and stop. This was due to the facts that the brake-wheel possessed considerable inertia and the entire mechanism operated under conditions of abundant lubrication so

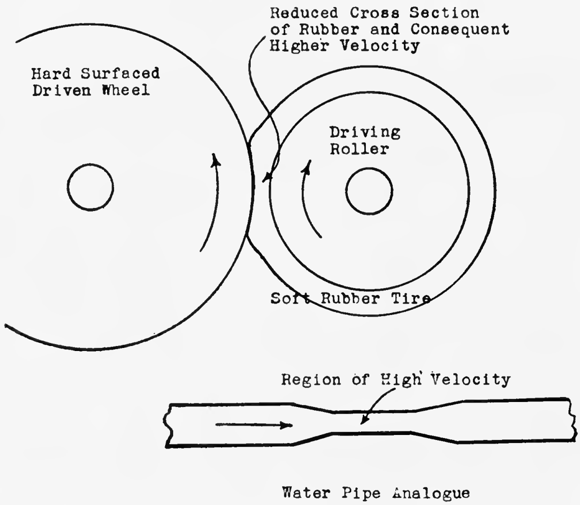

FIG. 14. Speed control by pressure on rubber tire, used by C. A. Hoxie.

that the brake produced a semi-viscous drag. Since the total speed change produced by stopping the brake-wheel amounted to only 2 or 3 per cent of the average, it is evident that even a rough approximation to constant brake-wheel slip would result in a very nearly constant speed of the driven member. Moreover, filtering may be employed between the driven member of the compensator and a drum. This method of operation permits the application of the geared compensator to machines such as recorders, which have to be strictly synchronized.

Rubber-Tired Compensator of C. A. Hoxie.—Hoxie built a sound head in which he provided continuous fine adjustment of the drum speed by altering the pressure between a rubber-tired roller, driven at constant speed, and a smooth-rimmed metal wheel.[21] I am not sure how Mr. Hoxie expected the device to work when he made the first model, but it may be said that a number of us expected exactly the opposite from the actual result. The working radius of the driving wheel becomes less as the tire is compressed. We therefore

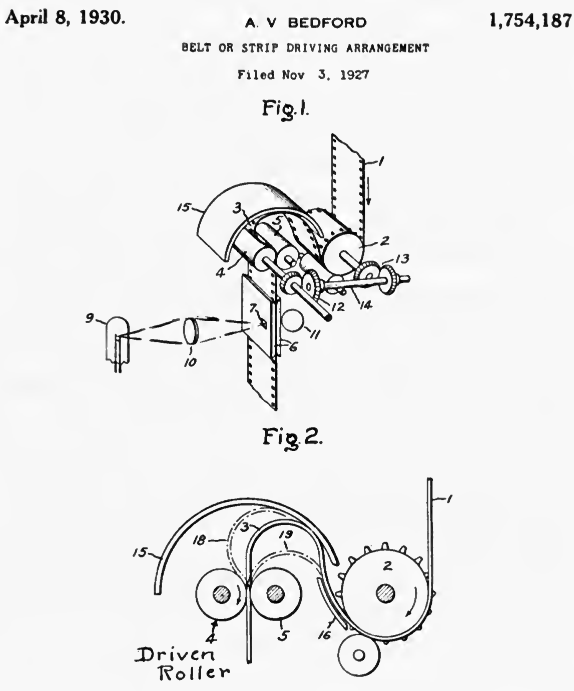

FIG. 15. Film speed control of A. V. Bedford.

inferred that the driven wheel would run slower as the pressure was increased, assuming, of course, that the driven wheel rotated easily and that the pressure was never reduced to a point where appreciable slipping occurred. What actually happened was that the greater the pressure, the faster the driven wheel ran.

The proposition may be illustrated in terms of a truck. We shall assume that the pavement is smooth and level, and that the truck has thick, soft tires of solid rubber, and that the diameter of the rear wheels is such that when they are rotating at 200 rpm. the truck will run 20 miles per hour when empty. The truck is now loaded sufficiently to compress the tires materially. With the same wheel rpm., will the loaded truck run slower or faster than it ran when empty? The answer is that the more you load it the faster it will go. I know of no actual test with a truck, but believe that the analogy is a fair one, and the explanation is quite simple.

Fig. 14 illustrates the relation of the rollers and also shows a diagram of a Venturi tube. For such changes of shape as a piece of soft rubber can undergo it acts much like a liquid, in that it permits large shearing deformations with little resistance. It is evident that at the point of maximum compression, the tire has smaller cross-section than at other points, but it is also obvious that the total volume of rubber passing this point in a given interval is the same as that passing other points. Therefore the velocity of the rubber must be greater where the tire is compressed, and the greater the compression, the higher will be the velocity of the rubber, just as the velocity of water at the constricted portion of the Venturi tube is greater than that in other parts of the pipe. Directly under the truck wheels the surface velocity of the rubber with reference to the truck may considerably exceed the velocity of other parts of the tire surface, and this effect much more than offsets the slight reduction in radius of action. If the tire were compressed to $^1/_2$ its normal cross-section, the velocity of the rubber at this point would need to be doubled, on the average; and since this increase in average velocity will be mostly at the surface and none at the rim, very substantial increases in speed may occur.

Pinch-Roller Compensator of A. V. Bedford.—A method of compensation that has surpassed even the rubber-tire compensator in its ability to provide subject matter for discussion and argument, and likewise resembles the rubber-tire arrangement in its extreme simplicity, is the pinch-roller compensator, first proposed by Bedford for projectors[22] and later applied to printers.[23]

In Fig. 15, the upper drawing shows the general mechanical arrangement, while the lower drawing shows the principal elements in simplified form. Roller *4* is driven at fixed speed, while roller *5*, which serves to hold the film in contact with roller *4*, may assume whatever speed the film imparts to it. If we could stretch or compress each film to such a degree that 64 sprocket holes corresponded to exactly one foot, thereby mechanically compensating for shrinkage, it would obviously be possible even in a synchronous machine to propel film by means of a smooth roller having a fixed peripheral speed. Fundamentally it is not necessary to stretch or compress the film throughout its entire cross-section, for the film is driven solely by contact between one surface and roller *4*. It is therefore sufficient to stretch or compress the material at this surface, and it is well known that the simple act of bending a flexible strip serves to compress one surface and stretch the other. It will be readily seen from the drawing that if a sufficient amount of film accumulates in the loop between the sprocket and the driving roller, the film will bend around the roller in such a way that the latter works on the concave side of the bent film. On the other hand, with a short loop, as indicated at *19*, the driving roller will operate on the convex side of the bent film. When the driving is applied to the convex side, the mean film speed is less than that of the driven surface. In other words, when the loop is short the film does not pass so rapidly through the driving point between rollers *4* and *5*. Whatever the degree of shrinkage of the film, an equilibrium is soon reached with the loop length such that the rate of passage between the rollers is exactly equal to the rate at which it is fed through by the sprocket. Engineers dealing with problems of belt drive are well acquainted with the necessity of making a distinction between pulley surface speed and mean belt speed, or the speed of the middle of the belt, and the Bedford drive depends upon exactly the same principle.

THE MAGNETIC DRIVE

The several systems just described, in which the drum is positively driven and compensation provided, possess one advantage over the system in which the drum is driven by the film only; namely, more rapid acceleration may be permitted, since the strength of the film is not a limiting factor. In most equipment, however, extremely rapid acceleration has not been essential, and in the case of the magnetic drive used in RCA recorders, the film is required to perform only a small part of the work of accelerating the drum flywheel.

During the period when the numerous fundamental problems of sound-on-film were being worked out, there were, of course, many machines both for recording and reproducing that fell seriously short of an adequate standard of constant speed. The recorder rather than the reproducer appeared to be the logical place to apply serious efforts to build a machine that would be less subject to speed fluctuations. In the machines, of which a number were built, that depended upon the film to pull the drum, there were two causes of failure to operate satisfactorily. In the first place, the tension on the film required to keep the drum running was sufficient to pull the film quite tight between the pulling sprocket and the drum, and this taut loop provided too little flexibility. This made it impossible to design the filtering system so that it would have the necessary low cut-off frequency, the importance of which has been discussed in an earlier part of this paper. A heavier flywheel would tend to lower the filter cut-off frequency, but all possible gain from heavier flywheels was in turn lost by the increased film tension needed to drive the heavier

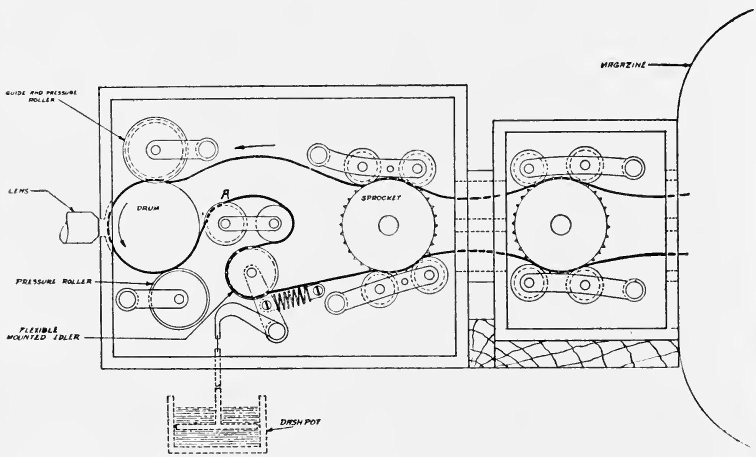

FIG. 16. Film path of original magnetic drive recorder.

system. In the second place, there was no provision for damping out oscillations. L. T. Robinson had introduced into such a machine a certain amount of damping by mounting upon the shaft a copper disk which rotated between the poles of a permanent magnet.[24] The result may have been helpful, but did not go far enough in damping, while it caused a further increase in the power required to rotate the drum. With this picture of the general problem, the writer decided to attempt to build a recorder in which these sources of trouble would be avoided. Attempt was made at the same time to avoid all other foreseeable sources of speed fluctuation that seemed likely to occur. In the machine as built there were some provisions that turned out to be unnecessary, but if one wishes to make sure that his horse will not be stolen, he may go so far as to lock the barn door, board up the windows, place guards around the barn, and in addition to the foregoing, he may remove his horse from the barn altogether and keep him in his cellar until the scare is over. Fig. 16 shows schematically the arrangement employed.

The sprocket that controls the speed at the drum is protected from jerks produced by the magazine take-up by a second, or buffer-sprocket geared to the driving system. Although it was planned to make the damping magnet help drive the flywheel rather than impose an additional drag, and thereby to make a more flexible film loop possible, there was no ready way of predicting whether the desired amount of film loop flexibility could be obtained by this expedient alone. A movable idler roller as shown at M in Fig. 16 was therefore introduced in the loop between the pulling sprocket and the drum. By this means a large amount of flexibility can be introduced. An oil dash-pot connected to the movable idler provided as much damping as was required to make this part of the system practically dead-beat.

Although the introduction of the movable idler provided flexibility and damping, there was some doubt as to whether it would provide the necessary filtering for rapid pulsations in the movement of the film at the sprocket. The effectiveness of the roller for this purpose would be impaired by its mass (although it was made of duralumin, and as light as practicable) and because the attachment of the dash-pot would increase the difficulty of its executing quick movements. It was therefore desirable to provide as much additional flexibility as could be obtained in the film loop itself. It appeared to the writer that if the film were passed around two adjacent rollers in the same direction, it would assume a more rounded curve between them, and would therefore show more flexibility at the same tension than if the more common arrangement were followed of placing consecutive rollers upon opposite sides of the film, giving *S*-shaped bends. Subsequent measurements indicated that this was true in even greater degrees than had been anticipated.

Two soft-tired pressure-rollers were employed to hold the film tightly against the drum. It is, of course, especially important that the film be wrapped tightly around the drum where it passes the optical system. Tension on the film is obviously conducive to the desired tight wrapping. A certain amount of drag on the upper pressure-roller adds to the tension on the film where it passes around the drum, but drag by the lower pressure-roller tends to subtract from the tension, or would do so if any slipping on the drum occurred. To secure the best possible conditions in this respect, the upper and lower pressure-rollers were geared together through a slipping clutch in such a manner that power was taken from the upper pressure-roller and

Dec. 27, 1932. E. W. KELLOGG 1,892,554

FILM SUPPORTING AND DRIVING APPARATUS

Filed July 27, 1928

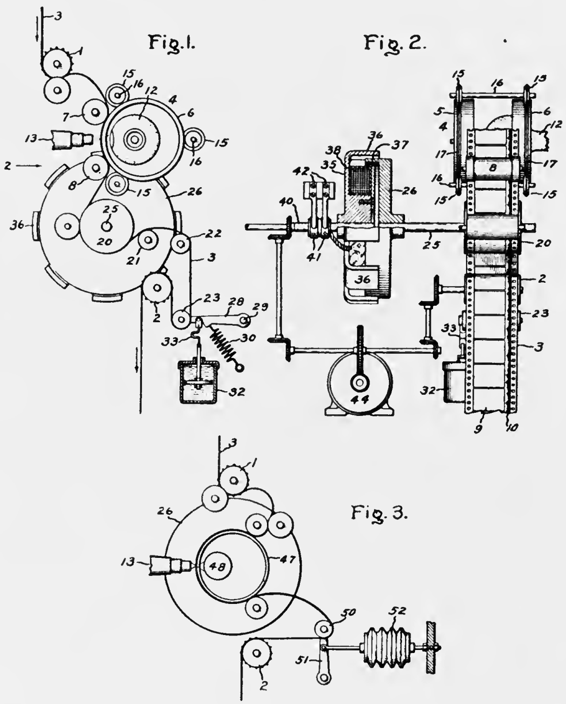

FIG. 17. Schematic illustration of magnetic drive.

delivered to the lower pressure-roller, thus providing a braking action above and at the same time applying a forward torque to the lower pressure-roller. The gear ratio was such that only slight slip occurred in the clutch. Most of the power absorbed by the upper roller was therefore delivered back to the drum by the lower roller, the purpose of this being to minimize the power that would have to be supplied to the drum.

In one respect the original design deserves criticism. We have since that time learned more about edge guiding, but the faults of this machine in that respect were soon overcome and its value was all the greater because it served to demonstrate one or two things not to do. The guiding problem is discussed in some detail in an earlier paper[24] describing the magnetic drive recorder.

It is well known that the reaction of a magnet upon a conducting disk of non-magnetic material is proportional to the relative velocity.

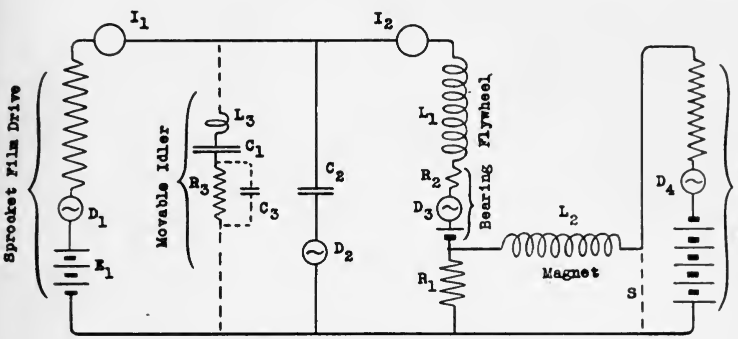

FIG. 18. Electrical analogue of magnetic drive.

Analogies:
I_1, film movement at sprocket.
I_2, film movement at drum.
L_1, mass of flywheel.
L_2, mass of magnet.
C_2, flexibility of film loop.
E_1, steady pull of film.
E_2, power supply to magnet.
D_1, disturbances in sprocket drive.
D_2, variations in film stiffness, splices, kinks, *etc.*
D_3, irregularities in drum shaft bearing friction.
D_4, irregularities in magnet drive gears.
R_1, coupling between magnet and flange.
R_2, bearing oil viscosity.
C_1, flexibility of spring attached to movable idler.
L_3, mass of roller and arm.
R_3, dash-pot resistance.
C_3, spring between roller and dash-pot, if spring is used (*33*, Fig. 17).
S, connection substituted for magnet drive, to make diagram applicable to rotary stabilizer.

The damping properties of such an arrangement are proportional to the steepness of the curve of torque *vs.* relative speed. The damping is therefore independent of the continuous torque resulting from any constant difference in speed. The purpose of the design was to provide enough damping to prevent oscillations, and only so much steady torque as would be needed to overcome bearing friction, and thus relieve the film of most of its load. The magnets were driven faster than the drum so that the continuous torque would be in the direction to help rotate the drum rather than retard it. About 15 per cent excess magnet speed was selected. This figure was a guess, but proved to be about right. In subsequent designs it has been found feasible to reduce the excess magnet speed to about 8 per cent, which change permits increasing the damping.

The ideal magnet arrangement for producing an eddy current drag on a disk or flange would consist of closely spaced and oppositely poled magnets, producing a flux that zigzags through the flange. Such a system, however, is much more difficult to arrange than one in which the flux through the flange is all in the same direction but

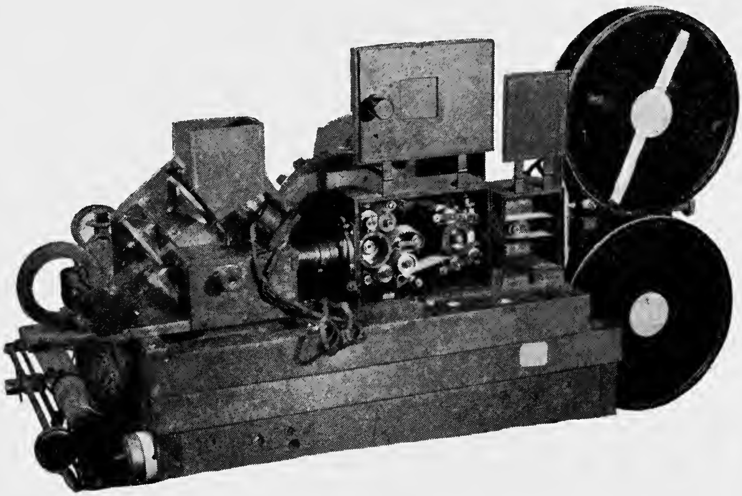

FIG. 19. Front view of original magnetic drive recorder.

concentrated at certain points by the shape of the poles. The latter arrangement was therefore chosen, and again the design, which was very much of a guess, seems to have been fairly well vindicated.

Consideration was given to the production of the necessary rotating magnetic field by means of a polyphase winding on a stationary laminated field structure. The choice in this instance can be based upon simplicity of construction or operating convenience. The employment of a polyphase winding would require a power supply of the correct frequency, whereas when the excitation is by direct current, a battery supply is always obtainable, and the correct rotational speed is provided by whatever source of power operates the driving motor.

Fig. 17 shows schematically the arrangement of the magnet drive. The figure also shows a refinement in the construction of the dash-pot and its associated idler. These are coupled together through a small spring *33*, which permits the idler to execute quick movements of small amplitude without encountering the restraining action of the dash-pot. On the other hand, if the stiffness of the springs *33* and *30* are correctly proportioned, the dash-pot is still effective for damping low-frequency oscillations, and it is only at moderately low

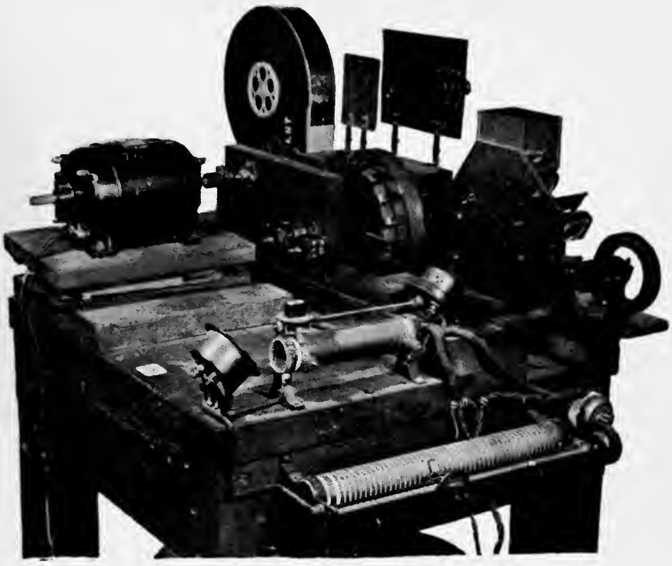

FIG. 20. Rear view of magnetic drive recorder, showing magnet.

frequency that the system has any tendency to oscillate. The electrical analogy of the drive and filtering systems is shown in Fig. 18. This diagram follows the usual conventions. A source of disturbance is indicated by the symbol for an alternator, sources of continuous torque by batteries, and speed corresponds to current. Bearing friction is represented by a resistance, for the component due to oil film viscosity, a counter emf. cell, for rubbing friction, and an alternator to imitate irregularity in the latter. It will be seen that by giving E_2 the necessary value, the necessary direct current can be made to flow through the circuit at the point I_2 (corresponding to drum rotation) with little or no, or even reversed, voltage supplied by E_1 (or by way of the sprocket). If we imagine, further, that the condenser C_2 has the property of showing greater and greater capacity as the d-c. voltage across it becomes less, we can see that the auxiliary source of power E_2 may serve greatly to improve the filtering, particularly if the movable idler is not employed.

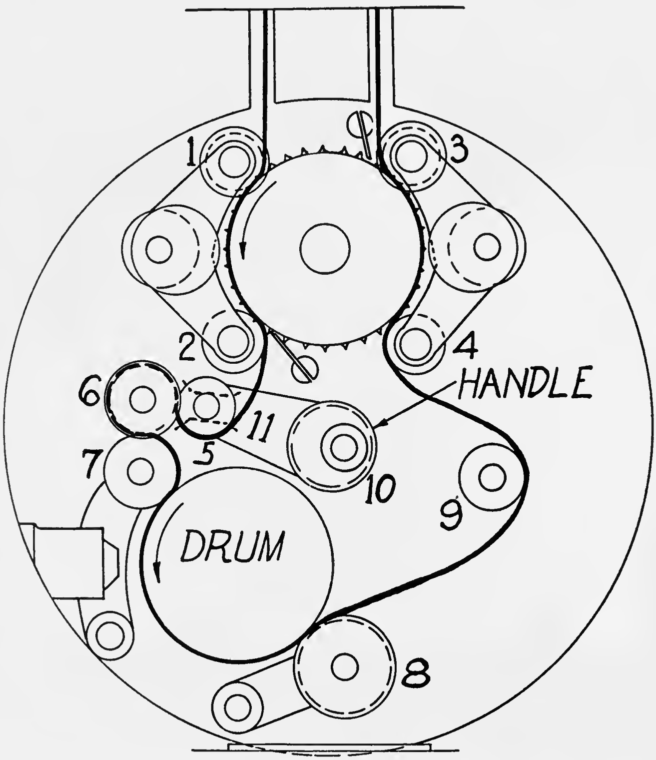

FIG. 21. Film path in first commercial magnetic drive recorder, type *PR-4*.

Some experiments were tried with a rubber bellows or sylphon, *52*, with an air vent instead of an oil dash-pot. There is some difficulty in making a small metal sylphon sufficiently flexible for use in an air-damping system. The air-damper combines the properties of the oil dash-pot and the intervening spring in that it permits small, quick movements while providing strong damping forces for disturbances of lower frequency.

Fig. 19 is a front view of the original magnetic drive recorder.

At the time this photograph was taken the machine was no longer in its youth, and its looks have suffered as a result of its having had 64 teeth extracted. In other words, the buffer sprocket had been removed.

Fig. 20 shows the damping magnet, slip-rings, the box containing the gear-train, and the driving motor. The motor was mounted upon cushions, and drove the recorder through flexible couplings. The performance of this machine was excellent, and sufficed to es-

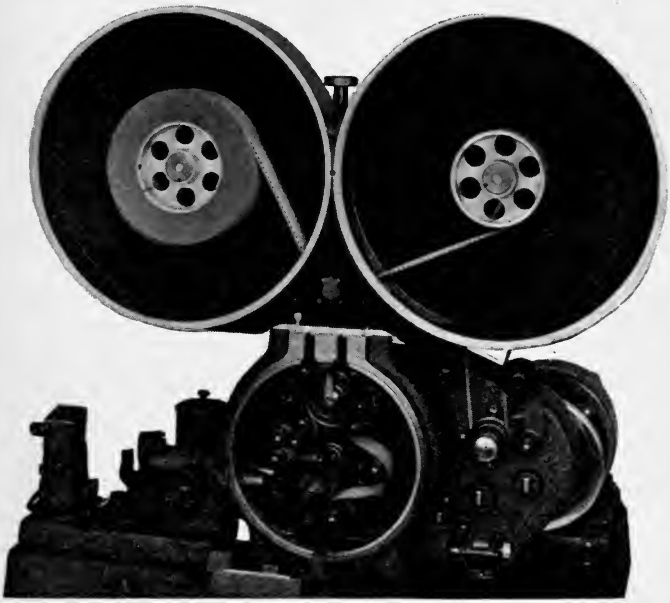

FIG. 22. Type *PR-4* recorder, showing film loops.

tablish the value of the magnetic drive. The photographs corroborate the statement that reliance for good performance was placed upon the design of the filtering system, and not upon precision workmanship.

First Commercial Magnetic Drive Recorder Type PR-4.—The film loop flexibility that it was possible to obtain by means of the magnetic drive so far exceeded expectations that the flexibly mounted idler and the buffer sprocket were found to be superfluous. Experience with guiding the film led to the conclusion that more satisfactory guiding can be provided when the film is not too slack where it is fed onto the drum but practically free from tension where it leaves the drum. For this reason, in subsequent machines employing the magnetic drive, the magnet current is given such a value that the slight residual tension on the film is such as to pull back on the drum, rather than to assist rotation. Fig. 21 shows the film path in the recording head. A large amount of wrap around the guide roller *6* is provided. Rollers *5* and *7* are both movable, so as to pro-

FIG. 23. Rear view of *PR-4* recorder.

vide for holding the film in close contact with the guide-roller. The arrangement for supplying power to the lower pressure-roller was unnecessary, and there is sufficient tension on the film, due not only to the tension of the loop between rollers *2* and *5*, but also to the bearing friction of rollers *5*, *6*, and *7*, to insure the film's maintaining good contact with the drum. Roller *9* is so placed as to cause the film to be under a very slight tension in the right-hand loop, which was regarded as desirable in the way of insuring against the film's failing to press tightly against the drum. It is quite possible for a film loop to resist having film fed to it, or in other words to exert a force in the opposite direction from tension. Figs. 22 and 23 are photographs of the *PR-4* recorder. More recent recorders have differed from this primarily in the gear-box arrangement.

One further comment on the magnetic drive might not be amiss. It is, of course, desirable that the drum shaft and bearings shall be in good shape, but it is important not to confuse smoothness of action

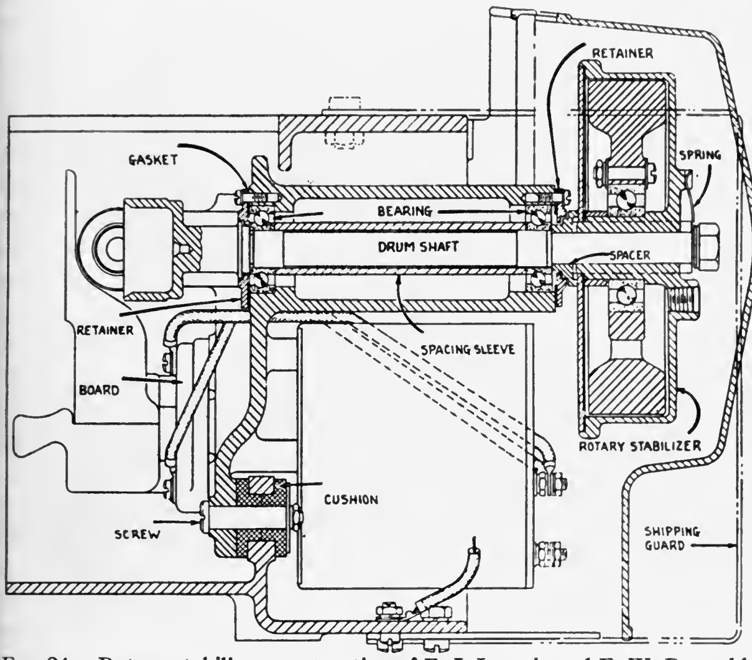

FIG. 24. Rotary stabilizer construction of F. J. Loomis and E. W. Reynolds.

with minimum bearing resistance. For example, a light oil may give less total bearing drag than a heavier oil, but the heavy oil maintains a more nearly complete film and reduces the amount of actual contact or rubbing of surfaces. All contact friction in the bearings is somewhat irregular, whereas the oil viscosity effect is smooth in action. In using the heavier oil we substitute viscous drag (which does no harm and may even be helpful for its contribution to the damping) for rubbing friction, which is objectionable. The extra power required is easily obtained by an increase in magnet current. Operating with higher magnet current gives more rapid acceleration of the flywheel, and more rapid damping out of the transient oscillation incidental to starting; but in view of the requirement of low film loop tension, the high magnet current is permissible only if there is enough bearing resistance to justify it. Light oil is desirable for testing bearings, but heavier oil, even though the flywheel may not spin as easily, may be better for operation.

The Rotary Stabilizer.—Simpler arrangements for securing the advantages of the magnetic drive have been the objective of development engineers, and a happy outcome of some of this work has been the "rotary stabilizer." It has been widely used in sound heads and has also been used in portable recorders and optical printers.

Fundamentally, the principle is the same as that of the magnetic drive, in that more or less moment of inertia is provided on the drum shaft, the drum speed is controlled by tension on the film, and the necessary damping is provided by viscous* coupling of the drum shaft to a coaxial member rotating at the same or nearly the same speed. The essential requirement for damping is that the connection be viscous in the sense that the force must increase with the increase of relative velocity.[25] This is true of the force imparted through an oil film as well as of the reaction between a magnet and a conductor. Ordinary rubbing friction (without at least some effect of a viscous lubricant) will not provide damping, and for satisfactory results friction of the rubbing type must be practically absent.

In some of the early experiments with damping by coupling the flywheel on the drum shaft with a coaxial flywheel, without auxiliary drive, the damping was found to be inadequate. C. R. Hanna, of the Westinghouse Electric and Manufacturing Co., showed that with such an arrangement critical damping could not occur unless the viscously coupled flywheel possessed at least 8 times the moment of inertia of the member solidly connected to the drum shaft.[26] Better proportioning of the moments of inertia therefore solved the problem of providing sufficient damping.

Fig. 24 shows the rotary stabilizer as developed by F. J. Loomis and E. W. Reynolds.[27,28] In the machines that have employed the rotary stabilizer, no movable idlers have been employed to increase the flexibility of the film loop. It is therefore essential that the film tension be low, in order that loop flexibility shall be adequate. There is no auxiliary drive, and the film must supply the torque

* Eddy current drag and viscous resistance are functionally equivalent (see reference *24*, p. 660; and U. S. Patents Nos. 1,892,554 Re 19,270 and 1,969,755).

necessary to overcome bearing friction. The success of the system thus depends upon minimizing the friction load. The mere expedient of employing ball bearings will not insure low friction, but with suitably selected and properly mounted ball bearings, the friction load can be made very low. A single roller serves as guide and pressure roller, and this is also provided with ball bearings. With this design it has been found possible to keep the pulling loop slack enough to provide good filtering.

If there is much bearing friction between the inner flywheel and the drum shaft, the two will rotate with no relative motion unless the accelerations of the drum shaft exceed a certain value. The result is that although the device might be effective for damping out oscillations of large amplitude, the damping would disappear as soon as the amplitude dies down below this critical value. Tests and practical experience have indicated that with the ball bearing mounting of the inner flywheel that is employed, damping is effective for all accelerations exceeding an extremely small magnitude. The tendency of bearing friction to lock the flywheel and drum shafts together is no doubt materially reduced by the fact that the direction of the gravity load with respect to the bearing is constantly changing, thus tending to break loose any slight binding condition between the balls and their races. Mention has been made of the close analogy between the rotary stabilizer and the magnetic drive. Fig. 18 may be used to represent the electrical analogue of the stabilizer, the only change being that the magnet drive elements indicated opposite the bracket in Fig. 18 are eliminated and the connection indicated at S is substituted. (The circuit branch that represents the movable idler is, of course, omitted.) L_1 represents the moment of inertia of the drum and shell. R_1 represents the resistance of the oil film to relative movements, instead of the magnetic drag; and L_2 represents the moment of inertia in the inner flywheel. L_2 is of zero resistance since no additional power is required to keep this inner flywheel rotating. The practical difference between the two systems is that, as compared with the magnetic drive, the effective masses or moments of inertia of the rotary stabilizer are very much smaller. If the film is to get the rotary stabilizer up to speed in a reasonably short time and without undue strain, it is not feasible to employ nearly as large masses as are represented in the magnetic drive; and since the film loop flexibility can hardly be made any greater than that in the magnetic drive, it is not practically possible to give the filter as low a cut-off frequency. In other words, the magnetic drive can go farther in filtering out low-frequency disturbances introduced at the sprocket. There are also sources of disturbance that operate directly upon the drum shaft. One of these is bearing friction and another is irregularities in the film, such as splices and kinks. These sources of disturbance are indicated in Fig. 18 by alternator D_3 in series with L_1 to represent bearing irregularities, and an alternator D_2 in series with C_2 to represent film irregularities. The ability of the system to resist speed changes due to these disturbances is directly proportional to the mechanical impedance at the drum, and in this respect the magnetic drive possesses an advantage. On the other hand, the magnetic drive may introduce disturbances if the magnet rotation is not constant, but it can readily be shown that this effect is small.[24]

In performance, the rotary stabilizer is regarded as a close second to the magnetic drive and it is obviously a much simpler and less expensive device.[29]

Sound Printers.—It has been the general practice to print soundtracks on a sprocket, both films being wrapped around the sprocket and the exposing light being projected through the negative film onto raw stock from the interior of the sprocket. By proper choice of the sprocket diameter a certain amount of compensation may be provided for the fact that, on the average, the negative film will have undergone some shrinkage while the raw stock will not. It is inevitable, however, that continual readjustments must take place of the positions of the two films with respect to each other and to the sprocket. These readjustments are all of very small amplitude, but occur with the engagement of each new tooth. The effect of any slippage of one film with respect to the other is to blur the print, while irregularities in movement of the raw stock result in variations of exposure. If the exposing light-beam is made very narrow, the blurring tends to become less, while the variations in exposure become more noticeable. If the light-beam were made as narrow as a recording slit, slipping would show its effects not so much in blurring as in periodic stretching out and compression of the waves; or, in other words, in introduction of true "wows" or speed fluctuations that are not in the negative. In practice, the light-beam in sprocket type printers has been made of such width that the principal effect is periodic blurring. Nevertheless, this effect is the outcome of speed variations, and hence is a logical part of this paper. The Bedford non-slip printer,[23] in eliminating this fault, has contributed in an important degree to quality improvement. The printer is based upon the same principle that has already been discussed in connection with projectors.[22] A printer employing the same principle was independently devised by R. V. Wood.[31]

Fig. 25 is a schematic diagram. In the case of the printer, the drum itself does not run at fixed speed as in Bedford's projector, but is driven by the negative film. The raw stock must accommodate itself to the surface speed of the moving negative that propels the raw stock past the printing point. It would be possible to drive the drum and cause the curvature of both films to change in accordance with shrinkage, but the expedient employed by Bedford is simpler.

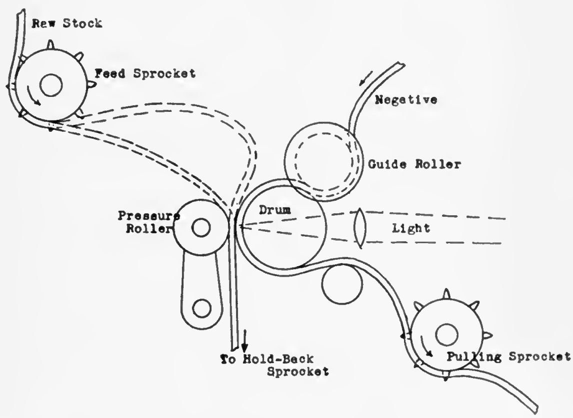

FIG. 25. Film paths in Bedford non-slip printer.

If the drum failed to run at uniform speed, the only effect upon the print would be variations in exposure. A rotary stabilizer is mounted on the drum shaft to minimize speed fluctuations. The printing is done by a concentrated beam of light so that it all occurs where the films are in tight contact. A degree of contact is possible in this printer that could not be permitted in the sprocket type, for the reason that continual readjustment to the sprocket teeth must be permitted in the latter, or the teeth will begin to cut the film at the perforations.

Fig. 26 shows one of the laboratory models of the non-slip printer. A number of commercial designs have been built and are now in use in several laboratories.

Gates.—It is frequently convenient to support the film where it passes the scanning light by means of a stationary support over which the film slides. This necessarily means more or less sacrifice of speed constancy, since the speed constancy is best where the film is held against the drum, and any fluttering of unsupported film or any inequalities in shrinkage between the driving and the scanning points introduces variations in velocity. The stationary support or "gate," as it is commonly called, also introduces friction.

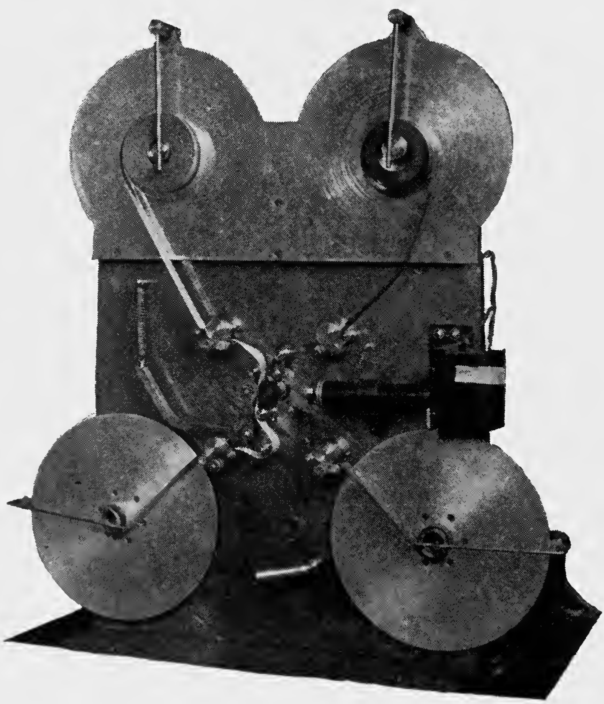

FIG. 26. Laboratory model of non-slip printer.

In many gate type reproducers, this friction has been unnecessarily large. It can be made extremely small. If in addition to minimizing friction, the design is such as also to minimize the amount of unsupported film as well as the total length of film between the drum and the scanning point, the harmful effects of employing a gate can be made quite small.

Fig. 27 shows the machine of the gate type that has come the closest of any within the author's acquaintance to matching the performance of a machine in which the scanning is done directly on a drum.

Motors.—Nothing has been said so far about the electric motor, upon which ultimate dependence is placed for speed constancy. Fortunately, the larger power supply systems provide a very high order of constant frequency, and the driving motors are electrically coupled to generators in which many tons of steel and copper are moving at a velocity of the order of 100 feet per second. Sudden frequency changes, such as to impair sound quality, do not often occur under such conditions. Small synchronous motors have been developed

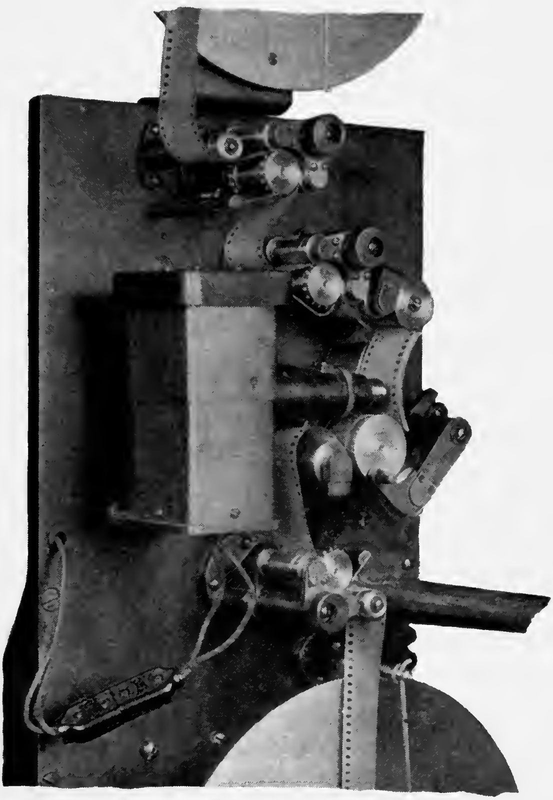

FIG. 27. Laboratory film phonograph employing "gate."

that have given no trouble with respect to "hunting." The type of construction is such as to provide very effective pole-face grids.

Various schemes have been worked out to meet the condition where the power supply is direct current. Centrifugal type governors, operating generally to control the field current, have been developed, which are quite satisfactory. It is, of course, necessary to avoid the type of governor that causes the speed to fluctuate above or below a correct average by alternately opening and closing a contact that short-circuits a part of the field resistance. If, however, this opening and closing occurs at an extremely rapid rate it is permissible. A number of systems have been worked out that regulate the motor in response to changes of frequency in a tone generated by a small high-frequency alternator coupled to the motor. Such a system was described by H. M. Stoller, 1928.[30]

Where several machines are operated synchronously, Selsyn motors are often employed. This arrangement practically gears the machines together, so that they can be brought up to speed without any relative phase-shifts. There are a few precautions that must be observed to insure that there will not be any slipping of poles during the starting, but with proper installation, the Selsyn systems have given very little trouble and do not seem to have been responsible for any appreciable speed fluctuations during operation. Although the connection between Selsyn machines is an elastic coupling, the damping is of the same order of magnitude as that of synchronous motors of comparable rating, and little trouble from hunting has been encountered. This assumes polyphase connections of both primary and secondary windings.

Other Designs and Inventions.—One of the purposes of this paper has been to call attention to some of the ingenious devices that have been employed or suggested for improving speed constancy, and to give credit to those who have taken part in this "Quest." Among the workers in other countries, Messrs. Vogt, Massole, and Engl deserve mention. Obviously, no review of this kind can include all the arrangements and inventions that deserve mention, and the list given here is necessarily limited to devices that have come to the writer's attention. It is to be hoped that other writers, perhaps through contributed discussions or in separate papers, will supplement this outline by describing other interesting arrangements and schemes that ought to have been included, especially if the devices in question have not been described in earlier technical publications.

REFERENCES

[1] BELL, A. G., AND TAINTER, S.: U. S. Pat. No. 341,214.

[2] MAXFIELD, J. P., AND HARRISON, H. C.: "High-Quality Recording and Reproducing Music and Speech," *Trans. A. I. E. E.*, **45** (Feb., 1926), No. 2, p. 334.

[3] FREDERICK, H. A.: "Recent Advances in Wax Recording," *Trans. Soc. Mot. Pict. Eng.*, **XII** (1928), No. 35, p. 709.

[4] KELLOGG, E. W.: "Electrical Reproduction from Phonograph Records," *Trans. A. I. E. E.*, **46** (June, 1927), No. 6, p. 903.

[5] RICE, C. W., AND KELLOGG, E. W.: "Notes on the Development of New Type of Hornless Loud Speaker," *Trans. A. I. E. E.*, **44** (April, 1925), No. 4, p. 982.

[6] BLATTNER, D. G., AND BOSTWICK, L. G.: "Loud Speakers for Use in Theaters," *J. Soc. Mot. Pict. Eng.*, **XIV** (Feb., 1930), No. 2, p. 161.

WENTE, E. C., AND THURAS, A. L.: "A High-Efficiency Receiver for Horn Type Loud Speakers," *Bell Syst. Tech. J.*, **VII** (Jan., 1928), No. 1, p. 140.

[7] MALTER, L.: "Loud Speakers and Theater Sound Reproduction," *J. Soc. Mot. Pict. Eng.*, **XIV** (June, 1930), No. 6, p. 611.

OLSON, H. F.: "Recent Developments in Theater Loud Speakers of the Directional Baffle Type," *J. Soc. Mot. Pict. Eng.*, **XVIII** (May, 1932), No. 5, p. 571.

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

BARTON, F. C.: "Victrolac Records," *J. Soc. Mot. Pict. Eng.*, **XVIII** (April, 1932), No. 4, p. 452.

"High Fidelity Lateral Cut Disk Records," *J. Soc. Mot. Pict. Eng.*, **XXII** (March, 1934), No. 3, p. 179.

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

[10] CONSTABLE, J.: U. S. Pat. No. 1,425,177.

[11] AMET, E. H.: U. S. Pat. No. 1,221,407.

[12] ELMER, L. A., AND BLATTNER, D. G.: "Machine for Cutting Master Disk Records," *Trans. Soc. Mot. Pict. Eng.*, **XIII** (1929), No. 37, p. 227.

[13] BEDFORD, A. V.: "A Planetary Reduction Gear System for Recording Turntables," *J. Acoust. Soc. Amer.*, **III** (Oct., 1931), No. 10, p. 207.

U. S. Pat. No. 2,027,666.

[14] MEAD, M. S.: U. S. Pat. No. 1,854,949.

[15] PFANNENSTIEHL, H.: "A Reproducing Machine for Picture and Sound," *Trans. Soc. Mot. Pict. Eng.*, **XIII** (1929), No. 38, p. 253.

U. S. Pat. No. 1,922,669.

[16] KELLOGG, E. W., AND BELAR, H.: "Analysis of the Distortion Resulting from Sprocket-Hole Modulation," *J. Soc. Mot. Pict. Eng.*, **XXV** (Dec., 1935), No. 6, p. 492.

[17] SHEA, T. E., MACNAIR, W. A., AND SUBRIZI, V.: "Flutter in Sound Records," *J. Soc. Mot. Pict. Eng.*, **XXV** (Nov., 1935), No. 5, p. 403.

[18] HOXIE, C. A.: U. S. Pat. No. 1,758,794.

[19] HEISLER, C. L.: U. S. Pat. No. 1,808,551.

[20] HEISLER, C. L.: U. S. Pat. No. 1,831,562.

[21] HOXIE, C. A.: U. S. Pat. No. 1,756,864.

[22] BEDFORD, A. V.: U. S. Pat. No. 1,754,187.

[23] BATSEL, C. N.: "A Non-Slip Sound Printer," *J. Soc. Mot. Pict. Eng.*, **XXIII** (Aug., 1934), No. 2, p. 100.

[24] KELLOGG, E. W.: "A New Recorder for Variable-Area Recording," *J. Soc. Mot. Pict. Eng.*, **XV** (Nov., 1930), No. 5, p. 653. (The title of this paper is misleading, in that the main features of the recorder were in no wise related to the type of sound-track to be recorded.)

[25] ROBINSON, L. T.: U. S. Pat. No. 1,880,106.

[26] HANNA, C. R.: U. S. Pat. No. 2,003,048.

[27] REYNOLDS, E. W.: U. S. Pat. No. 2,013,109.
LOOMIS, F. J.: U. S. Pat. No. 2,019,147.

[28] LOOMIS, F. J., AND REYNOLDS, E. W.: "A New High-Fidelity Sound Head," *J. Soc. Mot. Pict. Eng.*, **XXV** (Nov., 1935), No. 5, p. 449.

[29] COOK, E. D.: "The Technical Aspects of the High-Fidelity Reproducer," *J. Soc. Mot. Pict. Eng.*, **XXV** (Oct., 1935), No. 4, p. 289.

[30] STOLLER, H. M.: "Synchronization, and Speed Control of Synchronized Sound Pictures," *Trans. Soc. Mot. Pict. Eng.*, **XII** (1928), No. 35, p. 696.

[31] WOOD, R. V.: "A Shrinkage Compensating Sound Printer," *J. Soc. Mot. Pict. Eng.*, **XVIII** (June, 1932), No. 6, p. 788.

THE EFFECT OF ABERRATIONS UPON IMAGE QUALITY*

W. B. RAYTON AND A. A. COOK**

Summary.—*Lenses are used to form images for two principal purposes first, to produce the most accurate record possible of the original object; and second, to produce a pleasing effect. The character of the image formed by a lens depends upon diffraction and upon the residual aberrations remaining after the designer and the manufacturer have done their best. For pictures of the first type it is desirable that aberrations be reduced to a minimum, but for pictures of the second type they are very often deliberately employed to produce desired effects. In motion picture projection, lenses of the first class are doubtless always desired. In motion picture photography, some attention has been given to achieving special effects by deliberately introducing aberrations into the lens.*

Among the many aberrations that afflict lenses, one of the most important is chromatic. Since, in general, only two colors can be brought to a common focus, some thought has been given to the question of what two colors it is best to choose to meet the requirements of various kinds of lighting and different types of sensitivity of the emulsion. Recent experiments indicate that for a combination of particular interest in motion picture photography, namely, incandescent lighting and super-pan emulsion, no significant difference in performance is detectable among lenses of 12-inch focus or less, depending upon whether the two colors chosen for chromatism are yellow and violet, or red and violet.

The discussion that follows will be confined to photographic and projection lenses. The function of such lenses is to form images, and generally images in which each detail in the object is reproduced with the utmost fidelity. Any object whatsoever may be regarded as consisting of a vast number of points, and in the ideal image each point of the object would appear as a point in the image. The degree of approach to perfection in an image, or, if one prefers, the degree of departure from perfection, can therefore be studied by investigating the character of the images of several judiciously chosen object points.

No lens can possibly form a point-image of a point object. We were told in elementary physics that light travels in straight lines;

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but because of its wave nature, light refuses to behave in this manner when it passes the edge of an opaque object. Close examination will reveal that the edge of the shadow is not absolutely sharp and that some light is apparently bent into the shadow as it passes the edge of the opaque object. The same effect occurs at the rim of a lens; so that even if there were no other factors responsible for imperfection in the image, the light arising in a single object-point, instead of uniting in an image-point, would be distributed over an area of finite size in the manner illustrated in Fig. 1. The phenomenon responsible for this effect is called diffraction. In photographic and

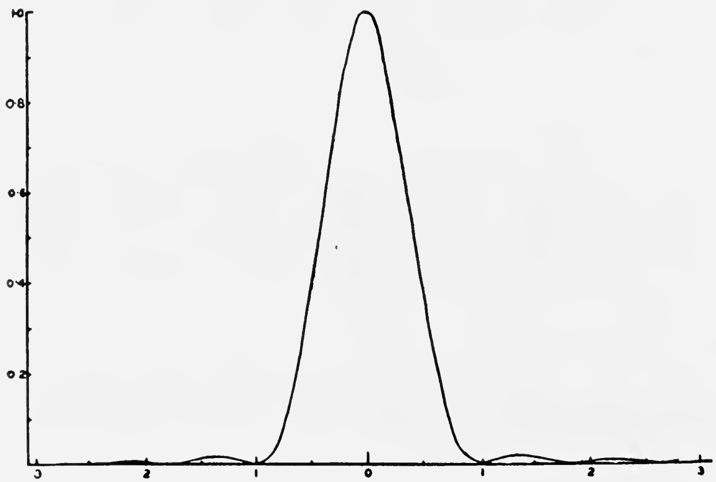


FIG. 1. Distribution of light in the diffraction image of a star.

projection lenses it plays a very small part, and we shall not refer to it again.

Even if we ignore diffraction, however, we can not meet the requirements of perfect image formation. In the language of geometrical optics, perfect imagery requires that a lens unite in a common image-point all the rays of light that leave the corresponding object-point within the range of the angular aperture of the lens. But no lens can do this, and as a result, no object-point can be imaged as a point but must appear as an area of finite size within which light may be distributed in a great variety of ways. Necessarily, it follows that if two object-points are too close together their images will overlap so badly that it will be impossible to recognize from a study of the image that there are two object points. This means that the image can not contain all the detail of the object, outlines are not absolutely sharp, light falls into areas that should be black and turns them gray, and, in general, the image, we say, is not sharp or does not have perfect definition.

While from the standpoint of performance, the end result is the same, regardless of how we name the cause, it has been very useful

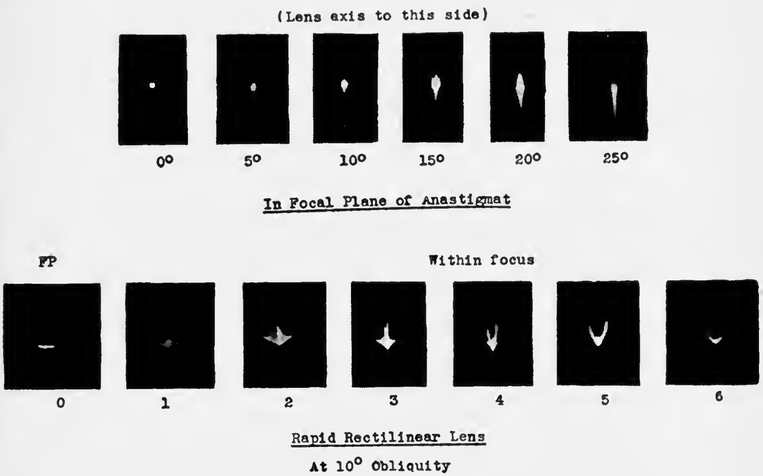
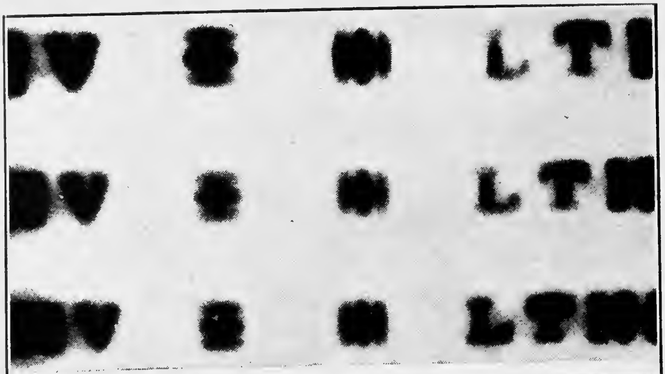


FIG. 2. (*Upper.*) The image of a star as it appears in the focal plane of a good anastigmatic lens. The plate was focused for best definition at the center of the field. Successive exposures were at 5-degree intervals from the center of the field to a point 25 degrees from the center.

(*Lower.*) A series of exposures made with a rapid rectilinear lens at a field of 10 degrees, beginning with an exposure in the focal plane that shows the image to consist of practically a straight horizontal line and followed by six other exposures, each plate being moved 1 mm. nearer the lens than its predecessor. These figures show the combination of coma and astigmatism.

to analyze this departure from perfection into separate entities called aberrations. Some of these, called "chromatic" aberrations, are due to the different refractivities of glass for light of different wavelengths or colors. Another called "spherical" aberration, is due to the finite aperture of the lenses; it increases in amount with increase of aperture. Other aberrations appear only in the case of light passing obliquely through the lens, as must occur in imaging any object-point outside the center of the field. Fig. 2 serves to demonstrate some of the irregular patches of light that must serve as the best attainable images of object-points under various conditions. It is



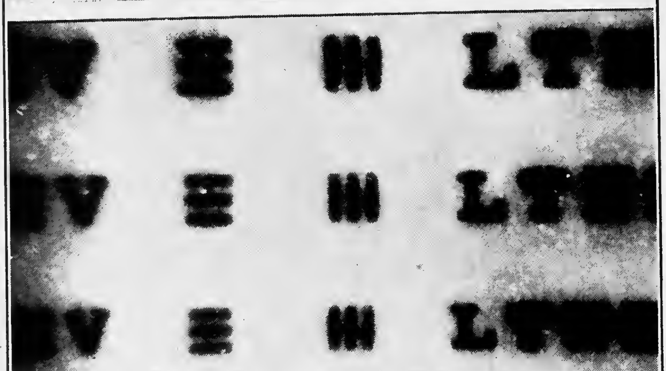


FIG. 5

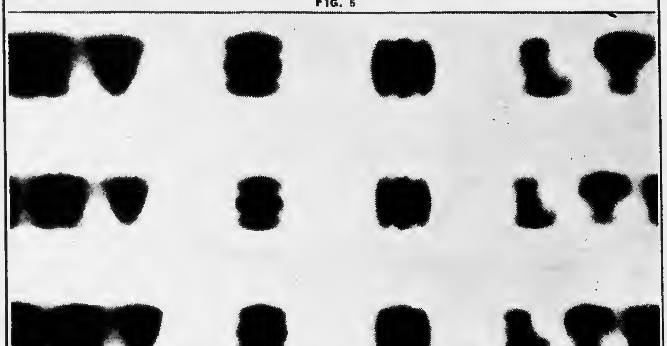


FIG. 6

In a lens with considerable spherical aberration there are frequently two points at different distances from the lens at which some approach to a sharp image is attainable; between these positions the image is inferior to either of the two best positions.

Figs. 4 and 5 show the two positions in which some semblance of image quality is obtained; Fig. 6, which is definitely inferior, is taken in a plane lying between the other two.

not the present purpose to discuss the nature of these aberrations at any length, since they have been considered in several papers presented to the Society in the past.[1] It is more the purpose to discuss some of the effects of these aberrations upon image quality and some of the dilemmas faced by the lens designer in his effort to reduce them to a minimum.

It is evident from an inspection of the photographed images shown in Fig. 2 that the distribution of light within these areas is far from uniform. This leads at once to the result that the definition of a photographic lens will appear to vary with exposure and development. Underexposure and high-contrast development will fail to reveal

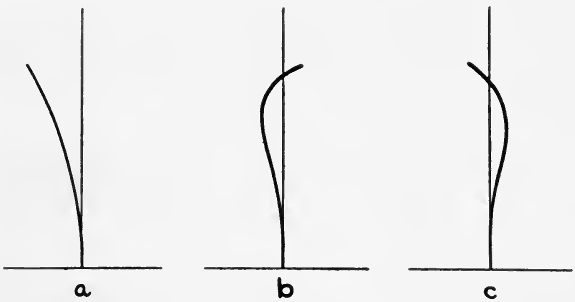


FIG. 3. Special aberration curves. For perfect correction the curve of aberration should be a straight vertical line. (*a*) Typical under-correction; (*b*) slight over-correction at the margin, and an under-corrected zone; (*c*) shows slight under-correction for the margin and an over-corrected zone.

aberration effects that, on the other hand, become overemphasized by overexposure and low-contrast development. Lenses can differ over a wide range both as to the character and the amount of spherical aberration present. In a simple lens the focal length decreases progressively for each zone as the distance of the ray from the center of the lens increases. Such a condition is indicated by the curve *a* in Fig. 3. This represents pure under-correction. Curve *b* in the same figure shows a condition common in photographic and projection lenses wherein correction is complete for some one zone, while there exists over-correction for zones farther from the center and under-correction in zones nearer the center. Such a condition is responsible for what is known as stop-difference. If the lens is focused with full aperture and then stopped down, readjustment of focus is necessary to obtain the best definition. Still another condition is represented in curve *c*. It seems obvious that such wide difference in the character of the residual spherical aberration should lead to substantial differences in the distribution of light in the image. In some cases it leads apparently to two image-planes at different distances from the lens. Figs. 4 and 5 show the character of the images in two such image-planes. Fig. 6 is a photograph of the image in a plane intermediate between these other positions.

From such considerations it is very obvious that different operators

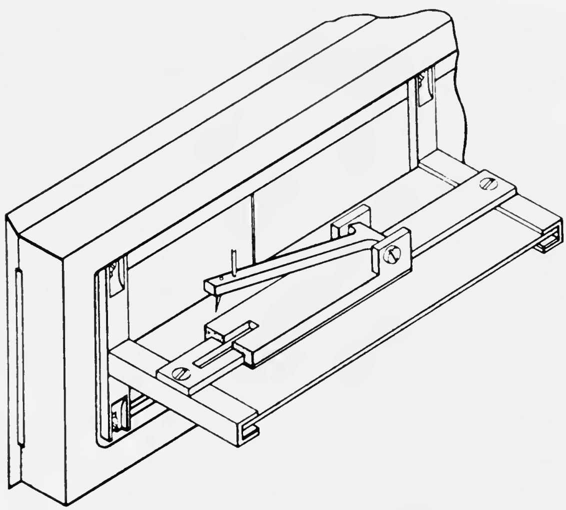


FIG. 7. Plate holder used in chromatic aberration tests.

may produce very different results with the same lens without understanding why they differ, while a skillful operator can at will use the same lens to produce quite different effects.

As a matter of fact, the effort has been frequently made by the designer to produce lenses that, by virtue of aberrations deliberately left in the lens, produce images characterized by a distinct haziness. Such lenses are popular for portraiture in as much as they have a tendency to suppress small skin blemishes that would otherwise have to be removed from the negative by a retoucher, and because there is a general belief that such "soft-focus" pictures are more life-like representations of the features of the subject than are pictures made with a sharp-focus lens. There is room here for nice judgment as to just how much aberration to leave in the lens; hence the opportunity for the existence of many lenses of this general character. In some cases the problem has been solved by making the amount of aberration, and hence the degree of diffusion, variable at the will of the operator by providing an adjustment that permits varying the position of one of the component elements of the system.

There is a further choice for the designer to make in deciding what kind of aberration to employ for producing the soft-focus effect. He can choose spherical aberration or chromatic aberration, or both. Since in the presence of chromatic aberration there are many focal points each corresponding to a different color, many different effects can be produced, depending upon the character of the emulsion used. In focusing the camera, the eye will select the image formed by green light if the subject is illuminated with anything approaching white light. The emulsion may have its sensitivity confined to the blue, in which case the image will look simply like an out-of-focus image when the photograph is made. On the other hand, if an emulsion is used that is almost equally sensitive to a long range of colors, a truly diffuse image will result, but one characterized by more unpleasant lack of sharpness of outline than in soft-focus lenses that depend upon spherical aberration for the diffusion.

The reference to chromatic aberration leads naturally to consideration of another matter that has given rise to considerable speculation in optical circles, *viz.*, the most profitable type of chromatic correction to employ. This has been discussed for the case of telescope objectives[2] for both visual observation and for photographic use, as well as for camera lenses.[3] In general, the designer can bring to a common focus two colors only, and that only for a single zone of the lens. Other colors will come to foci nearer or farther from the lens.

It has been standard practice to achromatize visual instruments for colors corresponding to the *C* and *F* lines of the spectrum. The *C* line is orange-red in color, and the *F* is blue. Photographic lenses have usually been corrected for the *D* line, which is yellow, and the *G'* line, which is violet. The wisdom of this choice in both cases has been called into question, and particularly in the case of camera lenses was it questioned upon the introduction of supersensitive panchromatic film and tungsten lights into motion picture practice. There has been some argument in favor of achromatizing for the *C* and *G'* lines for use under these conditions. The writers made some rather hasty tests in 1928 employing lenses that had been corrected for the yellow and the violet in the classical manner, with different kinds of illuminations and emulsions, to see whether there was any perceptible degradation of image quality resulting from the use of tungsten light and superpan emulsions, as compared with the performance of the same lenses used with orthochromatic emulsions and arc lights. No differences were discovered. These experiments were reported to a joint meeting of the Society and the Academy of Motion Picture Arts & Sciences. More recently we have investigated the matter somewhat more thoroughly by means of an experiment that it may be of interest to describe and with results that will be set forth shortly.

For this experiment we made three special lenses, each of 320-mm. focal length (about $12^1/_2$ inches), with a relative aperture of $f/6$. One of them was achromatized for the C and F lines, or red and blue; another for the D and G', or yellow and violet, corresponding to the classical practice in photographic lens design; and the third for C and G', or red and violet.

With each of these three objectives test photographs were made on 2 × 5-inch plates using process, orthochromatic, and supersensitive panchromatic emulsions. As a test-object we used a series of parallel vertical lines engraved upon glass and stationed in the focal plane of a collimator whose objective lens had a focal length of 1800 mm. The object appeared then to be at infinity. Because of the difference in the focal length of the collimator lens and the lens under test, the chromatic aberrations of the collimator lens were reduced to an utterly insignificant value in the focal plane of the lenses under test; namely, to about one-thirtieth of their actual value. A plate holder specially made for the purpose, shown in Fig. 7, supported the plate at an angle of 2 degrees to the optical axis of the system. Spring clips held the emulsion surface firmly against a shoulder. A device was provided to permit a fine needle to be drawn across the center line of the plate to mark the position of the best visual focus. The needle holder had a set-screw and lock-nut adjustment to fix its position so that it could move only in a straight line at right angles to the optical axis of the camera. The procedure employed in making a test negative was as follows:

The lens was mounted upon the camera front board and the plate holder, unloaded, was put into position. Observing through a 25X focusing microscope, the plate holder was first racked back into position until the needle point was in the focal plane of the microscope; then the target image formed by the lens was brought to the same plane by focusing the lens. This method was found to be accurate and reproducible, because there is parallax between the needle point and the image whenever they are not exactly in the same plane.

The camera front and back plates were then locked; the plate

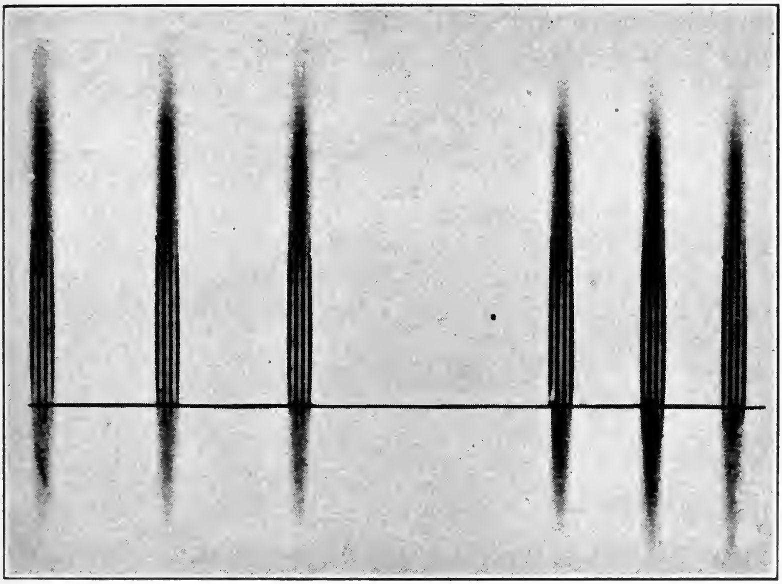


FIG. 8. Reproduction, ten times enlarged, of one of the photographs obtained in the chromatic aberration tests. The horizontal line is the plane of best visual focus. Distances above this line are farther from the lens. The best photographic focus in this particular case is about 0.5 mm. farther from the lens than the visual focus. The three exposures in the group at the left were made with tungsten light, and the three at the right with daylight.

was loaded into the holder, a line scratched across its center with the needle fixture, and the holder put back into the camera for a series of exposures. On each plate three exposures were made with tungsten light and three with daylight illuminating the target. The plate holder was arranged to move laterally between exposures. Fig. 8 shows the kind of result obtained. This is a $10X$ enlargement from the original negative.

The horizontal line in the figure indicates the position of best visual focus. Everything above this line is nearer the lens and everything below is farther away. The area through which the target lines show up sharply represents the depth of focus of the lens under test. It amounts to just about 1.0 mm., corresponding to a depth of field that extends from 335 feet to infinity. The center of that region of sharpness was assumed to be the point of best photographic focus, and the measurements shown in Table I were made between this point and the line marking the visual focal point. The measurements were made with a linear comparator on the original negatives. Fig. 8 is a reproduction of the negative made with the lens that was corrected for the red and blue on a process plate sensitive only to blue and violet light. The three exposures on the left were made with tungsten light and the other three with daylight. Similar exposures were made with the same lens on an orthochromatic plate and on a supersensitive panchromatic emulsion, all at the same visual focus setting. It is apparent by inspection of Fig. 8 and the data in Table I that with all three types of emulsion the photographic focus of this lens is farther from the lens than the visual focus.

TABLE I

Color Correction of Lens	Emulsion			
	Process		Orthochromatic	Supersensitive Panchromatic
C–F	Tungsten	+0.93 mm	+0.57 mm.	+0.18 mm.
	Daylight	+1.07	+0.78	+0.26
D–G'	Tungsten	+0.21	+0.07	+0.22
	Daylight	+0.26	+0.14	+0.14
C–G'	Tungsten	+0.33	+0.12	+0.20
	Daylight	+0.38	+0.23	+0.17

These values are displacements of best photographic focus from best visual focus. Each value is the average of several determinations. Plus values indicate that the best photographic focus is farther from the lens than the best visual focus.

A similar series of tests with both kinds of illumination and the three emulsions was made with each of the other two lenses. The photographs are not reproduced here but the results of the measurements made on the plates are set forth in Table I. Under *C-F* for example, the figure is +0.93 mm. for tungsten illumination. This means that the average photographic focus was 0.93 mm. farther from the lens than the visual focus, determined as an average of 12 separate readings, the largest of which was 1 mm. and the smallest 0.82 mm.

We found that results could be repeated with considerable accuracy, and the probable error of any of the averages is about 0.04 mm. This includes all possible sources of error. It is to be noted that there is no significant difference between the lens corrected for the C and G' lines and the lens corrected for D and G' in respect to their behaviors with either orthochromatic or panchromatic materials. The results of this experiment confirm our earlier tests, indicating that a lens corrected for the D and G' lines of the spectrum is at least as good as any of the other combinations that have been suggested even for specific use with tungsten light and panchromatic materials.

These tests were conducted with complete impartiality and with the sole purpose of trying to determine by carefully executed experiments the best type of chromatic correction for photographic lenses intended for professional motion picture photography. For the designer, one type of correction is no more difficult to achieve than another; hence, there was not the slightest incentive for our judgment to be biased one way or the other. These results should be reliable unless there was some error of principle involved that we have not been able to detect.

It is realized that the substance of this paper is not an adequate discussion of the subject represented by the title. It will have served its purpose, however, if it gives to the reader who is utterly unfamiliar with the problems of the lens designer some impression of the character of his task.

It is a pleasure to acknowledge our indebtedness to Professor Rudolph Kingslake of the Institute of Optics of the University of Rochester, for the use of Figs. 1 and 2.

REFERENCES

[1] CORY, A. S.: "Optical Requirements of Motion Picture Projection Objectives," *Trans. Soc. Mot. Pict. Eng.* (1918), No. 6, p. 9.

[2] SMITH, T. T.: "Color Correction of an Achromatic Doublet," *J. Opt. Soc. Amer. and Rev. Sci. Instr.*, **10** (1925), No. 1, p. 39; **15** (1927), No. 5, p. 247.

[3] DUBRAY, J. A.: "Chemical Focus in Cinematography," *Amer. Cinemat.*, **15** (Oct., 1934), No. 6, p. 248.

THE ANALYSIS AND SPECIFICATION OF COLOR*

K. S. GIBSON**

Summary.—*A brief résumé of the various methods used to describe, analyze, or specify colors, including color names, systems of material color standards, colorimeters, and spectrophotometric methods. The computation of colorimetric quantities from spectrophotometric data is considered, together with methods of specification based thereon.*

(I) INTRODUCTION

Color is an important factor in nearly every article of commerce, affecting the sales value of the article in one of three ways:

(*1*) The color may be the primary property because of which the article is desired. This is true of dyes, pigments and paints, and colored glassware used in railway, traffic, and aviation signalling.

(*2*) The color may be an indication of the quality or identity of an article, as in the case of vegetable and mineral oils, sugars and syrups, dairy products, flour, glass, paper, and raw materials such as cotton, wool, and silk.

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(*3*) The article may be artificially colored for the purpose of producing and increasing sales appeal. Such materials include textiles and wearing apparel of all kinds, automobiles, furniture, enamels and porcelains, and candy and other food-stuffs. Containers of food and other merchandise are often artistically colored for the same purpose.

The annual trade value of these materials is in the billions of dollars. The analysis and control of colors is thus seen to be a matter of immense importance in commerce and industry. If at the same time it be realized that there are millions of perceptibly differing colors, any of which it may be desired to analyze and specify, the importance of colorimetric research and testing can readily be understood.

Various methods of describing colors and of measuring and specifying color stimuli are available, the most suitable depending upon the problem. Most of these methods are briefly described or noted in the present paper, although particular instruments illustrating the methods are listed in but a few cases. The scope of the present paper is limited since it is not desired to duplicate any of the following publications:

(*1*) The monographs on color recently published by The International Printing Ink Corporation. There are three of these, entitled, *Color Chemistry*, *Color as Light*, and *Color in Use*, all with chromatic illustrations. They introduce the subject of color from the point of view of the chemist, the physicist, and the psychologist, respectively.

(*2*) The *Handbook of Colorimetry*,[1] prepared under the direction of Prof. A. C. Hardy. This publication should be very useful in the colorimetry of materials by way of spectrophotometric analysis.

(*3*) The colorimetry report being prepared by the Colorimetry Committee* of The Optical Society of America, Dr. L. A. Jones, *Chairman*. The report should be an authoritative consensus of opinion regarding the nomenclature and technic of colorimetry. Its publication is expected in the near future.**

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* This committee includes fifteen or more persons vitally interested in colorimetric matters and representative of industrial laboratories, universities, and government departments.

** Earlier publications that may profitably be read by those interested include a previous O.S.A. Colorimetry Committee report (L. T. Troland, *Chairman*),[2] and *Color and Its Applications*, by Luckiesch.[3]

The present paper at most is merely an introduction to the subject of colorimetry. To acquire a knowledge of the science adequate to enable one to avoid the pitfalls of unsound colorimetric methods and to make of colorimetry a safe and useful tool in the analysis, control, and specification of the colors of materials requires extensive study and experience. Those who wish to undertake any phase of colorimetric research or testing should at the least become familiar with the subject matter of the publications referred to herein. He will then be prepared to pursue the subject along his own special lines, both in reviewing the voluminous literature available and in conducting the investigations in which he is interested.

(II) COLOR NAMES

The simplest way of describing colors is, of course, by name. If, for example, one wished to use ten differently colored papers or cards for some sort of classification or filing system, he could specify red yellow, green, blue, purple, white, brown, pink, black, and gray, and the dealer would have no difficulty in supplying materials of those colors sufficiently differentiated from each other for the purpose. There also are a large number of other names, such as ivory, cream, lemon yellow, chrome yellow, chrome green, ruby, scarlet, maroon, amber, gold, orange, ultramarine, cobalt blue, violet, magenta, and so on, which doubtless in every case have given the reader a more or less definite mental picture of the color named; for each name is, by usage or derivation, closely associated with some particular color.

However, it is a matter of common knowledge that if one wishes to match the exact "shade" of a given material, it is a very unsafe procedure to order the material by color name. And, in general, while such names may serve to describe colors adequately for certain purposes, they rarely serve to specify them with sufficient precision for even the simplest colorimetric work.* However, if one has at hand a

* A system of color names on a scientific basis using a few of the most common names qualified by certain adjectives such as light, dark, pale, weak, *etc.*, has been formulated by Dr. I. H. Godlove, representing The Intersociety Color Council. A further study and revision of this system is being undertaken by Dr. D. B. Judd of the National Bureau of Standards and Mr. K. L. Kelly, representing the American Pharmaceutical Association. It is planned to use this system for naming the hundreds of drugs and chemicals of the U. S. Pharmacopœia and the National Formulary. Correlation is being made with the Munsell color system, and thereby with the I.C.I. system of color specification, described later in

sample of the desired color, the selection of a sample of closely matching color is greatly facilitated. This leads immediately to a consideration of color cards, atlases, dictionaries, *etc.*, which are discussed in the following section.

Before considering these, however, another class of color names may be noted, which, while of undoubted use in trade, can hardly be considered as on a scientific basis. It will be sufficient to quote the following from Maerz and Paul's *Dictionary of Color:*

"Challamel's *History of Fashion in France* states that in the sixteenth century for instance, 'French women wore colours, and great was their number—from *Rat-colour* to that called *widow's joy*, or *envenomed money*, or *chimneysweep*'! Nor was this the only period when such names flourished; succeeding centuries kept pace with and even outdid the sixteenth in the invention of these extraordinary names for colors. The eighteenth produced in France: *Rash Tears*, *Paris Mud*, *Brand from the Opera*, *Burnt Opera House*, *Stifled Sigh*, and similar inspirations, . . . ; while in England the *European Magazine* for January, 1783, describes as fashionable: *Elliott's Red-Hot Bullets* and *The Smoke of the Camp of St. Roche*. . . . If one is inclined to smile at the whimsical names quoted above, as being in any sense an indication of the affected or effete mannerisms of an earlier and less civilized age, one should remember that today we match them with *Folly*, *Lucky Stone*, *Basketball*, *Elephant's Breath*, *Skating*, *Wireless*, *Water Sprite*. Perhaps there is some deep psychological reason for this poetic feeling towards the names for colors."

The following quotation from the same source may also be of interest, although it may be uncertain in some cases whether the name refers to color, material, or clothing:

"A great sensation was caused at the opera one night by the arrival of a lady dressed as follows: Her gown was 'a stifled sigh,' trimmed with 'superfluous regrets,' with a bow at the waist of 'perfect innocence,' ribbons of 'marked attention,' and shoes of 'the queen's hair' embroidered in diamonds, with the '*venez-y-voir*' in emeralds. Her hair was curled in 'sustained sentiments,' a cap of 'assured conquest' trimmed with waving feathers and ribbons of 'sunken eye,' a 'cat' or palatine of swansdown on her shoulders, of a colour called 'newly arrived people' (*parvenus*), a 'Médicis' arranged 'as befitting,' a 'despair' in opals, and a muff of 'momentary agitation.'"

(III) COLOR SYSTEMS

There are several elaborate systems of material color standards

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this paper. This means of designating colors is intended to be "sufficiently standardized to be acceptable to science, sufficiently broad to be appreciated and usable by science, art, and industry, and sufficiently commonplace to be understood, at least in a general way, by the whole public."

available for general use,* in addition to innumerable "color cards" of one kind or another. Three of these systems have been selected for brief description to illustrate both the advantages and the limitations of this method of color specification.

(*1*) *A Dictionary of Color*,[5] by Maerz and Paul, to which reference has already been made. According to the authors, "This work is primarily intended as a reference for the individual who seeks to relate colors with the names by which they are commonly identified." Its pages are said to contain "the most extensive range of colors as yet published, together with a list of practically all recorded color names in use up to this time in the English language." The authors state that "the inks used in this work . . . are reasonably permanent to light and the color plates may be freely exposed." The following brief description of the charts is taken from NBS letter circular LC-481:[4]

"Contains approximately 7000 different color samples printed on semi-glossy paper, about 6000 of which are $^1/_2$ by $^5/_8$-inch rectangles, and about 1000 of the darker of which are $1^1/_{16}$ by $^5/_8$-inch rectangles. The hue circle is covered in 8 intervals, each interval by a series of 8 charts each, the hues within each interval being obtained by mixtures of the pigments representing the extremes of the interval. The first chart in a series shows one extreme pigment at the upper right-hand corner, the other at the lower left. The upper left corner is white, the lower right a mixture in about equal proportions of the two extreme pigments. The samples intermediate on the chart represent colors which are intermediate, and the color steps between successive samples have been adjusted so that they are, in general, about equal. Each chart, therefore, shows a progression of hues from the upper right to the lower left corner, while the hues of the samples along the lines parallel to the other diagonal are nearly constant. The second chart in a series differs from the first by admixture of a gray ink; the third chart corresponds to admixture of a darker gray ink; and so on down to the eighth chart which shows very dark colors. An alphabetical list of about 4000 color names is given together with a key by means of which each corresponding sample may be found in the charts. These samples are also identified by name in the charts themselves. The large number of the samples makes the steps between successive colors so small that interpolation is often not necessary. On this account they may be used conveniently as practical color standards in nearly every field. Furthermore, the scholarship and thoroughness of treatment have given this work a wide reputation as the foremost authority on color names."

For the purposes for which this work was designed and issued, it leaves little to be desired. It was intended primarily as a dictionary

* The more important ones of American origin are briefly described in letter circular LC-481 of the National Bureau of Standards.[4]

of color and not as a color system. As a convenient means of general color specification, it is subject to the limitation that the samples are not removable and would not seem to be readily duplicable in case of damage.

(*2*) *The Munsell Book of Color.*[6] The arrangement of colors in this system* follows the idea of Helmholtz, that color has three attributes or dimensions, designated in the Munsell system as hue, value, and chroma. In the O. S. A. Colorimetry Committee report[2] these attributes are designated as hue, brilliance, and saturation, respectively. This three-dimensional classification of colors has wide acceptance and both sets of terminology are in common use, the former among artists and educators, the latter among scientists and technologists. The Colorimetry Committee report and the Munsell *Book of Color* should be consulted for further discussion of these terms.

The following description of the Munsell books is taken from NBS letter circular LC-481:[4]

"Two editions, standard and abridged, each giving approximately 400 different color samples. The standard edition consists of charts, one for each of ten different hues, showing colors varying in lightness (Munsell term: value) and saturation (Munsell term: chroma); there are also charts, one for each of eight chromas, showing colors varying in hue and value; charts, one for each of six values, showing colors varying in hue and chroma; and two charts showing altogether 20 hues at maximal chroma for each of eight values. The samples are rectangles of matt or nearly matt paper, $^5/_8$ by $^7/_8$ inches, except for those of the constant-value charts which are $^1/_2$ by $^5/_8$ inches. The abridged edition consists of 20 constant-hue charts made up of $^1/_2$ by $^5/_8$-inch samples. In both editions the samples of the constant-hue charts are arranged in rows and columns, the samples in any one row being equally light, and the samples in any one column being equally saturated. The colors progress from very light at the top of each chart to very dark at the bottom by steps which are visually equal; and they progress from achromatic colors at the left side of each chart to saturated colors at the right by steps which are also visually equal. Each sample is identified by three symbols—the first indicating hue, the second, value, and the third, chroma. These charts, because of the logical arrangement of the samples and the fact that the color differences between successive samples are visually equal, have a wide application; they are used in color education, in the setting of color tolerances, and as practical color standards."

It is stated in the standard edition that these papers "will stand reasonable use, but they should be protected as much as possible from light and from gas fumes." They may be obtained in sheets of vari-

* The *Book of Color* is a revision and extension of the *Atlas* of the Munsell Color System.

ous sizes, or in disks for spinning, so that they are adaptable for use in colorimeters or in colorimetric research, as well as providing an atlas of color. As a method of specification, the system, as exemplified in the *Book of Color*, is limited in that the large number of highly saturated colors exhibited by dyes and pigments are not included. Also the total number of samples is so limited that considerable interpolation is, in general, necessary to place a color accurately in the system.

(3) *Lovibond Tintometer Glasses*, comprising the "Lovibond colour scale," sold by The Tintometer, Ltd.[7] The following description of these glasses is taken from a Bureau of Standards scientific paper[8] which in turn quotes from a description of the system published in 1912:

"There are three sets of colored glasses, red, yellow, and blue—the red glasses absorbing most strongly in the green, the yellow glasses in the blue-violet, and the blue glasses in the orange-red. Each set is numbered by the makers in units from 1.0 to 20.0 with many subdivisions, especially of the lower numbers. Glasses of higher grades may also be obtained. 'Each ordinary scale consists of glass slips all of one color, but differing in depth, the divisions of difference being equal throughout....

" 'The color units are not only of equal depth throughout each scale, but have also a color equivalence in relation to each other. ... This equivalence of color value is accomplished when a normal white light can be gradually absorbed to extinction without the development of any color by successive additions of an equal number of units of the red, yellow, and blue glass. ... The starting point of the system is the neutral tint unit, which is the quantity of normal white light absorbed by one red, one yellow, and one blue glass standard unit combined.

" 'The intervals between the units, or main divisions of the scales, are the smallest differences between which the normal vision can discriminate in the deeper shades of glass colors; these are subdivided into tenths as the shades get lighter, and ultimately into hundredths in the very light shades; in fact, increasing in minuteness as the discriminating power of the eye increases. The actual dimensions of the unit are arbitrary and of no real importance, so long as the divisions are equal both in dimensions and equivalence, and the subdivisions are sufficiently minute for the work required.' "

The red and yellow Lovibond glasses have been widely used in America in the color grading of vegetable oils, as well as of mineral oils and other products. They are convenient to use and relatively cheap, and are probably permanent in their characteristics with careful usage. When used with various instruments they provide a useful method of subtractive colorimetry, although limited somewhat in range and precision, as noted in Section IV.

As a means of color specification any system of material samples, such as the three just noted, is subject to certain general limitations. These are:

(*1*) *Lack of Permanence and Reproducibility.*—If the samples comprising the system, which are often called the "standards," are not reasonably permanent, they may be unsafe to use, because of the false information they will give. At best they can give only a very limited service. If permanent, they may be very useful, but in case of loss or damage it may be difficult to duplicate them exactly.

(*2*) *Restriction of Range.*—This has already been noted. The importance of this restriction depends upon the problem. The range of colors that can be produced by opaque materials is somewhat less than by transparent filters such as glasses and solutions. When, however, two or more such filters are used in combination, which would be necessary if one's set were not to contain a very large number of standards, the transmission of the filters, and therefore the resulting brightness, would be so reduced as to decrease seriously the precision of the values obtained. In general, therefore, it may be said that whereas several of the systems of material standards cover a wide range of colors they will not satisfactorily cover the highly saturated colors shown by certain dyes and pigments and by the spectrum.

(*3*) *Lack of Uniformity.*—All systems of material color standards exhibit occasional lack of uniformity in passing from one step to another. This reduces the precision of results obtained by their use. For example, lack of uniformity among the red Lovibond glasses proved so troublesome to the American oil chemists that they requested the National Bureau of Standards to calibrate these glasses for them, and more than 3000 such glasses have been given new grades[9] during the past few years.*

The usefulness of any system such as those listed is greatly improved when the standards can be used in a suitable type of colorimeter. An example of this is the disk colorimeter[11] employing Munsell papers, which has been used in the color grading of various agricultural commodities. This provides continuous variation of color by optical mixture of the colors of a few selected papers, thus eliminating any need for interpolation. Furthermore, by spectrophotometric standardization of the papers used, followed by appropriate colorimetric computations, the results may be expressed in terms of any desired colorimetric system.

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* For Bureau publications on Lovibond glasses consult letter circular LC-398.[10]

(IV) COLORIMETERS

Instruments designated as colorimeters will be discussed briefly under three headings: (*1*) Colorimeters dependent upon material color standards; (*2*) colorimeters using spectrum primaries; and (*3*) filter photometers. Such a division is rather arbitrary but will serve for the purposes of this paper.

(*1*) *Colorimeters Dependent upon Material Color Standards.*—These may be additive or subtractive. In an additive colorimeter the standards or primaries are mixed in such a way that the mixture is the sum of the components; the individual elements add up to give the final result. In a subtractive colorimeter the final result is obtained by passing light successively through the standards, each absorbing in turn a part of the light transmitted by the previous one, until the desired color is obtained.

An example of the former is the disk colorimeter, employing Munsell papers, noted above. The personal equation* can be made very small in this instrument by the proper choice of disks. The most serious drawback to the method would seem to be the uncertainty in the colorimetric values of the Munsell papers used as standards, either due to lack of initial certainty in the values or to change resulting from handling or other usage.

A second example of an additive colorimeter is that designed by Guild.[12,13] In this instrument lights of three different colors, obtained by transmission through red, green, and blue dyed gelatin filters, are optically mixed in the necessary proportions to match the sample. The personal equation with this instrument is doubtless intermediate between that of instruments like the disk colorimeter, where the two halves of the photometric field are more nearly physically matched, and those in which there is an extreme physical difference, as when spectral primaries are used. The instrument has had considerable industrial use in England but little in this country. In a recent paper[14] the method of transforming results obtained on this instrument to results expressed in terms of the 1931 I.C.I. coordinate system** is explained in detail.

An additive trichromatic colorimeter has recently also been de-

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* This expression is used to describe the differences in results obtained by even normal observers, because of differences in color vision, when matching colors evoked by stimuli of differing physical composition.

** *Vide infra*, Section VI.

scribed by Newhall,[15] who likewise outlines the procedure for converting values obtained thereby to the 1931 I.C.I. coördinate system. The instrument was designed especially for investigating color perception, adaptation, after-images, and allied transient phenomena. It functions as a combined visual stimulator and trichromatic colorimeter.

The Lovibond glasses when used in a suitable optical instrument afford an example of subtractive colorimetry. As they have often been used, for example, by the oil chemists in the color grading of oils, there has been no adequate means provided for independently varying the brightness of the field. The Lovibond scale is itself arbitrary; but, as on the Munsell scale, the results can, if desired, be expressed in terms of more fundamental colorimetric quantities. The glasses are probably permanent with careful usage. The personal equation depends, as usual, upon the degree of physical match in the two energy distributions whose colors are being compared.

Other means of subtractive colorimetry are available such as the use of glass wedges,[16] dyed gelatin wedges,[17] or solutions.[18]

It may be emphasized that the general reliability of such colorimeters, additive or subtractive, is dependent upon (*1*) the accuracy with which the colorimetric values of the material standards can be determined and maintained; (*2*) the reduction in the personal equation through similarity of the spectral transmissive or reflective properties of the sample and standard; and (*3*) the correctness of the optical and mechanical design of the instrument.

(*2*) *Colorimeters Using Spectrum Primaries.*—Such instruments have the advantage of eliminating the material color standards that form so essential a part of the instruments already described. They are usually of two types, the "trichromatic" colorimeter and the "monochromatic" colorimeter, both additive. In the first type the color of the sample is matched by a mixture of light from three different wavelengths in the spectrum. An example of this is the instrument designed by Verbeek,[19] in which red light of wavelength 700 mμ, obtained by means of an incandescent lamp and filter, is optically mixed with light of wavelengths 546.1 mμ in the yellow-green and 435.8 mμ in the blue-violet, obtained from mercury lamps. Trichromatic colorimeters have also been designed and used by Wright,[20] and by Guild.[21]

In the so-called "monochromatic" colorimeter, either light from the sample is matched by light from a small wavelength band in the spectrum mixed with light from some heterogeneous stimulus often designated as "white light;" or, if the sample is purple, the spectrum light is added to the sample light to match the "white" light. Two designs of colorimeters of this type may be cited: (*1*) that designed by Nutting[22,23] and that designed by Priest.[24]

The disadvantages of colorimeters of the type described in this section are that (*1*) the personal equation is at a maximum, and (*2*) the cost and complexity of the design are greater than those of other types. In general, these instruments are more suited to research than routine testing or control purposes and have probably been used most in investigations on the colorimetric properties of the eye.

(*3*) *Filter Photometers.*—There are many instruments on the market that are called colorimeters, or are designated by some term of which "color" is a part, but that should more properly be called comparators or filter photometers. So-called colorimeters of the Duboscq type, widely used in chemical analysis, may be put in this classification. In such instruments the color of one side of a comparator field is adjusted, usually by varying the length of optical path through a solution, until it is brought to the nearest color match with the other side of the field, whose color is produced by a standard solution or filter. In some cases filters isolating more or less narrow regions of the spectrum are used over the eyepiece of the instrument and a brightness match used as the criterion.

Another type of visual filter photometer includes those designed primarily for transmission or reflection measurements. Such are the Ives tint photometer,[25] employing five filters designated as red, yellow, green, blue-green, and blue-violet; the Priest-Lange reflectometer,[26,27] using the Martens polarization photometer; and the Pfund multiple-reflection instruments,[28] in which small color differences are accentuated by multiple reflections.

Several instruments are also on the market of similar kind except that a photoelectric cell is the detector instead of the eye. Examples of these are the Toussaint photo-colorimetre,[29] employing six filters and yielding data for a rough spectrophotometric curve; the General Electric "brightness tester"[30] used with blue filter to measure the "brightness" of paper; and the Hunter photoelectric reflectometer,[31] in which an effort is being made to use three filters of such characteristics as would justify calling the instrument a colorimeter. Further information regarding photoelectric "colorimeters" will be found in letter circular LC-473[32] of the National Bureau of Standards, in which are discussed the principles underlying the use of photoelectric instruments as simple photometers, filter photometers, and colorimeters. It may be noted that many of the claims made in the advertising literature with respect to photoelectric "colorimeters," *etc.*,[33] are misleading and unjustified.

(V) SPECTROPHOTOMETRY

One may well ask at this point whether any method of colorimetry is available that will avoid the defects apparent in the various color systems and colorimeters exemplified in the previous sections. These defects, it will be recalled, are lack of permanence, uniformity, or reproducibility of the material color standards or filters used, limitation of range of colors included by the system or instrument, and the personal equation resulting from differences in color vision which may cause results by normal observers to differ importantly and by color-blind observers to be utterly unreliable. This query leads at once to a consideration of the most fundamental method of colorimetry available, *viz.*, that by way of spectrophotometric measurement and colorimetric computation.

In the filter photometers noted above certain spectral regions are isolated by means of filters. In a spectrophotometer the isolation is accomplished with a prismatic dispersing system, by means of which a spectrum is formed, and the desired region is selected for use by means of entrance and exit slits. A photometric device is added to or incorporated with the spectrometric part, and these, combined with the proper illuminant and with means for holding the samples, comprise the usual spectrophotometer. Both visual and photoelectric methods are in common use in the visible spectrum.

It is unnecessary to enter into detailed discussion of spectrophotometers or spectrophotometric methods in this paper because the subject is sufficiently treated in three publications to which reference may be made. The first of these is the Optical Society of America Spectrophotometry Committee report,[34] published in 1925. This report deals with the nomenclature of spectrophotometry and discusses in detail the various factors entering into spectrometry and photometry, two subjects with which one should be thoroughly familiar in order to conduct accurate spectrophotometric measurements. Various visual instruments are illustrated and briefly discussed, together with various auxiliary methods of spectrophotometry used to supplement the visual method. While slightly out of date in certain parts, it still is recommended for those who wish to become familiar with the fundamentals of spectrophotometry.

The other two papers to which reference is made discuss the subjects of photoelectric and visual spectrophotometry, respectively. In the first of these[35] the subject of photoelectric spectrophotometry is reviewed from its beginning, near 1900, to 1930. The advantages and limitations of amplified-current instruments are discussed, in addition to the various types of errors to which all spectrophotometric methods, including the photoelectric, are liable. In the second paper[36] typical present-day visual instruments and methods are described and illustrated and various factors affecting the reliability of spectrophotometric data are discussed.

In addition to these general references mention should be made of the most recent design of recording photoelectric spectrophotometer,[37,38] which incorporates two important features not found in most spectrophotometers. These are (*1*) the second prismatic dispersion, which effectively eliminates errors in measurement arising from stray energy of other wavelengths, and (*2*) the dispersion of the energy and the selection of the desired wavelength band prior to its incidence upon the sample, which avoids undue heating of the sample during measurement.

The principal advantage of a spectrophotometer over a filter photometer is the accurate analysis that is possible with the former in the measurement of transmission or reflection quantities as a function of wavelength. In filter photometry one is always limited by the number of available filters; he does not have complete freedom in the selection of wavelengths, and the spectral regions transmitted by the filters are in most cases relatively broad. With the spectrophotometer, on the other hand, one can set accurately at any wavelength in the spectrum to which the instrument and detector are suited, and he can by means of accurate bilateral slits restrict the wavelengths transmitted to a very small range, so small in most cases that further decrease would not significantly affect the value obtained. Over the wavelength range for which the instrument is designed and to which the detector is adequately sensitive, therefore, the spectrophotometer affords a complete spectral analysis of the radiant energy transmitted or reflected by any given object for those angular conditions of illumination and viewing used on the instrument.

We may next consider the purpose of spectrophotometry. This is usually one or other of the following: (*1*) The spectral transmissive or reflective data may be the sole purpose of the measurements. The data obtained are a fundamental property of the material and afford an extremely valuable supplement to other chemical and physical analyses. As such, one is often interested in the ultraviolet and infrared regions of the spectrum, as well as the visible region, and other methods—photographic and radiometric—are used to extend and supplement the visual and photoelectric methods. Since, however, this application of spectrophotometry is not under consideration in the present paper, it will be given no further attention here. (*2*) The spectral transmissive or reflective data may serve as a fundamental basis from which a minimum of three numbers may be computed serving to specify the color of the material under certain specified conditions and for an assumed average normal observer. Such computations will now be considered.

(VI) COLORIMETRIC COMPUTATIONS

It may be emphasized that, while a spectral transmission or reflection curve is the most fundamental basis for a colorimetric specification, it does not in itself specify the color except in a very crude way. It is true that with a little experience one can estimate from such a curve what the color is, whether red, yellow, dark green, purple, brown, *etc.*, and can also often judge qualitatively as to the difference in color corresponding to two curves. But it is quite impossible for one to define the color in terms adequate for precise specification; or in similar terms to describe the difference between the two colors corresponding to two curves that differ only slightly.

The trichromatic nature of normal color vision has been noted several times above. It is apparent in the hue-brilliance-saturation classification of color by the O.S.A. Colorimetry Committee and the hue-value-chroma arrangement of the Munsell color system, in the three series of colored glasses comprising the Lovibond color system, and in the various trichromatic colorimeters. It is further exemplified in the colorimetric system established by the International Commission on Illumination in London in 1931.[39] At that time data were adopted defining a hypothetical normal observer and a trichromatic coördinate system by means of which spectrophotometric values may be converted by computation into three numbers serving as a specification of the color. The data so adopted define "The 1931 I.C.I. standard observer and coördinate system." They are described in detail in papers by Smith and Guild[14] and by Judd,[40] and in the *Handbook of Colorimetry*.[1]

The methods of converting spectrophotometric data into colorimetric terms are so fully described in these publications that it is unnecessary to describe them here. The end result of the computations is to obtain a minimum of three numbers which will serve to specify the color. This specification may be given in any of three commonly used forms:

(*1*) Values designated as X, Y, Z may be computed, which are the amounts of the I.C.I. primaries (red, green, and blue, respectively) required by the standard observer to match the stimulus whose color is to be specified.

(*2*) If S be the sum of X, Y, and Z, the trilinear coördinates (also called trichromatic coefficients) are defined as $x = X/S$, $y = Y/S$, $z = Z/S$. The values of x, y, and z serve to specify what is termed the chromaticity of the color, which is that quality of the color determined by its hue and saturation, but not by its brilliance or lightness. Since $x + y + z = 1$, any two of these numbers serve to specify chromaticity. The complete colorimetric specification consists, therefore, in giving values of (usually) x and y, in addition to a third term, identical with Y above, representing the luminous value of the color, such as the luminous transmission or apparent reflectance of the sample.

(*3*) It is sometimes desirable, in place of x and y, to compute what are known as the dominant wavelength, Λ, and the purity, p, which may be derived from the quantities x and y and certain other colorimetric data. The dominant wavelength and purity of the stimulus correlate loosely with the hue and saturation of the color and may thus be more immediately comprehended than the trichromatic coefficients. As a means of specification, however, they are somewhat less flexible to use than are the values of x and y. When the method is used, the complete specification consists of giving values of Λ, p, and Y.

(VII) COLORIMETRIC SPECIFICATIONS

A complete colorimetric specification suitable for use both in the standardizing laboratory and in the factory or control laboratory will usually consist of three parts:

(*1*) There must be a fundamental definition of the color or range of colors that it is desired to specify. This is afforded by giving values of x, y, and Y, as above, or of other equivalent values. These being expressed in terms of the 1931 I.C.I. standard observer and coördinate system, or in terms of any other defined observer and system, one can tell by spectrophotometric analysis and colorimetric computation whether the sample meets the specification, and there need be no important uncertainty in the result except that due to uncertainty in the spectrophotometric data. Questions as to permanence of material standards and personal equations of individual observers do not enter, and there is no restriction as to range of colors. Such a specification is necessary before a standardizing laboratory can act as referee in a disputed case.

However, such a specification is of little practical value to the manufacturer or inspector who must control the quality of his output. At present the only general, satisfactory method in such cases is the use of working standards, of as great permanence as possible. The question of tolerances then becomes of immediate importance. An example may assist toward a clearer understanding of what is involved.

Consider the green glasses used in railway signalling. The manufacturer must have a certain range of color within which his product will be acceptable, if the cost of manufacture is not to be excessive. Furthermore, since only six colors are used in railway signalling there is no reason why a considerable range of colors should not be acceptable as "green." Obviously, however, there must be a yellow limit to avoid confusion with the yellow signal, a blue limit to avoid confusion with the blue, a pale limit to avoid confusion with white, and a dark limit to prevent the signal from being of too low intensity. The manufacturer or inspector who is not equipped to test according to the type of specification given under (*1*), above, must therefore have "limit glasses," by means of which he may test the quality of his output. In order that one manufacturer shall not be penalized relatively to another it is obviously important that the various limit glasses of any one kind going to different manufacturers shall be extremely close duplicates.

(*2*) A second specification is therefore necessary, setting tolerances within which the limit glasses must come. This specification must also be expressed in terms of x, y, and Y, or similar quantities.

(*3*) A third specification is then necessary, outlining the procedure to be followed by the manufacturer or inspector on testing the output by means of the limit glasses.

An example of this three-part type of specification is found in

A.A.R. Signal Section Specification *69–35*.[41] It is of course true that a specification as elaborate as this need not in all cases be formulated. In some cases merely the fundamental definition with tolerances may be sufficient. It should be noted, however, that a specification without tolerances, while adequate in most cases as a record of a color, will usually not prove of practical value for testing purposes.

(VIII) COLOR OF ILLUMINANTS

So far we have considered only the colorimetry of illuminated objects and have for the most part passed over the colorimetry of illuminants. This, however, has been a matter of convenience in presentation rather than indicating a lack of importance. Indeed, the most accurate colorimetry of objects requires the use of a standardized illuminant. Natural daylight is greatly used, of course, in the direct comparison of the colors of two objects, this including the use of the various color systems mentioned in Section III, but this illuminant is often unsatisfactory because of variability in both chromaticity and intensity. Artificial daylight is therefore extensively used for this purpose.

Likewise the most accurate use of any of the colorimeters noted in Section IV requires the use of a standard illuminant, both to illuminate the sample and to illuminate the standards or calibrate the primaries. An illuminant standardized with respect to color or spectral energy distribution is not required for accurate spectrophotometry, but is required for the colorimetric computations based upon the spectrophotometric data.

For such computations, as well as for use in direct colorimetry, the International Commission on Illumination, at the same time that data were adopted defining the standard observer and coördinate system in 1931, also defined and recommended the use of three standard illuminants, designated as I.C.I. illuminants, *A*, *B*, and *C*, respectively.

Illuminant *A* is defined as a gas-filled lamp operated at a color-temperature of 2848°K. The term "color-temperature" is defined below.

Illuminant *B* is defined as the same lamp (*i. e.*, illuminant *A*) used in combination with a specified Davis-Gibson filter, the light transmitted by the filter having a color and spectral energy distribution approximating those of both 4800°K and average noon sunlight (skylight excluded).

Illuminant *C* is defined as illuminant *A* combined with a second similar filter, the transmitted light in this case having a color and energy distribution approximating those of both 6500°K and average daylight as given by an overcast sky or by the combined sunlight and skylight on a horizontal surface.

The filters specified for use in I.C.I. illuminants *B* and *C* are two of an extensive series of reproducible liquid filters designed[42,43] for use in colorimetry and photographic sensitometry, one of them having been also adopted by the 8th International Congress of Photography for use with an illuminant at 2360°K to give standard artificial sunlight for use in photographic sensitometry.

Color-temperature is defined as the temperature* at which the ideal Planckian radiator or "black body" must be operated to produce the chromaticity of the color in question. The importance of this concept is that the chromaticities of most illuminants can be specified in terms of a single variable, accurately in the case of incandescent illuminants and approximately in the case of natural and artificial sunlight and daylight. One can readily visualize this color-temperature scale by remembering the color-temperatures of certain well-known illuminants—the candle and kerosene flames near 2000°K, the acetylene flame and vacuum tungsten lamps near 2400°K, gas-filled lamps from 2700° to 3200°K, the bare carbon arc near 3700°K, average noon sunlight and daylight near 5000° and 6500°K, respectively, and blue sky from 10,000° to 25,000°K.

An illuminant such as the mercury arc can not be specified in terms of color-temperature, as it departs too much from the Planckian locus. However, sources such as sunlight and daylight, which have colors close to but usually not exactly on the Planckian locus can be specified on the color-temperature scale by computational methods derived by Davis[45] and Judd.[46]

Experimentally, color-temperature may be determined by direct comparison with lamps standardized to give color-temperatures in

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* The spectral energy distribution given by Planck's equation for any specified temperature depends upon the value of the constant C_2. The color temperatures of 2848° and 2360°K, stated above in connection with I.C.I. illuminants *A*, *B*, and *C*, and with the photographic standard of intensity, were defined with $C_2 = 14350$. On the basis of the new color-temperature scale recently established at the National Bureau of Standards[44] with $C_2 = 14320$, in agreement with the international temperature scale, the same respective energy distributions will be obtained at temperatures of 2842° and 2355°K.

terms of voltage or current; or, above the range where a standard lamp can be safely operated, by comparison with standard lamp and filter combinations. Such filters may be those of the Davis-Gibson series, just noted, carefully selected daylight glass or dyed-gelatin filters, or the quartz-nicol combinations used on the rotatory-dispersion colorimetric photometer.[47]

(IX) CONCLUSION

In concluding this brief review of colorimetric methods we may recall that increasing refinement of colorimetric specification is afforded by (*1*) color names, (*2*) color systems, (*3*) colorimeters, and (*4*) spectrophotometric analysis followed by colorimetric computation. The last method is undoubtedly the only fundamental one; the first three partake of a fundamental nature only to the extent that they are based upon the spectrophotometric method in any particular case. This is not to say that methods *1* to *3* should not be used when desirable; it means rather that, when used, they should be based upon method *4* to an extent that in reality makes them largely equivalent to method *4*. For example, consider the system of color names previously referred to,* which is being used to name the colors of drugs and chemicals. Each of these names represents a certain "pocket" in the "color solid," the boundaries of which will be specified in terms convertible to values of x, y, and Y for the 1931 I.C.I. standard observer and coördinate system.

Likewise, as a result of spectral apparent reflectance measurements on a large number of Munsell samples[48] followed by the usual colorimetric computations, it is now possible to convert a colorimetric specification in the Munsell system to a specification in terms of this same 1931 I.C.I. standard observer and coördinate system. Due to slight imperfections and lack of uniformity in the Munsell system such a conversion can not at present be made with the greatest precision. However, a movement is under way to "idealize" this system by eliminating the obvious irregularities now existing therein. If this were done, colorimetric specification could be made with equal soundness upon either the Munsell or the I.C.I. basis, for they would be interconvertible, both based in reality upon spectrophotometric measurements and computations in terms of the I.C.I. standard observer.

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* Section II.

Examples of colorimeters that may be used to obtain results upon a fairly sound basis by means of proper calibration were illustrated by the disk colorimeter and the Guild trichromatic colorimeter.

A further word may be said about the 1931 I.C.I. standard observer and coördinate system. There are two outstanding advantages of this system. First, the chromatic and luminous characteristics of the average normal observer are so accurately incorporated in this hypothetical observer that revision will probably be unnecessary for a long time. Second, the international standing of this system enables people in every country to speak a common language of color specification.

However, the I.C.I. coördinate system, not the standard observer, has one serious defect that should not be overlooked. Distances on the (x,y) diagram do not properly represent chromaticity differences as seen by the normal eye. This has been pointed out by Judd,[49] who has proposed an equal-chromaticity-scale coördinate system which is a transformation of the I.C.I. system. While it should be subjected to further practical tests and will probably need some revision, it is undoubtedly a considerable improvement over the I.C.I. coördinate system in its correlation with visual judgments. This is of great importance in the specification of tolerances.

In deciding upon the method to use for the measurement and specification of color stimuli in any particular problem one must consider the two elements of time and accuracy. Lack of time has often been the excuse for the employment of loose methods of colorimetry and color specification. The time required for accurate spectrophotometric measurement and colorimetric computation has often made such a method impossible to use. And indeed there are many colorimetric problems in the control laboratory that do not need any fundamental method of measurement and specification. However, the commercial development of recording photoelectric spectrophotometers may so reduce the time of measurement that this method may become a strong competitor with less exact methods even in the control laboratory.

In closing, one important defect (for many purposes) of practically all spectrophotometers may be noted. This defect is that but one set of angular conditions of illuminating and viewing are available on any one instrument now commercially available. A consideration of these angular conditions is of particular importance in the analysis and specification of the colors of glossy materials. The colors of such materials, for example, a glossy red enamel, change notably under differing conditions of examination. Diffuse illumination may mask differences between two samples readily apparent by ordinary inspection when one can examine the samples under various angles of illumination and viewing. No answer to this problem is attempted in this paper. Gloss specification is in itself of great complexity.[50] The 45°-normal conditions of illuminating and viewing, recommended by the I.C.I.,[14,39] are probably the best single set of conditions to use for glossy materials, but complete colorimetric specification of glossy chromatic materials has not yet been accomplished. The subject is too important to be ignored, however. Until it is solved, direct visual comparison with permanent working standards must be used to some extent for such materials.

Rapid progress will doubtless be made along this line, as is being made along other lines. The interest in color measurement and specification is much greater than ever before. An example of this interest is afforded in the hundreds of requests that were received at the Bureau for a recent letter circular[32] on photoelectric colorimeters and by the fact that several hundred copies of the letter circular[4] on color charts have been issued to applicants during the past three years.

Those in the motion picture industry have their own color problems to solve. The material in this paper may not at first seem to have much practical application in the development of accurate color reproduction in motion pictures. Those in charge of such development can not fail, however, to benefit by a knowledge of the fundamentals of colorimetry to which reference is made in this paper.

REFERENCES

[1] *The Technology Press*, Massachusetts Institute of Technology, Cambridge, Mass. (1936).

[2] Report of the Colorimetry Committee, L. T. Troland, *Chairman*, *J. Opt. Soc. Amer. and Rev. Sci. Instr.*, **6** (Aug., 1922), No. 6, p. 527.

[3] LUCKIESH, M.: "Color and Its Applications," *D. Van Nostrand Co.*, New York (1915).

[4] "Color Charts," Letter Circular LC-481, *National Bureau of Standards*, Washington, D. C.

[5] MAERZ, A., AND PAUL, M. R.: "Dictionary of Color," *McGraw-Hill Book Co.*, New York, N. Y. (1930).

[6] "Munsell Book of Color," *Munsell Color Co.*, Baltimore, Md. (1929).

[7] "Colour Measurement," *The Tintometer, Ltd.*, Salisbury, England.

[8] GIBSON, K. S., AND HARRIS, F. K.: "The Lovibond Color System; I. A

Spectrophotometric Analysis of the Lovibond Glasses," Scientific Paper No. 547, *National Bureau of Standards*, Washington, D. C.

[9] HAUPT, G. W.: "Statistical Investigation of the Uniformity of Grades of Lovibond Red Glasses," *J. Opt. Soc. Amer.*, **27** (Jan., 1937), No. 1, p. 63.

[10] "Publications on Colorimetry and Spectrophotometry," Letter Circular 398, *National Bureau of Standards*, Washington, D. C.

[11] NICKERSON, D.: "A Colorimeter for Use with Disk Mixture, and Color Measurements in Psychological Terms," *J. Opt. Soc. Amer.*, **21** (Oct., 1931), No. 10, p. 640.

[12] GUILD, G.: "A Trichromatic Colorimeter Suitable for Standardization Work," Trans. Opt. Soc. London, **27** (1925), No. 2, p. 106.

[13] "The Guild Colorimeter," *Adam Hilger, Ltd.*

[14] SMITH, T., AND GUILD, J.: "The C.I.E. Colorimetric Standards and Their Use," *Trans. Opt. Soc. London*, **33** (1931), No. 3, p. 73.

[15] NEWHALL, S. M.: "An Instrument for Color Stimulation and Measurement," *Psychological Monographs*, **47** (1936), No. 212, p. 199.

[16] JUDD, D. B.: "A Subtractive Colorimeter for the Measurement of Small Chromaticity Differences between Surfaces of Moderate Spectral Selectivity of Reflectance," *J. Opt. Soc. Amer.*, **26** (May, 1936), No. 5, p. 225.

[17] JONES, L. A.: "A: Colorimeter Operating on the Subtractive Principle," *J. Opt. Soc. Amer.*, **4** (Nov., 1920), No. 6, p. 420.

[18] ARNY, H. V., AND TAUB, A.: "Standardized Colored Fluids and Some Official Colorimetric Tests," *J. Amer. Pharm. Assoc.*, **12** (Oct., 1923), No. 10, p. 839.

[19] VERBEEK, H. P. J.: "Een Trichromatische Colorimeter," *Physica*, **13** (1934), No. 3, p. 77.

[20] WRIGHT, W. D.: "A Trichromatic Colorimeter with Spectral Primaries," *Trans. Opt. Soc. London*, **29** (1927), No. 5, p. 225.

[21] GUILD, J.: "The Colorimetric Properties of the Spectrum," *Phil. Trans. Roy. Soc.* (London), **A230** (1931), p. 149.

[22] NUTTING, P. G.: "A New Precision Colorimeter," *Bull. Bureau of Standards*, **9**, 1 (1913); B. S. Sci. Paper No. 187.

[23] "The Nutting Colorimeter," *Adam Hilger, Ltd.*

[24] PRIEST, I. G.: "Apparatus for the Determination of Color in Terms of Dominant Wavelength, Purity, and Brightness," *J. Opt. Soc. Amer., and Rev. Sci. Instr.*, **8** (Jan., 1924), No. 1, p. 173.

[25] Descriptive material issued by the Palo Co., New York, N. Y.

[26] PRIEST, I. G.: "The Priest-Lange Reflectometer Applied to Nearly White Porcelain Enamels," *J. Research, National Bureau of Standards*, **15** (Nov., 1935), No. 5, p. 529.

[27] Descriptive circular issued by Akatos, Inc., New York, N. Y.

[28] Descriptive material issued by the Munsell Color Co., Baltimore, Md.

[29] Descriptive material published by J. Carpentier, Paris.

[30] DAVIS, M. N.: "Instrumentation in Brightness Grading," *Paper Trade J.*, **101** (July 4, 1935), No. 1, TS 36.

LEWIS, L. C.: "Definition of Brightness," *Paper Trade J.*, **101** (Aug. 8, 1935), No. 6, TS 64.

[31] Descriptive material issued by H. A. Gardner Laboratory, Washington, D. C.

[32] "Photoelectric Colorimeters," Letter Circular LC-473, *National Bureau of Standards*, Washington, D. C.

[33] Gibson, K. S.: "Photoelectric Photometers and Colorimeters," *Instruments*, **9** (Nov., Dec., 1936), No. 11, 12, pp. 309, 335.

[34] "Spectrophotometry," Report of O. S. A. Progess Committee for 1922–23 (K. S. Gibson, *Chairman*), *J. Opt. Soc. Amer. and Rev. Sci. Instr.*, **10** (Feb., 1925), No. 2, p. 169.

[35] Gibson, K. S.: "The Use of the Photoelectric Cell in Spectrophotometry, Photoelectric Cells and Their Applications," *Phys. and Opt. Societies* (London). Also obtainable from Adam Hilger, Ltd., London (1930).

[36] Gibson, K. S.: "Visual Spectrophotometry," *J. Opt. Soc. Amer.*, **24** (Sept., 1934), No. 9, p. 234.

[37] Hardy, A. C.: "A New Recording Spectrophotometer," *J. Opt. Soc. Amer.*, **25** (Sept., 1935), No. 9, p. 305.

[38] Michaelson, J. L., and Liebhafsky, H. A.: "A New Spectrophotometer and Some of Its Applications," *Gen. Elect. Rev.*, **39** (Sept., 1936), No. 9, p. 445.

[39] Proceedings, *International Commission on Illumination* (1931), p. 19.

[40] Judd, D. B.: "The 1931 Standard Observer and Coördinate System for Colorimetry," *J. Opt. Soc. Amer.*, **23** (Oct., 1933), No. 10, p. 359.

[41] A.A.R. Signal Section Specification 69–35, *Assoc. Amer. Railroads*, New York, N. Y.

[42] Davis, R., and Gibson, K. S.: "Filters for the Reproduction of Sunlight and Daylight and the Determination of Color-Temperature," Miscellaneous Publication No. 114, *National Bureau of Standards* (1931).

[43] Davis, R., and Gibson, K. S.: "Artificial Sunlight for Photographic Sensitometry," *Trans. Soc. Mot. Pict. Eng.*, **XII** (1928), No. 33, p. 225.

[44] Wensel, H. T., Judd, D. B., and Roeser, W. F.: "Establishment of a Scale of Color-Temperature," *Bureau of Standards J. of Research*, **12** (May, 1934), No. 5, p. 527; RP677.

[45] Davis, R.: "A Correlated Color-Temperature for Illuminants," *Bureau of Standards J. of Research*, **7** (Oct., 1931), No. 4, p. 659; RP365.

[46] Judd, D. B.: "Estimation of Chromaticity Differences and Nearest Color-Temperature on the Standard 1931 I.C.I. Colorimetric Coördinate System," *J. Opt. Soc. Amer.*, **26** (Nov., 1936), No. 11, p. 421.

[47] Priest, I. G.: "The Colorimetry and Photometry of Daylight and Incandescent Illuminants by the Method of Rotatory Dispersion," *J. Opt. Soc. Amer. and Rev. Sci. Instr.*, **7** (Dec., 1923), No. 12, p. 1175.

[48] Glenn, J. J., and Killian, J. T.: "Trichromatic Analysis of the Munsell System" (Unpublished thesis), *Mass. Inst. of Tech.*, Cambridge, Mass. (1935).

[49] Judd, D. B.: "A Maxwell Triangle Yielding Uniform Chromaticity Scales," *National Bureau of Standards, J. of Research*, **14** (Jan., 1935), No. 1, p. 41; RP-756. Also *J. Opt. Soc. Amer.*, **25** (Jan., 1935), No. 1, p. 24.

[50] Hunter, R. S.: "Methods of Determining Glass," *National Bureau of Standards J. of Research*, **18** (Jan., 1937), No. 1, p. 19; RP958.

DIRECT RECORDING AND REPRODUCING MATERIALS FOR DISK RECORDING*

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Summary.—*Recently materials for direct disk recording and reproducing work have been improved so that they are now suitable for many uses. These materials, as they are available on the market, are classified chemically into five groups, and measurements are given of frequency characteristic, surface noise, life, distortion, etc., and data have been taken with both lateral and vertical recording.*

There has been a need for some time for a suitable combined recording and record material of the disk type for use in mechanical recording. Materials for this work must be suitable for recording, and after recording must be capable of being played back satisfactorily. As recording materials, they should be capable of good-quality recording with relatively simple apparatus. As record materials, they must render reproduced sound of good quality and low surface noise with simple apparatus, and must also have adequate life and be capable of being satisfactorily reproduced with a sturdy reproducer. These requirements are, of course, all relative, and depend upon the technical character of the work to be done and upon the the standards of excellence required.

Of course, wax cylinders have been, and are being, used for similar types of work for which disks of the kind to be discussed in this paper can be used, and these are capable of producing good results. Wax disks have also been used, but their applications have, in recent years, been largely confined to sound-picture studio and other more elaborate uses. Even though these cylinders and disks of wax have done many types of work satisfactorily, there has been a real need for a thin, sturdy, and easily stored disk of a material upon which sound can be recorded and reproduced with rugged instruments. This statement seems justified by the growing number of suppliers

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of a newer type of record, which usually takes the form of a thin disk from 10 to perhaps 60 mils thick and of a variety of materials.

This paper presents data on some of the materials of this type as they are now available on the market for general use. As there are many possible combinations of recording instruments, reproducing instruments, styli, *etc.*, the data will give a rather general idea of what can be expected from the various recording materials. The materials will be referred to as of certain types of distinguishing physical or chemical characteristics, and not by their trade names. While it might be interesting to mention the disks by name, the more general classification entirely satisfies the needs of this paper.

The disk record materials that have come to our attention for this type of recording may be classified according to the following groups, listed in Table I:

(*1*) Materials containing cellulose esters. These materials have been mainly plasticized cellulose nitrate. All the disks that we have tested that were stated to be cellulose acetate or "acetate" by the suppliers, contained a predominant amount of cellulose nitrate.

(*2*) Metal disks such as aluminum, zinc, lead, pewter, *etc.*

(*3*) Plasticized thermo-setting phenolic resins which are used soft and uncured as recording materials. A baking operation after recording transforms the material into a hard record material.

(*4*) Various types of resinous compounds other than the cellulosic and phenolic compositions mentioned above.

(*5*) Gelatin and gelatin compositions.

TABLE I

Classification of Disk Record Materials

Group	Material
1	Cellulose esters
2	Metal disks (aluminum, zinc, lead, pewter, *etc.*)
2	Plasticized thermo-setting phenolic resins
4	Resins other than those of group *1* or *3*
5	Gelatin and gelatin compositions

Except for the metal disks under group *2*, some of the materials of all these groups are or have been available as coatings on metal disks. A typical coated metal disk will consist of a $^1/_{32}$-inch aluminum disk with a 5- to 10-mil coating upon either side. Some disks are available only as thin sheets of the recording material, and others are available also as coatings. A few have also been supplied as coatings upon paper, and this appears to be a somewhat less expensive method of preparing the disks; but judged by the relatively few that are or have been on the market, it is apparently not as easy to produce these of equivalent quality of reproduction and ease of use.

These direct recording and reproducing disks can be recorded in a variety of ways. Many of them are recorded with a cutting stylus in much the way that waxes are cut in the phonograph industry. The fact that the materials are somewhat harder than wax makes the use of an advance ball unnecessary. It will be recalled that the usual advance ball used in phonograph work is a carefully ground portion of a jewelled sphere located adjacent to the cutting stylus of the recording instrument and adjustable with respect to it in such a way that a predetermined width of groove may be obtained even in very soft materials such as wax, *etc.* The recording styli used for direct recording work are of steel, sapphire, or diamond. The life of these is a function of the character of the material itself, the cleanliness of the material, and the skill of the operators using them. In general, sapphire and diamond styli are more costly, but are harder and have a longer life on many materials than the steel styli now available. The jewelled styli are, however, more brittle, and for this reason are subject to breakage when used with materials that contain small particles of foreign matter.

The shavings that occur in the cutting operation are not generally removed by a suction tube, as in wax recording. The continuous thread of material that is obtained under properly adjusted recording conditions is handled in a number of ways. It has been collected, for example, by a radial brush resting lightly upon the record surface, and it has also been collected when recording by permitting the shaving to coil up inside the position of the cutting stylus upon the record.

Some of the coated disks are pre-grooved, in a molding operation, by the use of suitable matrices. These disks require somewhat less expensive recording equipment in that the usual lead-screw and associated mechanism are not required to feed the recording device across the surface of the disk during recording. Pre-grooved disks have mainly been used for so-called home recording and similar uses, whereas many of the other disks discussed here have been used for more critical work. All the materials discussed in this paper are capable of being reproduced with rugged instruments guided across the record surface during reproduction by the recorded grooves themselves, without the aid of a lead-screw. The pre-grooved records are recorded as an embossing operation in which a blunt tool is used in contrast to the cutting tool mentioned earlier. The embossing or rubbing tool or stylus in the recording operation embosses a somewhat wider and deeper modulated groove than the original molded unmodulated guiding groove.

The metal disks under group *2* are also available as pre-grooved or plain disks. The pre-grooved variety of disks is recorded in the same way as just described for the pre-grooved coated disks. The plain metal surface disks, however, are not generally cut as were the coated disks, but rather embossed with a blunt stylus in the manner used for pre-grooved disks. A surface lubricant is often used during the recording of metal disks.

The gelatin disks under group *5* are generally recorded with a cutting tool in the manner of disks of groups *1*, *3*, and *4*. After recording, gelatin disks are frequently treated chemically in order to harden the record surface. These treated surfaces have a somewhat longer life in reproduction.

For reproducing from these direct recording materials, a number of stylus shapes and materials have been used. Stylus materials have been steel, sapphire, diamond, and various forms of fiber, thorn, *etc.* In general, the type of needle used will depend upon the design of the reproducing instrument and the number of times it is wished to reproduce the record. It is possible to design reproducing instruments of small enough mechanical impedance so that pressures of the stylus upon the record material can be reduced to a value such that any of the stylus materials mentioned are capable of reasonably satisfactory reproduction provided that the stylus has a slightly rounded point, that is, has a tip radius of the order of 2 mils. Instruments that may be satisfactorily used at these moderate record pressures are a refinement over those available for use in the ordinary electrical home phonograph.

Rapid wear of either the stylus or the record, or both, has been encountered at the higher record pressures with some combinations of record and reproducer stylus materials. This can also be due to the higher coefficient of friction between these material combinations. For this reason, even with a properly contoured needle (or one that has been approximately contoured by playing a few grooves of a common phonograph record, which is somewhat abrasive) certain combinations of stylus and record materials will require lower pressures in order not to injure seriously either the stylus or the record in a few playings. For example, the coefficient of friction between a steel stylus and an aluminum record is about 0.3, compared with the unusually low value of somewhat less than 0.02 for a fiber stylus and an aluminum record.

Apart from difficulties arising from the coefficient of friction between materials, the contour of the stylus is very important. For example, a new steel phonograph needle is relatively sharp, and the area of contact between it and the record is of the order of a few millionths of a square inch; so that with a reproducer resting upon a record, the needle point pressures are of the order of 20 to 100 tons per square-inch. Pressures of this order will rapidly wear either the stylus, the record, or, most probably, both. An abrasive material is included in commercial phonograph records in order to grind the needle to fit the groove of the record and to prolong the record life. In a matter of seconds the needle point pressures of a steel needle playing a common phonograph record are reduced to values of the order of 5 tons per square-inch. It is interesting to note that even these lower pressures are very large, and somewhat higher than pressures known to be the upper limits for which lubricants will remain between surfaces. This is the reason that lubricating phonograph records by various substances has rarely shown any effect upon either surface noise or record life. Only for instruments that are capable of being satisfactorily used at very low record pressures can the effect of lubrication be measured.

The nature of the reproducer stylus material and the stylus design will also affect the quality of reproduction even if used at needle point pressures for which the effect upon either the record material or the stylus is negligible. For example, a needle with a large effective mass will tend to reduce the high-frequency response of the reproducer, and a similar effect will be obtained by the use of a thin or relatively flexible needle. While the amount of reduction of high-frequency response will depend upon the effective mass and stiffness of the stylus, it will depend also upon the relationship of these to the vibratory constants of the reproducing instrument itself and upon the relationship of the mechanical impedance of the complete reproducing instrument to the mechanical impedance of the record material. A reduction of high-frequency response is, in general, not desirable, because it will tend to make the reproduction less natural, at least for many types of recording. However, a reduction in high-frequency response will also have the effect of reducing surface noise, and this may be important under some conditions.

To give a complete picture of record materials of the type being discussed and the reproduction from them with all available reproducers would make a subject beyond the scope of this paper. Typical data will rather be shown, taken with some of the materials and instruments that are at present available.

Quantitative measurements taken with both lateral and vertical recorders and reproducers at linear speeds of 14 to 20 inches per second will include:

(*a*) Response *vs*. frequency characteristics.
(*b*) Surface noise.
(*c*) Wear (life).
(*d*) Distortion measurements.

Frequency Characteristics.—The frequency response has been measured by recording single frequencies and then measuring the reproducer response as the record is played back. The curves that follow show the *relative* response compared with that obtained from pressings made from processed matrices. The waxes used for producing the comparison matrices were recorded in the same way and with the same recorders used for each of the materials under test. Figs. 1, 2, and 3 are frequency response measurements taken with lateral recording. Fig. 4 shows similar measurements with vertical recording.

Fig. 1 shows lateral cut frequency characteristics of materials of the cellulosic type, which has been called group *1*. The recording has been done with a steel recording stylus. In general, the response differences of this and other groups occur as the frequency is increased. Fig. 1 shows the effect obtained with two reproducers of different design and vibratory characteristics. Curve *A1* taken with reproducer *A*, a commercial reproducer fitted with a contoured (about 2-mil tip radius) steel stylus and material No. *1*, shows poorer high-frequency response than does curve *B1* taken with laboratory reproducer *B* fitted with a contoured diamond stylus on the same record. Material No. *1* is the best of those tested with lateral recording and classified under group *1*. Fig. 1 shows also the variation of materials of this group as supplied by two manufacturers. Curve *B2* has been taken on another material of the cellulosic group which showed the poorest frequency response of the materials tested of this group. A considerable difference in response will be noted in the region of 5000 cps. between these materials, and the better material is down very little in this frequency range as compared with the molded record.

Fig. 2 shows lateral frequency response characteristics taken with embossed grooves. These curves are *relative* to measurements taken with molded records made from matrices which in turn have been made from lateral cut waxes. Curve *A10* has been taken with a pre-grooved material of group *4*. Prior to recording, the grooves were unmodulated and relatively narrow and shallow. After recording, the grooves were similar to those of a standard phonograph record, that is, about $2^1/_2$ to 3 mils deep and 6 to 7 mils wide. The frequency response of curve *A10* shows a relative drop of more than 30 db. at 4000 cps., much poorer than any other material tested.

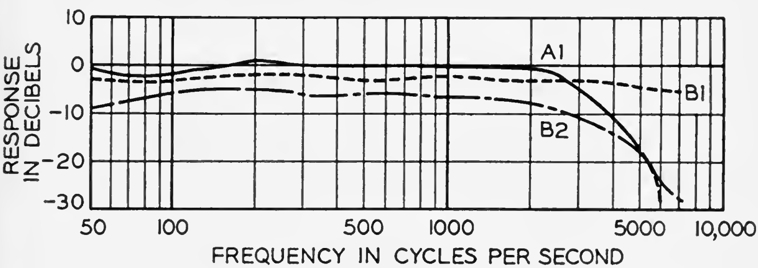


FIG. 1. Lateral recording—group 1.

Curves *B3* and *B4* of Fig. 2 show the results with an aluminum disk and lateral embossed recordings. This material is probably the most widely used at present of the solid metal group. Curve *B3* has been taken with a plain aluminum disk and curve *B4* with a pre-grooved aluminum disk. In recording, the aluminum surface is often lubricated with a wax such as paraffin, or with kerosene. The use of the lubricant produces a record that is several decibels quieter than one recorded without a lubricant. These curves were taken with the laboratory reproducer *B*, which is fitted with a diamond stylus, and show that with an adequate recording instrument frequencies up to 4000 to 5000 cps. can be satisfactorily recorded on aluminum. The measurements at 5000 cps. and higher were considered doubtful because of the high surface noise levels in this region.

In order to show the effect of the reproducer stylus upon the frequency response, curves *A3* and *A'3* are shown on Fig. 2. Reproducer *A*, although somewhat inferior to reproducer *B* in response and mechanical impedance, lends itself to rapid stylus changes and has been used for this reason. Curve *A3* is a remeasurement of the record used for getting curve *B3* using a contoured steel stylus in the reproducer. Curve *A'3* is another measurement of the same record and reproducer *A* fitted with a fiber needle. The difference in response in the region of 5000 cps. can be seen to be considerable. Fiber or

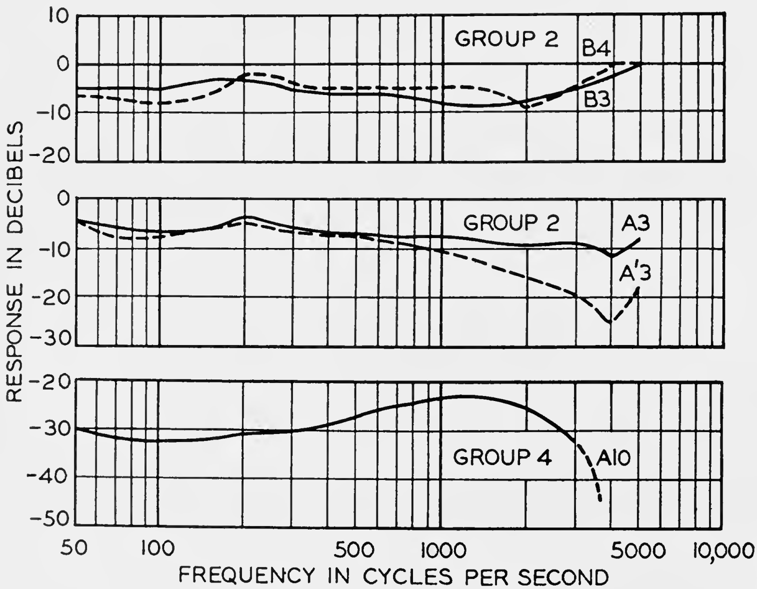


FIG. 2. Lateral embossed recording.

thorn needles wear quite rapidly on aluminum records because of their mechanical properties. The characteristic shown is about the best that can be obtained with needles of this kind and instruments now available. As the needle wears, the response decreases at the higher frequencies and the distortion products increase rapidly. Fiber or thorn needles are frequently badly worn before completely playing a single record with a playing time of the order of a few minutes.

Curve *B5* of Fig. 3 shows the *relative* lateral cut recording frequency characteristic of a plasticized thermo-setting phenolic material of group *3*. The response has been taken after baking the record for two hours in a small oven at about 350°F. During the baking operation, there is some flow of the material which undoubtedly changes the frequency characteristic of the recording. Curve *B5* was taken after baking. Difficulty was encountered at some of the higher frequencies in measuring this material due to high noise levels on some of the records.

Curve *B6* of Fig. 3 shows the *relative* lateral cut frequency response characteristic of a resinous material of group *4*. This material is

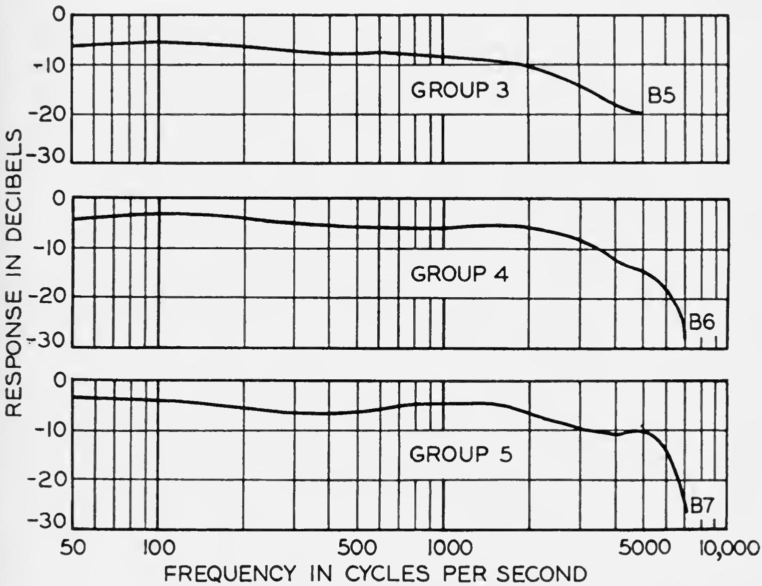


FIG. 3. Lateral recording.

the best of those examined of this group. This group, however, covers a wide range of materials that have very little in common, so that curve *B6* must be taken as a measurement of one material only and not necessarily as illustrative of this group.

Curve *B7* of Fig. 3 shows the *relative* lateral cut frequency response characteristic of the best gelatin compound of group *5* that was measured. This group also gave trouble with high noise levels interfering with the measurements at higher frequencies.

Fig. 4 shows the *relative* frequency response measurements taken with materials of groups *1*, *3*, *4*, and *5* with vertical cut recording. As with the measurements with lateral recording, these data have been plotted to show the *relative* frequency response compared with that obtained from molded records prepared from processed matrices. Here again, the waxes used for producing the matrices were recorded in the same way and with the same recorders used for each of the materials under test. Measurements are not shown for materials of group *2* with vertical recording. Although only a limited amount

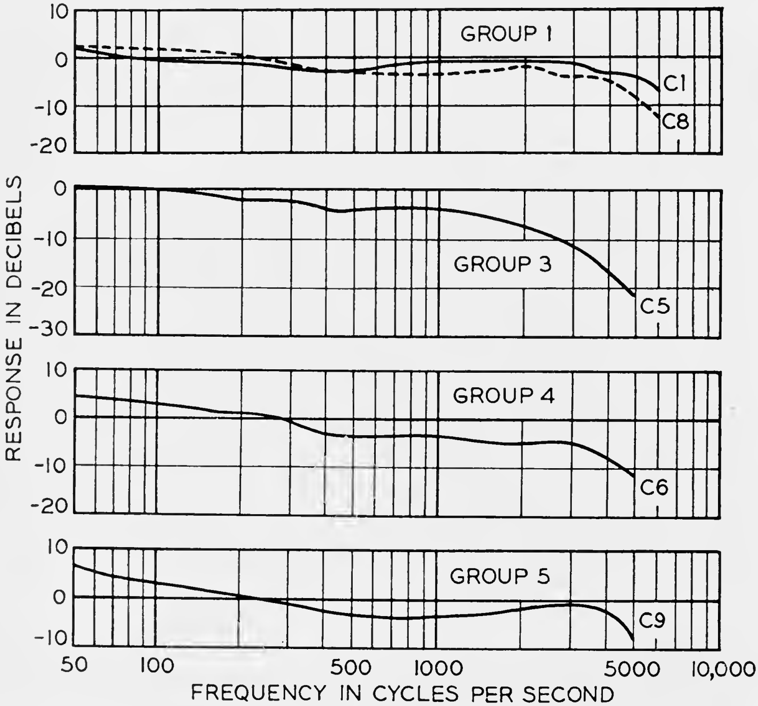


FIG. 4. Vertical recording.

of work has been done recently with embossing vertically modulated grooves in these materials, their mechanical impedances are generally large enough compared with that of the recorders used to make the measurements of doubtful value as performance ratings. Curves *C1* and *C8* of this Fig. 4, taken with vertical reproducer *C* fitted with a diamond stylus, show the approximate range of frequency characteristic of materials of the cellulosic group (group *1*) measured with vertical instruments. Curve *C1* has been taken with material No. *1*, and is the same material that was used for the lateral recording shown in curves *A1* and *B1* of Fig. 1. The poorest material of group *1* for vertical recording, however, was not found to be the same as the poorest for lateral recording.

Curve *C5* shows the *relative* vertical cut frequency response characteristic of a material of group *3*. The response is down about 20 db. at 5000 cps.

Curve *C6* shows similar data for a material of group *4*. The relative response is down about 10 db. at 5000 cps.

Curve *C9* shows similar data for a material of group *5*. The relative response is down about 8 db. at 5000 cps.

In taking these data on frequency characteristics, electrical equalization has not been used, in either recording or reproducing, in order to obtain the overall frequency response characteristic. It is possible to equalize within reasonable limits at either step and thereby to improve the frequency characteristic. When equalizing in recording, particularly at the higher frequencies, care must be taken to avoid excessive curvatures in the grooves for increasing recording levels, because these will give rise to severe distortion. When equalizing in reproducing, care must be taken to avoid excessive correction because this will increase surface noise.

The value of frequency response measurements, although very great, does not give all the important facts that are necessary for quantitatively rating the performance of recording materials. Two other very important items are surface noise and distortion.

Surface Noise.—A tabulation of the data on surface noise for both lateral and vertical recording is shown in Table II. The noise measurements have been taken with a noise meter having a frequency weighting network and a damped meter of the volume indicator type. While this kind of noise measurement does not precisely check ear measurements, it is sufficiently accurate for the record measurements being taken here and has the advantage of being simple and quick, which is important because of the large number of measurements needed. The values are given in decibels, and are referred to a convenient arbitrary zero. The larger the db.-value given, the noisier the record.

The measurements are again divided into five groups according to the material, and show a range of surface noise from the minimum value measured to the maximum measured, not, however, necessarily on materials of a single supplier. The range of values measured on the quietest record in each group is also given.

The lateral measurements have been taken with reproducer *A* equipped with a steel stylus, except where noted, and with a record pressure of 50 grams. The vertical measurements have been taken with reproducer *C* equipped with a diamond stylus and at a record pressure of about 30 grams. The lateral and vertical noise levels are not exactly comparable because the vertical reproducer used had about twice the frequency range of the lateral reproducer. These noise measurements show that some of the records of group *1*, as lateral records, are somewhat quieter than a commercial phonograph

TABLE II

Surface Noise Data in Decibels

	Lateral Recording Reproducer *A*, Steel Needle 50-Gram Pressure		Vertical Recording Reproducer *C*, Diamond Stylus 30-Gram Pressure	
Material Group	Range	Best Record	Range	Best Record
1	10–45	10–13	11–52	11–13
2	29–38*	29–32*	18–26	18–26
	33–39	33–36		
3	25–32	25–28	25–31	25–27
4	20–33	20–27	24–36	24–30
5	27–38	27–29	28–37	28–30
Lateral cut phonograph record	23–40			
Vertical cut electrical transcription			10–15	

* Measured with a fiber needle.

(Note: The lateral and vertical record noise levels are not exactly comparable because of the wider frequency range of the vertical recording.)

record. The surface noise level of vertical recording with materials of group *1* measured with a vertical reproducer are occasionally within a few db. of a quiet molded vertical cut transcription record. These measurements have been taken without equalization in the reproducer circuit to give a uniform frequency response characteristic. Such equalization for the characteristic measured on these materials will increase the measured noise levels.

The measurements listed in Table II, excepting those of group *2*, were all taken on records that were cut with the best steel recording styli tested, which closely approached the results obtained with sapphire styli. The measurements on records of group *2* were taken on records embossed with a diamond stylus. The noise levels on a given material with steel recording styli as received from several suppliers showed a variation of more than 10 db.

In many cases, it has been difficult to obtain consistent data. Sometimes this has been due to variations in the material itself, and at other times to the effect of the recording materials upon the recording stylus. Some recording materials contained abrasives which caused rapid wear of the recording stylus.

Wear Data.—The record life has been measured in concentrically recorded unmodulated grooves with lateral and vertical instruments, and is shown in Table III. The record life has been taken as the

TABLE III

Record Life on Unmodulated Concentric Grooves

Material Group	Lateral Recording Reproducer *A*, 50-Gram Pressure, Steel Needle	Vertical Recording Reproducer *C*, 30-Gram Pressure, Diamond Stylus
1	5–>500‡	12–>500
2	5–12*	8–25
	2–4	
3	22–>500	26–>500
4	39–211	32–>500
5	4–>500‡	235–305
Lateral cut phonograph record	>500	
Vertical cut electrical transcription		>500

‡ High initial surface noise level.

* Measured with a fiber needle.

(Note: Vertical reproducer *C* has approximately twice the frequency range of lateral reproducer *A*.)

number of times the groove is played for a 5-db. rise in noise level. Measurements were not carried beyond 500 playings. It has been assumed that the recorded levels on the records are such that a 5-db. rise in surface noise is reached before the record is regarded as worn out due to the wear on modulated grooves. This is not true for records made with excessive recording levels or with records reproduced with instruments of high mechanical impedance. The reproducers and styli used for these tests were the same as those used in the surface noise tests. A number of measurements were obtained that indicated a record with a life greater than 500 playings. Some of these records, however, started with high initial noise level, and were so rough at the start that they showed little noise increment during test. These are specifically noted in the table. Omitting these records, many showed good wearing qualities adequate for many uses, even though not entirely comparable to commercial molded records. A life greater than 500 playings has been measured for commercial phonograph records. This is due to the low (50-gram) value of record pressure used. For a record pressure more commonly used, about 125 grams, this figure is reduced to 50 to 100 playings.

TABLE IV

1000-Cycle Harmonic Distortion Data (Measurements Are Decibel Range Down from 1000-Cycle Component)

Material Group	Lateral Recording Reproducer *A*, Steel Needle		Vertical Recording Reproducer *C*, Diamond Stylus	
	2000 Cycles	3000 Cycles	2000 Cycles	3000 Cycles
1	6–27	14–36	21–36	28–39
2	12–25	20–30		
3	22–24	27–32	17–23	Noisy
4	17–24	27–35	14–22	27–34
5	17–26	23–26	15–21	27–40
Lateral cut phonograph record	20–30	22–34		
Vertical cut electrical transcription			28–34	35–41

Distortion Data.—It is difficult to give a simple rating of distortion that will satisfy all conditions and will rate the various materials as a trained observer would for this factor if listening to speech or music. As a simple rough measurement data have been taken of the harmonics found in the reproduced output of a 1000-cycle recorded tone.

The 1000-cycle data are tabulated for both lateral and vertical recording in Table IV. These data show that the materials are all somewhat inferior to molded records. The measurements have been corrected for frequency response characteristic. If equalization for frequency response had been used in recording, the distortion would be greater than the tabulated measurements. The reproducers used for these measurements were reproducer *B* for the lateral and reproducer *C* for the vertical data.

Power Requirements.—All materials tested, except aluminum and the pre-grooved material of group *4* shown in curve *A10* of Fig. 2, required power inputs to the recording instrument at 1000 cps. that were only a few decibels more than that required for wax recording. Aluminum, depending upon the source of supply, required about 5 to 15 db. more recorder input power at 1000 cps. than did the control wax recording. The group *4* material of Fig. 2 required about a 20-db. increase in power input to the recorder.

The increase of turntable power required has been found to be relatively moderate as compared with wax recording for most materials. Here again, aluminum required considerable increase in turntable power. No exact measurements of this have been made, but it is evident that the increase will be a function of the depth of the recorded groove.

Processing.—A few of the better records tested have been recorded and processed; that is, matrices have been electroplated from them and molded records made from these matrices. These few have shown an increase in surface noise in the processing of the order of 10 db. Some of the other materials are not suitable for the present type of processing and would probably be re-recorded to wax if matrices were required.

Fire Hazard.—The materials of the cellulosic group (group *1*) are most frequently supplied as coated metal disks, and are usually recorded by a cutting process. The shavings from all the materials tested of this group were found to be inflammable, due to the large amount of cellulose nitrate contained in them. The coated disks themselves are not readily inflammable because it is necessary to raise the metal core and the coating to kindling temperature in order for the record to burn, and this requires relatively long exposures at fairly high temperatures. The shavings from all other materials tested were found to be non-inflammable.

Humidity Tests.—All the materials tested were subjected to a humidity test at 95°F. and 90 per cent relative humidity for 24 hours. The materials of group *1* showed a surface noise increase of from 0 to 5 db. in this test. The coated metal disks showed inappreciable warping, but the thin disks of recording material alone showed considerable warping. The materials of groups *2*, *3*, and *4* showed little evidence of change in the humidity test except for warping of some materials of group *4*, where thin disks of resin were used. The gelatin materials of group *5* were the most seriously affected in this test. The warping was generally very severe and noise measurements were impossible after the test, even for records where the material had been attached to metal disks. For the latter, severe wrinkling of the recording material occurred which caused regional separation from the metal base.

Time did not permit an aging study of these materials which would correspond to storing them as recorded disks for long periods of time. For some uses very little change in the record is tolerable even over a period of years.

Conclusion.—The measurements show that considerable progress has been made in the field of direct recording materials in the past few years and that many of these disks are capable of reasonably satisfactory recording if used with care. They have been shown to have a life that should be adequate for many uses. The newer disks do not, in general, have the life of good molded records, so that their uses may often be regarded as complementary to those of molded records. The new records are thin and light in weight, and are therefore easily shipped and stored. Many of them are not easily damaged by ordinary handling, storing, or shipping. These newer direct recording materials will therefore probably greatly add to the rapidly growing use of recording.

NEW MOTION PICTURE APPARATUS

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

THREE-WIRE D-C. SUPPLY FOR PROJECTION ARCS*

C. C. DASH**

Three-wire d-c. systems for projection room service provide a flexible and economic means for supplying current to the miscellaneous projection equipment usually found in the projection rooms of the larger theaters. Small theaters,

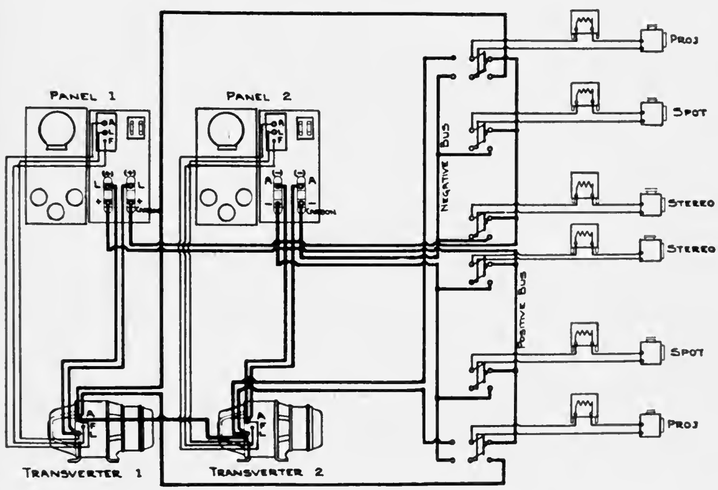


FIG. 1. Connections for two type H. I. Transverters and panels.

too, usually have spotlamps for special occasions, and the stereopticon also is a useful piece of projection equipment.

The advent of the low-voltage d-c. projector lamps with their high efficiency when operated on d-c. sources particularly designed to supply current to such lamps has resulted in changes in generator equipment from high- to low-voltage generators. The auxiliary equipment could not be used on these low-voltage

* Received September 21, 1936; presented at the Fall, 1936, Meeting at Rochester, N. Y.

** Hertner Electric Co., Cleveland, Ohio.

sources, as it is outfitted with arcs that operate normally on 55 to 65 volts across the arc.

The three-wire Edison system is admirably suited to meet these conditions in a projection room. The diagram in Fig. 1 shows how three-wire service has been provided by using two 42-volt generators. Each projector is operated on one of the motor-generator sets. The switching arrangement permits either projector to be operated by either motor-generator set; but when the stereopticon and spotlamps are to be used, both sets are operated and the d-c. outputs of the two are connected in series. It is obvious from the way in which the switching scheme is worked out that when only the projectors are being used, only one motor-generator set need be operated; and in the event of difficulty with either

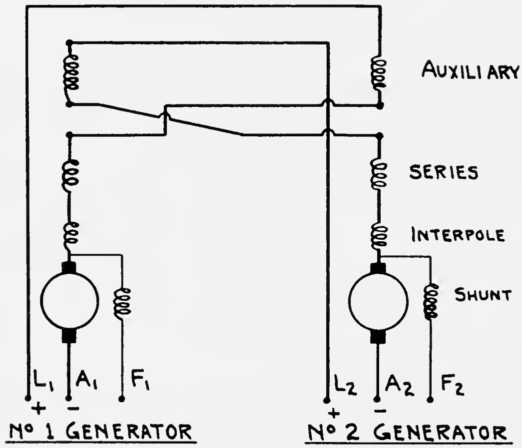


FIG. 2. Generator connections for universal Transverter.

of the motor-generators, current can still be supplied to the projectors from one motor-generator set.

There are installations where it is not desirable to install duplicate motor-generator sets with two control panels and the necessary switching arrangement to take care of possible emergencies. A single-unit motor-generator set has been produced particularly for this service, in which two 42-volt generators are driven by one motor, the two generators being not only flat-compounded, but having auxiliary series fields so that the voltage of the generator is maintained constant regardless of changes of load and, consequently, of the speed of the driving motor when the load is placed upon the other generator.

The motor of this particular type of motor-generator set is designed for high pull-out torque and high overall efficiency over a wide range of load. The generators are identical. In order to maintain constant voltage over a wide range of load, it is desirable that the magnetic circuit of the generators be quite saturated. This provides stable operation with but little fluctuation with sudden changes of load, and with the large amount of space provided for shunt field windings the temperature rise in the shunt fields is extremely small. Current-densities in the armature and series field are extremely low so that the resistance drop is kept to an absolute minimum. A large number of commutator bars is used so as to improve the commutation and reduce the commutator ripple. By properly

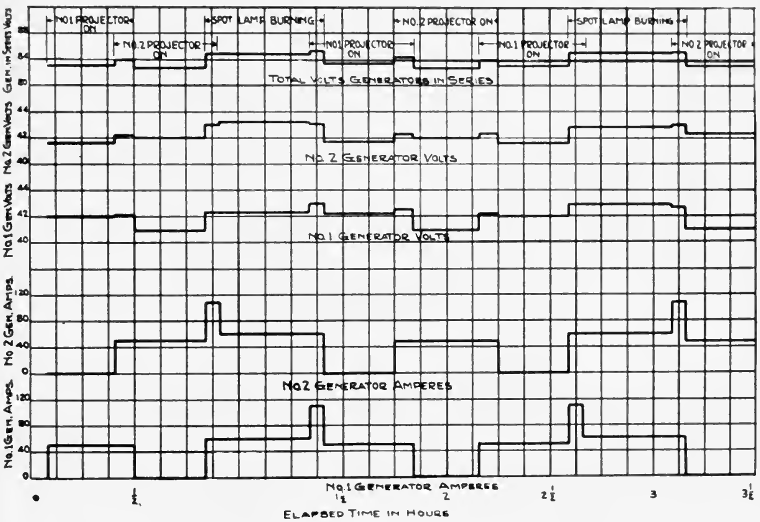


FIG. 3. Performance curves of Universal Transverter.

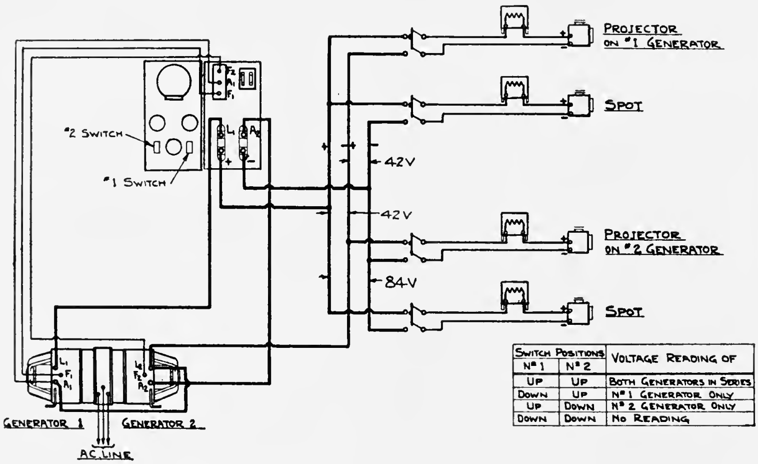
skewing the armature slots the commutator ripple is further reduced to a minimum.

Fig. 2 shows the manner in which the series fields are connected into the circuit. Any load placed on No. 2 generator increases the excitation of generator No. 1 sufficiently to compensate for the change of speed of the driving motor. Fig. 3 shows the voltage regulation of this type of motor-generator set under various conditions of load such as would be encountered in the projection room.

When two motor-generator sets are used they are equipped with individual control panels, and the two machines are operated practically independently of each other. Any adjustment of the output voltage of one machine does not affect the output of the other. The panels may be equipped with ammeters or merely a voltmeter, depending upon whether or not the projectors are equipped with suitable meters.

The panel equipment usually furnished with the two-generator motor-generator set has two independent field regulators, which are operated independently and which control the voltages of the generators independently so that the output voltage of either generator may be adjusted to the point at which the best operation of the arc results. The voltmeter circuit is provided with three-way switches so connected into the circuit that the voltage across either generator or across the two in series may be read on the single voltmeter.

The equipment was designed to meet the projection needs of some Midwest



SWITCH POSITIONS		VOLTAGE READING OF
Nº 1	Nº 2	
UP	UP	BOTH GENERATORS IN SERIES
DOWN	UP	Nº 1 GENERATOR ONLY
UP	DOWN	Nº 2 GENERATOR ONLY
DOWN	DOWN	NO READING

FIG. 4. Connections for Universal Transverter and panel.

theaters where 20- or 25-ampere generators were being used for reflector lamps with small carbons. To increase the current to 38 amperes for the S.R.A. carbons it was necessary to buy new generators, and in order to take care of the possible introduction of the Suprex lamp at a later date this particular type of generator was installed.

The generators are built in various capacities—as high as 200 amperes on continuous duty. The momentary service, or momentary overload duty, during a change-over period would be 300 amperes per generator at 84 volts.

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SPRING, 1937, CONVENTION

SOCIETY OF MOTION PICTURE ENGINEERS

HOLLYWOOD-ROOSEVELT HOTEL

HOLLYWOOD, CALIF.

MAY 24th–28th, INCL.

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Headquarters

Headquarters of the Convention will be the Hollywood-Roosevelt Hotel, where excellent accommodations are assured. A reception suite will be provided for the Ladies' Committee, and an excellent program of entertainment will be arranged for the ladies who attend the Convention.

Special hotel rates, guaranteed to SMPE delegates, European plan, will be as follows:

One person, room and bath	\$ 3.50
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	6.00
Parlor suite and bath, 1 person	9.00
Parlor suite and bath, 2 persons	12.00

Room reservation cards will be mailed to the membership of the Society in the near future, and everyone who plans to attend the Convention should return his card to the Hotel promptly in order to be assured of satisfactory accommodations. Special garage rates will be provided for SMPE delegates who motor to the Convention.

Railroad Fares

The dates of the Convention have been chosen in order that delegates may avail themselves of the summer tourists' rates, which go into effect May 15th. The following table lists the railroad fares and Pullman charges:

City	Railroad Fare (round trip)	Pullman (one way)
Washington	$120.75	$20.50
Chicago	86.00	15.75
Boston	132.80	22.25
Detroit	98.30	18.00
New York	126.90	21.75
Rochester	112.50	19.25
Cleveland	101.35	18.00
Philadelphia	122.85	21.00
Pittsburgh	107.10	18.75

The railroad fares given above are for round trips, forty-five day limits. Arrangements may be made with the railroads to take different routes going and coming, if so desired, but once the choice is made it must be adhered to, as changes in the itinerary may be effected only with considerable difficulty and formality. Delegates should consult their local passenger agents as to schedules, rates, and stop-over privileges.

New streamlined trains will be operating from Chicago to Los Angeles and San Francisco, making the trip to Los Angeles in 39 hours. Special fares are levied on these trains.

Technical Sessions

The Hollywood meeting always offers our membership a rare opportunity to become better acquainted with the studio technicians and production problems. Accordingly, arrangements are being made to hold two evening sessions at two of the studios. The Monday evening session will be devoted to a practical demonstration on a studio set of the function of the various personnel units who contribute to making a picture. On Tuesday evening arrangements are being made to demonstrate outstanding examples of sound recording and color photography, special effects, and picture quality. Also tentatively scheduled for this evening is a demonstration of stereophonic sound reproduction by Mr. Douglas Shearer.

The Academy of Motion Picture Arts & Sciences is arranging a session by leading Academy members, and reports will also be made of the work of the various Academy committees.

The general technical sessions will include papers on production problems, studio design and organization, push-pull recording and reproduction, critically damped filters, electrical engineering problems and equipment for studios, film storage, density measurements, and other pertinent subjects.

An endeavor is being made to schedule a symposium on the production of color stills. A new color process will be described and demonstrated, and papers on lighting for color pictures have been promised.

A large number of interesting papers are promised for the Apparatus Symposium.

The Local Papers Committee under the chairmanship of Mr. William A. Mueller and with Lawrence Aicholtz as secretary is collaborating closely with the General Papers Committee in arranging the details of the program. Other members of this committee are: C. N. Batsel, O. O. Ceccarini, E. C. Richardson, H. C. Silent, and H. G. Tasker.

Complete details of the program will be published in the May issue of the JOURNAL.

Semi-Annual Banquet

The Semi-Annual Banquet of the Society will be held at the Hotel on Wednesday, May 26th. 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.

Inspection Tours and Diversions

Arrangements are under way to visit one or more of the prominent Hollywood studios, and passes will be available to registered members to several Hollywood motion picture theaters. Arrangements may be made for golfing and for special trips to points of interest in and about Hollywood.

Ladies' Program

An especially attractive program for the ladies attending the Convention is being arranged by Mrs. K. F. Morgan and Mrs. P. Mole, *hostesses*, and their Ladies' Committee. A suite will be provided in the Hotel, where the ladies will register and meet for the various events upon their program. Further details will be published in a succeeding issue of the JOURNAL.

Points of Interest

En route: Boulder Dam, Las Vegas, Nevada; and the various National Parks.

Hollywood and vicinity: Beautiful Catalina Island; Zeiss Planetarium; 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 SMPE motion picture exhibit); Mexican village and street, Los Angeles.

TENTATIVE PROGRAM

Monday, May 24th

10:00 a.m. *Blossom Room*
Registration
Society Business
Committee Reports
Technical Papers Program

12:30 p.m.	*Florentine Room* Informal Get-Together Luncheon for members, their families, and guests. Brief addresses by several prominent members of the industry.
2:00 p.m.	*Blossom Room* Technical Papers Program.
8:00 p.m.	(To be announced later.)

Tuesday, May 25th

10:00 a.m.	*Blossom Room* Technical Papers Program
2:00 p.m.	(To be announced later.)
8:00 p.m.	*Blossom Room* Technical Papers Program

Wednesday, May 26th

10:00 a.m.	*Blossom Room* Technical Papers Program
2:00 p.m.	(To be announced later.)
8:00 p.m.	*Blossom Room* Semi-Annual Banquet and Dance of the SMPE; Addresses by eminent members of the industry: dancing and entertainment.

Thursday, May 27th

10:00 a.m.	Open morning
2:00 p.m.	*Blossom Room* Technical Papers Program
8:00 p.m.	*Blossom Room* Technical Papers Program

Friday, May 28th

10:00 a.m.	*Blossom Room* Technical Papers Program
2:00 p.m.	*Blossom Room* Technical Papers Program Open Forum Adjournment of the Convention

NOTE: All technical sessions will be held in the *Blossom Room* of the Hollywood-Roosevelt Hotel. There will be no public exhibit of apparatus in the Hotel; although members registered in the Hotel will, of course, be privileged to display any equipment they wish in their own rooms.

SOCIETY ANNOUNCEMENTS

ATLANTIC COAST SECTION

At a meeting held on January 20th at the Hotel Pennsylvania, New York, N. Y., a symposium of three presentations was held on the subject of lighting. Mr. G. Mili, of the Westinghouse Electric & Manufacturing Company, Bloomfield, N. J., presented a paper on the subject of "Light and Light Control in Photography," followed by a discussion of "New Developments in Lamps for Photography," by J. H. Kurlander of the same company. The papers were accompanied by a demonstration of lighting equipment employing incandescent lamps used in studio practice. In addition, Mr. F. E. Eldredge, also of the Westinghouse Electric & Manufacturing Company, re-presented the paper, "A Demonstration Triode Tube," written jointly with H. F. Dart, previously presented at the Rochester Convention last October.

At the meeting held on February 25th at the studio of Movietonews, Inc., Mr. H. I. Reiskind presented a paper describing the new RCA single-channel recording and re-recording installation recently completed at the Movietonews studio. Following the presentation, members attending the meeting were privileged to inspect the equipment and listen to several samples of recent recordings made on the system.

Both meetings were very well attended, in the latter case to the extent of more than two hundred members and guests, and considerable discussion followed the presentations.

MID-WEST SECTION

On March 11th, at the auditorium of Bell and Howell Co., Chicago, a paper entitled "Some Aspects of Motion Picture Photography" was presented by D. E. Hyndman, of the Eastern Division Motion Picture Film Department of the Eastman Kodak Company.

The next meeting of the Section is scheduled for April 8th.

STANDARDS COMMITTEE

At a meeting held on February 18th at the General Office of the Society, further consideration was given to the revision of the standards drawings as a consequence of the actions taken some months ago at the meeting of the International Standards Association at Budapest, and of various proposals made in the interim for the purpose of achieving greater unanimity between the standards of the S.M.P.E. and those of various European standardizing organizations.

The revision has been practically completed, and the Committee will probably be voting upon adopting them about the time this issue goes to press, after which the Board of Governors will take action upon submitting the revisions to the American Standards Association for formal adoption as American national standards.

SECTIONAL COMMITTEE ON MOTION PICTURES, ASA

On March 10th, a meeting of Technical Sub-Committee No. 2—Optical, under the chairmanship of J. O. Baker, was held at the General Office of the Society, the purpose of this meeting being primarily to establish the scope of activity of the Sub-Committee and to formulate an agenda for the coming season.

The Sub-Committee plans to investigate the standards of the various scientific and engineering societies for the purpose of determining whether any such standards may be suitable for adoption as American motion picture standards.

ADMISSIONS COMMITTEE

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

BECKWITH, R. F.
Recordak Corp.
235 W. 23d St.
New York, N. Y.

BINDER, M.
42 E. 28th St.
New York, N. Y.

BISHOP, M.
40 Grey St.
Gisborne, N. Z.

BORRAS, A.
Cinefilm Laboratories
Large St. & Solly Ave.
Philadelphia, Pa.

DARLING, C. W.
3412 Addington Ave.
Montreal, P. Q.
Canada.

DENNISON, L. I.
Patterson & Dennison, Inc.
6210 Greenfield Ave.
West Allis, Wis.

GOULD, M. E.
Photoelectric Business Machines, Inc.
74 Trinity Place
New York, N. Y.

HUMBERSTONE, F. G.
39, Highdown
Worcester Park
Surrey, England.

KERDEL, O.
Llaguno a Bolero 44
Caracas, Venezuela.

KLINEDINST, M. S.
395 Warburton Ave.
Yonkers, N. Y.

KOJIMA, E.
The K. S. Talkie Seisakusho
Kyobunkan Bldg., 3 chome
Ginza, Tokyo, Japan.

MARASCO, B.
Via Melchiorra Gioia 121
Milan, Italy.

MEEK, C. P.
4165 Ellis Ave.
Chicago, Ill.

MERSAY, H. A.
20th Century-Fox Film Corp.
444 W. 56th St.
New York, N. Y.

NAKAJIMA, Z.
D. Nagase & Co., Ltd.
7, Itachibori Minamidori
1 chome, Osaka, Japan.

OGURA, J.
D. Nagase & Co., Ltd.
7, Itachibori Minamidori
1 chome, Osaka, Japan.

RAMSEY, A. B.
Ramsey Tower Bldg.
Oklahoma City, Okla.

ROBACH, M.
c/o Film Daily
1501 Broadway
New York, N. Y.

SEELEY, A. J.,
421 S. Roxford Road
Syracuse, N. Y.

STOCKER, A. J.
551 Fifth Ave.
New York, N. Y.

ULMER, A. R.
64 Shelby St.
Dumont, N. J.

WALTERS, W. H.
Walters Electric Co.
739 Third Ave.
New York, N. Y.

WHEATLEY, R. T.
RCA Photophone, Ltd.
19, Blythswood Sq.
Glasgow, Scotland.

WOLAK, A. J.
114 Belvidere St.
Waukegan, Ill.

In addition, the following applicants have been admitted by vote of the Board of Governors to the Active grade:

HOPPER, F. L.,
599 S. Hudson Ave.,
Pasadena, Calif.

KOENIG, W.,
Universal Pictures,
Universal City, Calif.

PEMBERTON, H. L.,
9 Place des Martyrs,
Brussels, Belgium.

REISKIND, H. I.,
RCA Manufacturing Co.,
Camden, N. J.

The Society regrets to announce the death of

MAX MAYER
September 15, 1936

Mr. Mayer was one of the founder members of the Society, and held office in the Society as Vice-President from 1918 to 1921, inclusive, and was elected member of the Board during 1928 and 1929. He continued as a member of the Society up to 1931, at about which time his health began to fail. Mr. Mayer's activities were concerned primarily with arc lamp lighting, although prior to 1912 he had been engaged in much experimental work with x-rays and the fluoroscope. In 1915 he became interested in the Prizma process of color cinematography, and for some years was associated with the M. J. Wohl Company of New York, manufacturers of arc lamps.

The Society regrets to announce the death of

J. P. SKELLY
March 8, 1937

JOURNAL

OF THE SOCIETY OF

MOTION PICTURE ENGINEERS

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See p. 541 for Technical Committees

A BRIEF SURVEY OF THE PHYSICS AND TECHNOLOGY OF THE BERTHON-SIEMENS COLOR PROCESS*

E. GRETENER**

Summary.—*An analysis is made of the advantages and limitations of the lenticular color-film system over that of the screen-film method as well as processes using three separate images. Exposure of lenticular films requires a perfect system of objectives with uniform optical filter position. Entirely new types of negative emulsions of high resolving power were devised to overcome irradiation effects.*

Methods of printing lenticular films are described. Objectives of small aperture were developed to offset color fringing resulting when large-aperture objectives were used. The three separation images are registered by a mirror system.

New arc lamps of very high efficiency are described for use in projection. They operate with horizontally arranged square carbons and magnetic stabilization. The luminous gas portion extends in front of the positive carbon and can radiate laterally without obstruction. With 60 amperes the intrinsic brilliance in the crater was found to be 800 candles per sq. mm.

A further increase of screen brightness was realized by the use of a special projection screen which confined the reflected light within the needed angle. Metal sheets are used into which one million small concave mirrors are rolled per square meter. On the basis of conditions prevailing in the German theaters, an increase of screen brightness by a factor of 3 can be attained with the use of the new screen.

In the past few years in Europe the lens-screen method for color films has been further developed. The most active group worked with the inventor, Rodolphe Berthon. Their interests are embodied in Opticolor A.G., Glarus, Switzerland. At the request of this company, Siemens & Halske A. G. (Berlin), in connection with other firms, developed the method into an industrial process. It has received the name Berthon-Siemens Color-Film Process. During the 1936 Olympic games a short film, made by this process, was shown publicly in Berlin. It is believed that this represents the first time in the world that a lens-screen color-film (35-mm.) has been shown successfully on a motion picture theater program. Additional films are being made.

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* Received September 29, 1936; presented by title at the Fall, 1936, Meeting at Rochester, N. Y.

** Siemens & Halske A. G., Berlin-Siemensstadt, Germany.

INTRODUCTION

(1) *Color Distortion*

Making satisfactory color motion pictures is largely a problem in reproducing the impressions produced upon the senses when an object is viewed. Equivalence between the original colored object and its reproduction results when definite properties of a mixture of wavelengths for a color print are carried through the entire process. It is well known that a color can be characterized clearly by a statement of three numbers, designated as tri-stimulus values. Any color can be matched by an additive mixture of suitable amounts of three fundamental colors, red, green, and blue. The amounts of the fundamental colors necessary to match a sample color are called the tri-stimulus values of the color. A primary color coördinate system is obtained in terms of these tri-stimulus values. Specification of dominant wavelength, purity, and brightness is thereby much simplified. These quantities may be derived in a simple manner for any color from the coördinates of the color in the tri-stimulus coördinate system.

The performance of color-film processes can be judged at present by the color distortion. The way in which the color coördinates of the reproduction are related to those of the original object is determined. Indistinguishability between the reproduction and the original is possible only with identity of the tri-stimulus values. In general, there are certain distortions in dominant wavelength, purity, and brightness, which may be considered analogous to the sound distortions occurring in sound-films. However, alteration of the color coördinates by reproduction does not provide a measure of the physiological effect of the print. The relations are the same here as in sound-film in respect to which, likewise, no direct conclusion as to quality of tone reproduction can be drawn from a statement of the frequency characteristic or the noise factor. It is a case of learning to determine which physical color distortion can be permitted without giving rise to an unnatural appearance of the color print.

A physiological measurement of the difference between colors has been attempted by stating the smallest number of perceptible steps between them (color threshold). This method applied to the partial errors in dominant wavelength, purity, and brightness, gives a good idea of the quality of color-films. The combination of the three individual errors into one final color error does not appear to be possible by any simple means. Information has been obtained from many investigations that greatest emphasis should be laid upon the correct dominant wavelength reproduction. Distortions in color purity are less disturbing and deviations in the relative reproduction of brightness are noticeable only in extreme cases.

As an example of color distortion we studied the error in reproduction of a simple continuous spectral region, for constant energy at the individual wavelengths. The spectral width of the reflectivity

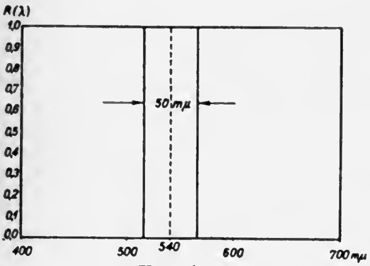


FIG. 1.

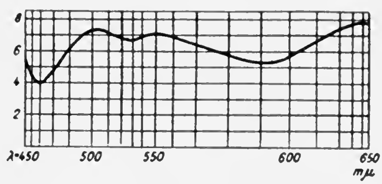


FIG. 3.

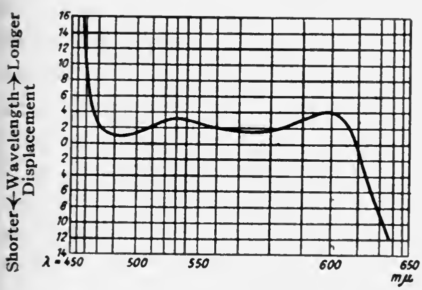


FIG. 2.

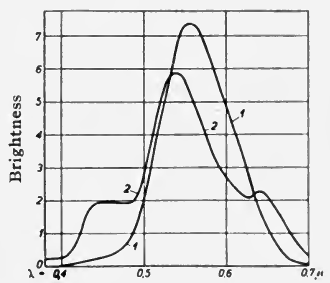


FIG. 4.

FIG. 1. Optimal width of reflectivity band.

FIG. 2. Color displacement of lenticular film in relation to threshold sensibility.

FIG. 3. Saturation displacement of lenticular film in relation to threshold sensibility.

FIG. 4. Spectral brightness curves in (*1*) taking, and (*2*) reproduction.

function amounts to 50 mμ (Fig. 1). Dominant wavelength and purity errors are represented in Figs. 2 and 3, respectively, by the number of the perceptible color steps between the print and the original subject. The brightness distortions are exhibited in Fig. 4, in which curve *1* shows the visual brightness of 50-mμ spectral bands located in various parts of the spectrum, and curve *2* shows the brightness of the photographic reproductions of such colors. The color distortion represented here was computed on the assumption of ideal photographic rendering of the color components and upon the basis of conditions that could actually be realized in practice, for taking and projection.

(2) *Three-Color Additive Processes*

The colors used for the reproduction must be so chosen that the range of colors that can be represented comprises, as far as possible, all the colors occurring in nature. The use of pure spectral color is eliminated, since the screen brightness attainable with such sources is far too low for practical purposes. The combination of a white light-source with suitable red, green, and blue filters is the only type of source that can be considered for the projection of color reproductions. The relative intensities of the projection colors chosen for use can be standardized by determining the relative amounts of these colors that must be projected simultaneously upon a white screen in order to produce a white image. The intensities of the projection components present in the synthesis of white are taken as units of the components, red, green, and blue in the colors of objects. The components of the color of an object are determined by producing a mixture of the particular red, green, and blue lights to be used in projection such that the color of the mixture is identical with the color of the object. Such a system of standardized reproduction filters is shown in Fig. 5. This kind of component determination is not usable in practice; in its place the components are controlled by color filters. The action of such filters is determined by the spectral distribution of the light reflected from the colored objects.

The colors of objects can be conceived as the superposition of spectral colors. The wavelength mixture radiated from an object is determined by the quality of the illumination and the reflectivity of the surface observed. The desired spectral transparency for the red, green, and blue filters depends upon the requirement of the highest possible similarity between the colored image and the original object. Thus, in the illustration of an object a picture is formed through a red filter whose energy distribution matches, point for point, the distribution of the red component in the original object. In the same way the green and blue components are formed. This energy distribution can be registered photographically.

It is the function of the negative emulsion to rearrange the energy distribution of the parts of the picture into a proportional transparency distribution. This rearrangement must be independent of the spectral composition of the energy; and, over the greatest possible range, must be independent of the absolute intensity of the color components. The first requirement must be fulfilled in order that, on the whole, simultaneous rearrangement of the energy into transparency values results for all colors. The second requirement represents a condition of linearity, which makes the color independent of the brightness. For motion pictures the second condition is particu-

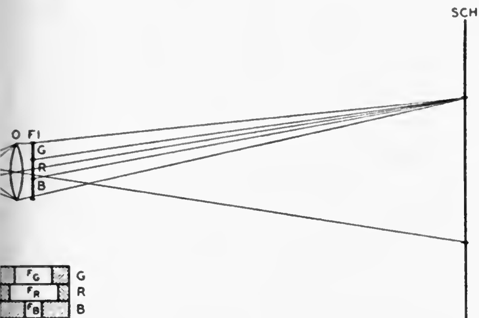


FIG. 5.

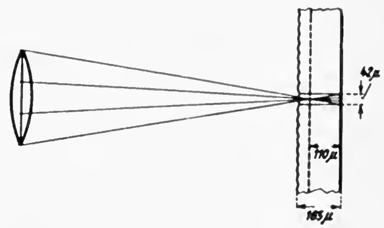


FIG. 7.

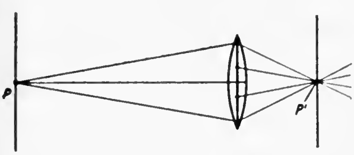


FIG. 6.

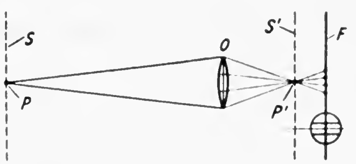


FIG. 8.

FIG. 5. Additive color mixture.
FIG. 6. Distribution of light-rays in lens.
FIG. 7. Path of light-rays through section of lenticular film.
FIG. 8. Lens diagram showing circle of confusion.

larly important, since, otherwise, a color would change with alternating degrees of brightness.

Now, if the three partial pictures are projected in register by means of the fundamental colors, then a colored picture of the original object is formed upon a white screen.

THE LENTICULAR FILM

(1) *Fundamentals*

The method of three-color separation pictures is not usable in practice since, in addition to the great inconvenience of the method, registration of the three partial images in projection is not attainable. On that account, the idea of combining the three color-separation pictures to form a single picture has been tried. This method, for example, is used in the generally known Lumière autochrome plates. The filters are comprised of microscopically small elements in intimate contact with the emulsion. It has been attempted to introduce the color-screen method in films as well as in plates. Many difficulties arise in printing, since registration of the original screen and the printing screen is not attainable. Furthermore, projection of a color-screen film shows a "boiling" of the color-screen elements, produced by their differing distribution from picture to picture.

The lens-screen film separates the color filter and photographic record. The three-part taking filter is placed in the pupil of the camera lens so that three component pictures are formed lying one over the other (Fig. 6). On account of the coördination of the directions of the image-forming bundles with the zones of the color filters, separate registration of the three component pictures is possible when a film provided with microscopically small cylindrical lenses on the celluloid side is used.

The cylindrical lenses run parallel to the zones of the taking filters so that the energy values of the light-beams are recorded proportionally to the color components separated by the red, green, and blue zones of the taking filters. The whole picture is split into narrow strips by the lens screen (Fig. 7). The color values of the object, in recording, are distributed over the width of the strips. Therefore, the photographic emulsion contains, packed within it, the red, green, and blue components of the object.

Reversal of the path of the rays during projection, in turn, coordinates the registration of the components in relation to the zones of the reproducing filters over the lens-screen, and thereby produces a naturally colored image upon a white projection screen. The superiority of the lenticular film in relation to the color-screen method follows from the separation of the filters from the photographic record. The print is possible fundamentally without screen superposition. The disturbance caused by "boiling" (moiré) of the screen does not occur upon projection, since each film lens is illuminated with the color mixture, and not in the three fundamental color strips. White would be represented upon the color-screen film by three strips of red, green, and blue, lying side by side; while in lenticular films, each individual lens appears homogeneously white.

Separation of the color-filter from the photographic recording, on the other hand, gives rise to the fundamental difficulties of lenticular film which now have been overcome. Falsities in color rendition occur if the coördination between the recording strip and the filter zones of the objective is not exact. Correct color reproduction is possible only when the illumination systems for exposure, printing, and projection are free from vignetting; that is, the three-zone filter must be visible over its entire extent on every point of the image field. If this condition is not fulfilled, falsification of the color occurs, depending upon the position of the point observed in the image field. There are special requirements for the illuminating beam in printing and projecting. It is required that the illumination of the individual components be homogeneous over the entire image field. If the distribution of energy at different elementary angles of the bundles of rays is not constant over the entire image field, then errors in color occur over the entire field on account of the splitting up of the image-forming rays into the three partial light-beams, red, green, and blue. As a further consequence, the separation of the filter from the photographic emulsion makes it necessary to use a very accurate film-gate track. Any wrong orientation of the elementary lenses through curvature of the film leads to distorted color rendition.

(2) *Technology of Lenticular Films*

(*a*) *Exposure Optics.*—In practice, objectives of different focal lengths are used for the exposure. Since projection must be considered, the distance of the filter image from the film (during exposure) must be the same for all focal lengths. By using field lenses in the image plane, it is possible to make the distance of the filter image from the film identical for all focal lengths. This solution is of little practical importance, since the field lenses of the required power cause considerable loss of sharpness of the image when used in conjunction with the common objectives on the market. The requirement of freedom from vignetting and of uniform filter position for the exposure lens system limits the types of objectives suitable for lenticular film. The greatest difficulties arise at short focal lengths, so that wide-angle objectives are not yet available for color-film. The subdivision of the lens aperture into the three color zones leads to poor registration of the three separation images outside the focal plane. The circle of confusion of an illuminated point demonstrates the separation of the filter areas (Fig. 8). Therefore, color fringes result on objects that are not sharply focused that are especially disturbing in close-ups where the requirements of depth of focus are extreme. For this type of scene, a special lens system has been developed. By placing a light-mixer in front of the objective, the pupil of the compound objective becomes identical for all three separation images. The circle of confusion of an illuminated point outside the sharp focus is in this way homogeneous as to color, and hence the appearance of color fringes is fundamentally eliminated. For clarity, in Fig. 9 only

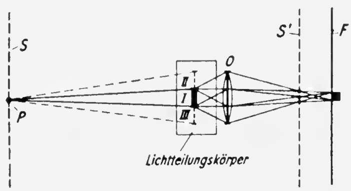


FIG. 9.

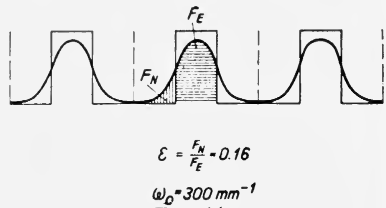


FIG. 11.

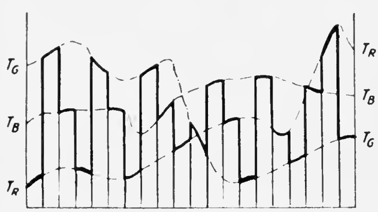


FIG. 10.

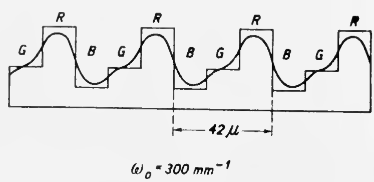


FIG. 12.

FIG. 9. Light-mixer in front of camera lens.
FIG. 10. Diagram showing exposure variation from element to element of lens-screen.
FIG. 11. Monochrome exposure behind several lens elements.
FIG. 12. Alteration of step exposure through diffusion in the emulsion.

the splitting of the light passing through area *I* is shown. In reality, the light passing through zones *II* and *III* is also utilized.

Looking from the film side, one sees the normal three-zone filter; while from the object side, a homogeneous pupil appears through the effect of the light-mixer.

(*b*) *The Photographic Recording of the Color Components.*—The lenticular film requires highest efficiency in the photographic emulsions in regard to resolution. The amount of exposure given to the individual color zone images jumps discontinuously from zone to zone (Fig. 10). A step-like exposure is formed transversely to the cylindrical lenses. Keeping in mind that the width of a zone image is of the same order of magnitude as the thickness of the silver bromide layer, and considering that the silver bromide gelatin emulsion is a turbid medium having very strong light-diffusing properties, it is easy to recognize how difficult is the problem of recording the individual color components clearly. A clear view of the above-mentioned factors is obtained if exposures are made over a single color zone, excluding the other two zones (Fig. 11). It can be seen that due to the silver bromide diffusion, part of each color component reaches the areas provided for the other components in the photographic layer. The reproduction of a desired color takes place by superposition of the single exposures made through the red, green, and blue filters. Fig. 12 shows the alteration of the impressed exposure by silver bromide diffusion.

Of special interest is the effect of the silver bromide diffusion in a non-stationary case; that is, in the parts of the image where the color changes. The transparency function of a single zone is obtained by superposition of two exposure steps of opposite sign with their phases shifted by the width of a filter image (Fig. 13). Any desired color shade can be obtained through superposition by means of the transparency function of the single zones, and the color consequences can be viewed in the color triangle.

In order to limit the effect of the silver bromide diffusion to a practical degree, Perutz, in connection with the Siemens Company, developed new types of emulsions. With proper adjustment of the taking and reproduction filters, and by maintaining certain symmetrical conditions for the exposure distribution of the successive screen lenses, one can avoid the effect of the silver bromide diffusion upon the reproduced hue. The reduced saturation that results can be compensated by application of silver bromide solvents to the first developing solution. The effect is the same as if another gamma were adopted for the finest details than for the distribution of the image contrast as a whole. The concentration of the silver bromide solvents must be chosen in accordance with the properties of the photographic emulsion.

In printing, another loss in saturation of the colors takes place due to the silver bromide diffusion. In this case, its effect can be checked by using relatively insensitive emulsions of very high resolving power.

(*c*) *The Printing Problem.*—In the printing process a correct-phase transfer of the black-and-white component records of the original relative to the edges of lenses of the film used for prints must take place. This task can be solved fundamentally without registration of the screen of the copies with that of the original. Fig. 14 shows the course of the rays in contact printing. This procedure leads to moiré appearances by the action of both sets of lines in the screen, and this can be suppressed only with a very high-illumination aperture, which causes considerable loss of sharpness. The record lying behind an original lens is divided between several lenses of the positive film, which can also cause color fringing.

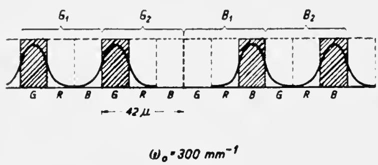


FIG. 13.

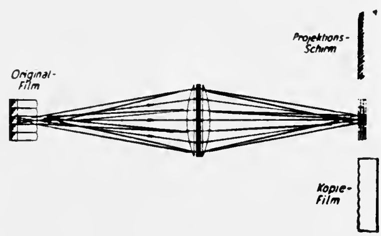


FIG. 15.

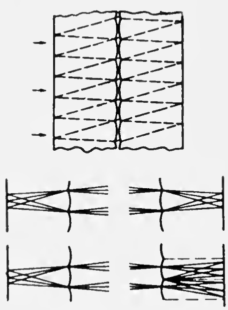


FIG. 14.

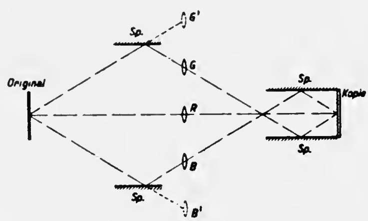


FIG. 16.

FIG. 13. Color changes occurring from one element to another.
FIG. 14. Course of rays in contact printing.
FIG. 15. Diagram of optical printing or projection.
FIG. 16. Printing with multiple lens system.

Another possibility of duplication of lenticular film consists in optically printing the original upon the film used for prints. Fig. 15 shows the fundamental arrangement. In practice, this method involves great difficulties, since a printing lens of the required high aperture can not meet the requirements of image sharpness. With an aperture of the screen lenses of $f/2.5$, an aperture of the printing objective of $f/1.25$ becomes necessary. Such an objective shows marked distortion of the images projected over the partial zones, and this leads to very disturbing color fringing. Tests with modern high-aperture objectives have proved the hopelessness of this printing method. Fundamentally different ways had to be found.

Three separate objectives of small aperture, which must present a large corrected-image field, are arranged in relation to the original film so that they individually register and record the red, green, and blue parts of the original. Fig. 16 shows the principal arrangement of the optics of the printer. The three-part images are registered through a mirror system. The printing optical system projects an image of the screen pattern of the original film, whereby the brightness of the individual lenses corresponds to the average brightness of the three components belonging to the lens in question. The screen of the film used for prints is brought into the focal plane of the original screen. Since the images corresponding to the three fundamental colors are arranged directionally with the three printing objectives, separate registration is possible of the part images over the lens screen, as in the original exposure. In this printing method, the moiré appearances can be suppressed by using illumination of high aperture at right angles to the cylindrical lenses of the original film, without causing loss of sharpness.

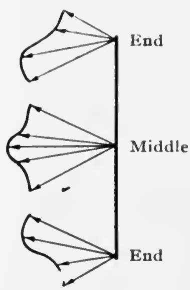


FIG. 17. Variation in light-intensity in projector aperture.

(*d*) *Projection.*—The light requirements of the lenticular film are about ten times as high as those of the black-and-white film. The losses occur in the reproduction filters and through the reduction of aperture necessary to overcome vignetting of the illumination and reproduction systems. Besides the necessary increase in intensity of the projection light, special requirements are created as to the quality of the illumination in the projector aperture. The illumination systems used at present for black-and-white film all produce light rays with energy distribution that varies for different angles of the image field. The only necessary condition for black-and-white projection is an approximate proportionality of energy in the light rays belonging to the individual image points (Fig. 17). This alone fulfills the condition of approximately constant illumination of the whole image field.

The special conditions for the illumination of the lenticular film have been fulfilled by creation of a new type of arc lamp. Considerable increase in the efficiency of illumination was attained as compared to present illumination systems.

For small theaters a pure carbon arc was developed. In accordance with the form of the picture aperture, square carbons are used. A stabilizing arrangement at the hot end of the positive carbon effects the concentration of the total discharge upon the front surface, and protects the shell from oxidation. A magnetic field of a special type, with its axis parallel to the carbon axis, takes care of the stabilization of the arc. It is constructed so that rotation of the total discharge takes place at such high frequency that the homogeneity of the crater

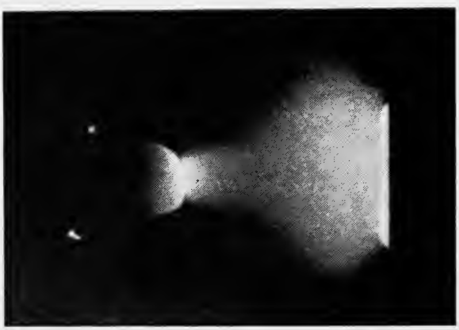


FIG. 18. Discharge form of new pure carbon lamp.

for the illumination time of a single frame is assured during projection.

The space stability of the crater is so great that only a small safety margin of the crater image over the film-gate area is required. Fig. 18 shows the burning form of the new pure carbon lamp. The positive and negative carbons have a common horizontal axis. The thermal lifting force on the arc is practically equalized through the electrodynamic forces of the stabilizing field. Fig. 19 shows the stationary form of the positive carbon.

Large theaters use high-efficiency lamps of very high intensity. Here also, new ways had to be found. In the existing high-intensity lamps, employing the Beck-effect, a deeply burned-out crater prevents the reflection of the luminous gas ball to the sides on account of the high crater walls. A considerable part of the current goes to the carbon shell, and is therefore lost for light production. In Fig. 20, the burning form and the cross-section through the crater of the positive carbon of a commercial high-efficiency lamp are shown. The light-intensity distribution is not homogeneous, and is disturbed by flames emerging from the space between the shell and the core.

FIG. 19. New positive carbon.

FIG. 20. Burning form and cross-section of commercial high-efficiency carbon.

In the newly developed high-efficiency lamp, square carbons are used. The lamp burns with absolute freedom from soot. Fig. 21 shows the discharge form of the new lamp. An intensely luminous gas ball is visible which extends well in front of the positive carbon and therefore can radiate laterally without obstruction. Fig. 22 shows the stationary form of the positive carbon. The flame gases are absorbed by a cover surrounding the negative carbon and escape through the bore of the reflecting mirror. In order to give an idea of the efficiency of the new lamp, it may be stated that with a current of 60 amperes, the density (intrinsic

FIG. 21. Discharge form of new lamp.

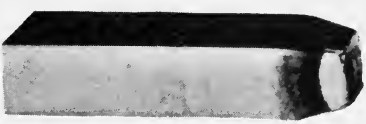


FIG. 22. Stationary form of new positive carbon.

brilliance) in the crater was measured as 800 candles per sq. mm.

Further increase of screen brightness above the limit reached with the new lamp could be attained by development of a special projection screen. The screens that are at present in common use in motion picture theaters, and which provide diffuse reflection, throw a great deal of the light from the projector upon the ceiling and the walls of the theater. The new reflector type of screen reflects the light only in those directions in which it is intended to go. Metal sheets are used in constructing the reflector, and small concave mirrors are rolled into them of such form that the desired diffusion diagram is obtained. The dimensions of the elementary mirrors must be kept very small, so that one million elementary mirrors are present in one square meter. Fig. 23 shows the increase achieved by concentration of the reflected light, compared to the diffusing screen. On the basis of present conditions in German motion picture theaters, an increase of screen brightness by a factor of 3 can be obtained through introduction of the new screen. The precision requirements of the elementary mirrors and the uniformity of impregnation must be extremely high, since otherwise changes of brightness appear at the borders of the individual metal sheets.

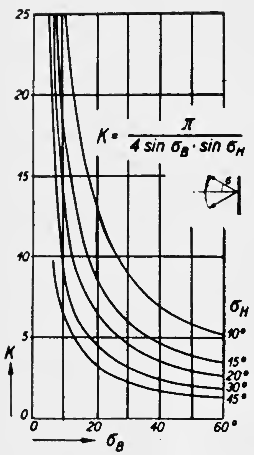
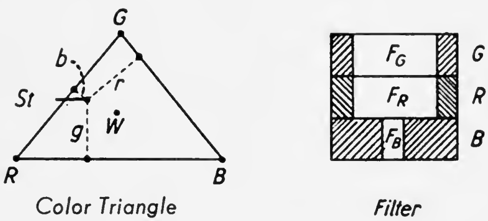


FIG. 23. Increased screen brightness of new screen, compared with old screen.

COLOR CONTROL

Upon projecting a color-film, the viewing conditions are different from those when the object is viewed directly. The colored image appears luminous in a black frame. The connection with the surroundings is missing. The change from one scene to another occurs in jumps, so that the eye has no time to adapt itself to the changed mood. If pictures taken under varying conditions of illumination are combined into a single film, one gains the impression that, for example, evening scenes appear too red compared to noon exposures. In general, the eye adapts itself to the predominating mood of the picture, so that in a change of scenery the next image at first shows a mood corresponding to the complementary color of the preceding image. These difficulties can be avoided if, in changing an image, the mood of the following image is adapted to that of the preceding image. In an optical print from the lenticular film, the light-rays belonging to the red, green, and blue component images can be controlled separately. By introduction of diaphragms in the printing optics, the mood of a picture can be changed at will.

In practice color control is effected in the following manner: At first, an uncontrolled copy is made, which is projected through an objective having controllable apertures in the red, green, and blue zones. In order to facilitate fine color tone changes, a controller is used which influences the objective diaphragms by movement of a single control member in the control triangle which is coupled to the diaphragm. The transmission of the movements of the control member on the filter zone diaphragms takes place electrically. The connection of the open filter areas to the positions of the control member in the control triangle is so arranged that changes of the



$$F_R : F_G : F_B = r : g : b$$

FIG. 24. Diagram showing method of color ratio control.

white point of the projection correspond to the movement of the control member in the control triangle. If the control member is adjusted for the white point of the control triangle, the projected image reproduces a mood as it actually was at the time of the exposure. If one describes a circle about the white point with the control member, the color tone runs through the entire color circle around the white. Fig. 24 shows schematically the construction of the projector control.

A trained judge of color quality decides the necessary correction for the individual images with the aid of the control triangle. In order to judge the effect of the correction of the individual scenes during the run of a film, a perforated strip is made which automatically controls the diaphragms of the projector objective (on a contact apparatus). The start of the adjustments of the diaphragms is effected by a film contact. After the necessary fine adjustments, further prints are made by control of the printer diaphragms by means of this controlling strip. The threater prints are then uniform in the color tone assigned to them by the color-quality judge on the control projector, without the use of any control arrangement upon the theater projectors.

The physical principles upon which the lens-screen process is based have been known since the close of the last century.[1] The method concerned the combination of three color-separations into a single picture with the aid of a three-zone filter within an objective. At that time, for separate registration of the three color images, a line-screen diaphragm was placed in front of the photographic layer. In 1908, the Frenchman, Berthon, used, instead of the impracticable line-screen, the lenticular screen in the form of microscopically small cylindrical lenses.[2] The lenses are impregnated by rollers into the celluloid support. Berthon is then the inventor of the embossed film. The efforts of the French group, which had set itself the task to develop to a commercial stage a color-film process based upon the embossed film, appeared to have led to a certain success by 1930. It was believed that a printing process for lenticular film had been developed that permitted printing the original in theater quality. At that time further development was taken over by Siemens, and investigations in the laboratory very soon showed that the process was still very far from the commercial stage. A considerable number of technical difficulties arose which have required about six years of intensive laboratory studies with great expenditures.

CONCLUSION

The general principle of the additive color film is explained: The composition of the colors in reproduction is discussed and analysis of the components is described. Absolutely natural reproduction is practically impossible; the task is to make the deviations as small as possible.

The lenticular film differs from the color-screen film by separation of screen and filter. This has the following advantages: more liberal choice of dyes, easier and cheaper manufacture of the film, no "boiling" in the reproduction. The disadvantages could be removed by proper selection and design of new taking optics, as well as by improved film-gates. The moiré-free printing is done with a special printing lens and large illumination aperture.

The photographic difficulties, which were eliminated in the films developed by Perutz, are described.

The necessary projection brilliance is attained by new arc lamps and grooved aluminum reflectors for screens. In printing, the color mood can be controlled in an easily predetermined manner.

REFERENCES

[1] AHRIMAN LIESEGANG, R. E.: "Von der Zukünftigen Photographie ein neues Prinzip der Farbenphotographie," *Phot. Arch.*, **37** (Aug., 1896), No. 96, p. 249.

[2] French Pat. No. 399,762. German Pat. No. 223,236 (1910).

RECENT DEVELOPMENTS IN MAGNETIC SOUND RECORDING*

S. J. BEGUN**

Summary.—*Although first work in magnetic sound recording occurred probably as far back as 1900, it has been only recently that any considerable interest has been aroused in it. The present paper describes the principles underlying the methods of recording and reproducing by magnetic means, both by longitudinal and perpendicular magnetization, and a steel tape machine used in European broadcasting stations is illustrated. The advantages of the magnetic systems of recording over other systems are outlined.*

Looking backward, it seems rather strange that of the three known methods of recording sound, only the mechanical and photographic methods have come into wide use, while the magnetic method has been hardly touched.

Magnetic sound recording was invented by the Danish physicist, Valdemar Poulsen, in 1900. Quite a number of patents were granted to Poulsen and his associates on various recording methods and machines devised by them in the early part of the century. Poulsen has shown that when a carrier made of magnetic material, such as a steel wire or tape, is moved between magnetic poles magnetized by speech currents, the successive elements of the carrier are converted into a succession of elemental magnets of varying degrees of magnetization. By passing a carrier with such elemental magnets between a similar set of reproducing poles, corresponding speech currents are induced in the coils surrounding the poles.

Although various companies in Europe, and the American Telegraphone Company in the United States, took up Poulsen's invention, little progress was made in the commercial exploitation of magnetic recording and its practical application was abandoned. However, the inherent advantages of magnetic recording have again aroused interest in its possibilities, and magnetic recording machines have within recent years appeared on the market in

* Received March 5, 1937.

** Guided Radio Corp., New York, N. Y.

Europe, particularly in Germany. It is safe to predict that before long magnetic sound recording machines will become of commercial importance in the United States.

A brief description of the fundamental principles underlying magnetic recording may be of interest in this connection. Poulsen has already shown that magnetic recording may be accomplished either by aligning two pole-pieces upon the opposite sides of the magnetic carrier to produce a succession of perpendicularly magnetized elemental magnets perpendicular to the direction of the travel of the carrier, or by offsetting the recording pole-pieces on opposite sides of the carrier to produce a succession of longitudinally magnetized elemental magnets in the direction of the travel of the carrier.

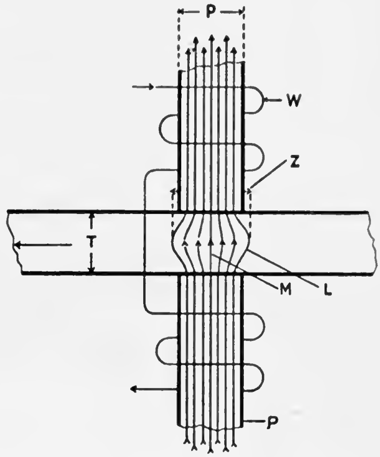


FIG. 1. Magnetic head arranged for perpendicular magnetization.

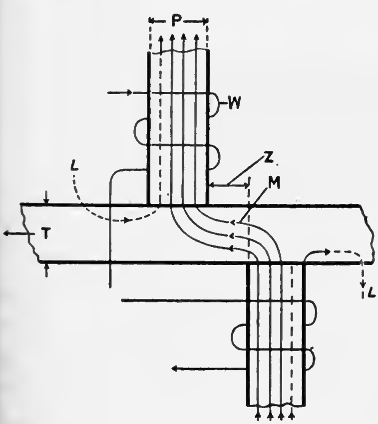


FIG. 2. Magnetic head arranged for longitudinal magnetization.

Sound recording and reproducing by either of these methods of magnetization involves three operations, namely, the blotting, the recording, and the reproducing operation. Each of these operations is carried out with substantially the same kind of magnetic structure, which, depending upon its function, is designated as the blotting or obliterating head, the recording head, and the reproducing head.

Fig. 1 illustrates an arrangement of a magnetic head for perpendicular magnetization. The magnetic pole-pieces *P* are aligned upon opposite sides of the magnetic carrier, for instance, a flat steel tape of thickness *T* moving in the direction of the arrow. Current flowing through a magnetizing winding *W* surrounding the pole-pieces *P* produces a main magnetic flux *M*, which passes perpendicularly through the tape element lying between the pole-pieces, and a leakage flux *L* which spreads out in the tape on both sides of the zone lying between the pole-pieces *P*.

Fig. 2 illustrates an arrangement of a magnetic head for longitudinal magnetization. The two pole-pieces *P*, upon opposite sides of the carrier, are offset by a distance *Z*, and the winding *W* surrounding the pole-pieces produces a main flux *M* which passes from one pole piece through the tape to the other pole-piece, and a leakage flux

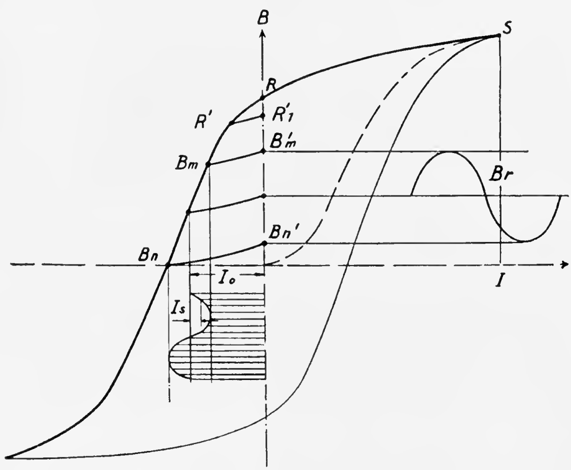


FIG. 3. Hysteresis loop of steel carrier.

L extending through the tape in a direction opposite to the main flux.

Although there are certain practical differences between the recording by the perpendicular and longitudinal methods in the actual recording, the magnetic phenomena underlying the blotting, recording, and reproducing operations are similar for both methods, and may be analyzed by reference to the magnetization curve of the magnetic carrier, shown in Fig. 3, on the theoretical assumption that the magnetizing effect of the pole-pieces is confined to a point of the moving tape.

After the tape material has been initially magnetized, following the broken curve from zero to the saturation point *S*, the magnetization curve takes the form of the well known hysteresis loop, and a tape element may at any time be magnetized to its saturation point S by a magnetizing current I.

In the recording process, the tape travels at a constant speed, and each element of the tape passes between a pair of obliterating magnets which are magnetized to saturation by the current I. This forces through each tape element passing between the magnets a uniform saturating flux corresponding to a point S on the hysteresis loop. This saturating flux blots out all previous magnetizations of the tape, and all previous recordings are accordingly wiped out. As the element of the tape, thus saturated, moves away from the blotting magnets, the magnetization decreases, following the de-

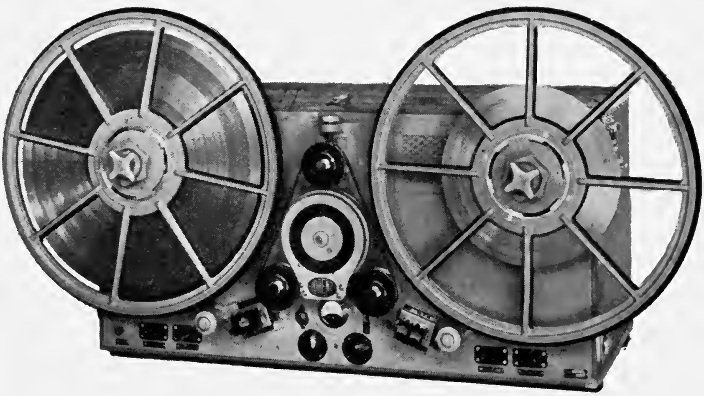


FIG. 4. Magnetic sound recorder (*Electrical Communication; July, 1936*).

scending branch of the magnetization curve to the value of the remanent magnetization R, which remains uniform for the successive elements of the tape passing through the blotting magnet.

Continuing the motion of the tape, each uniformly magnetized element passes between a set of recording magnets, which are subjected to the joint action of a demagnetizing direct current I_o and an alternating speech current I_s, which force a resultant demagnetizing flux through each element and reduce the magnetization along the descending branch of the magnetizing curve to a point below R—for example, to the point B_m—so that upon leaving the demagnetizing zone of the recording magnets, the magnetization of the tape element increases along the minor ascending loop from B_m to B_m' and attains a new value of remanent magnetization, B_m'.

Under the action of the oscillatory recording current I_s, the successive elements of the uniformly magnetized tape will be subjected to successive demagnetizations oscillating between the values B_m and B_n, along the descending branch of the curve, so that upon leaving the recording magnets, the magnetizations of the successive tape elements will increase along minor ascending loops to corresponding remanent magnetizations varying between B_m' and B_n', converting the recorded carrier into a succession of elemental magnets which form along the carrier a magnetic wave B_r, corresponding to the recorded sound.

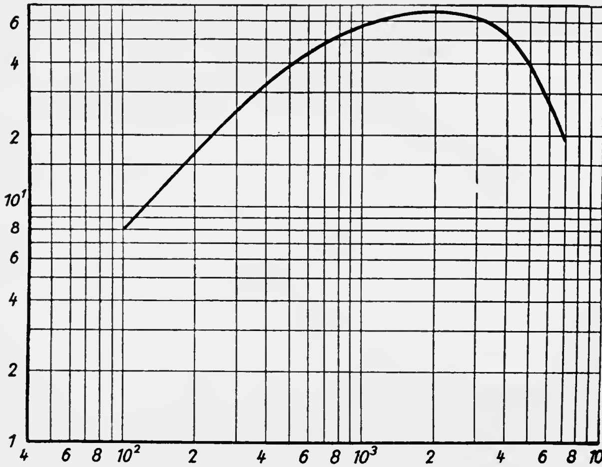


FIG. 5. Unequalized response curve of commercial magnetic recorder.

In the reproducing process, the recorded carrier is passed with the same speed and in the same direction between a set of similar reproducing poles, and the remanent magnetomotive forces of the elemental magnets forming the recorded magnetic sound-wave force through the reproducing cores magnetic fluxes that induce in the surrounding coils alternating currents for reproducing the recorded sound. In distinction from photographic sound recording systems, the induced reproducing currents are not proportional to the amplitude of the recorded sound-waves, but to the rate of change of the magnetic flux waves along the carrier.

In the practical design of magnetic recording systems, the inducing zone of the magnet poles can not be confined to a single point of the wire or tape, and the magnetic phenomena of the recording and reproducing processes are much more complicated. In order to approach such ideal operating conditions, the thickness of the pole-faces and the inducing zones of the carrier are made as small as practicable. This is also important, because in order to accomplish satisfactory reproduction, the length of the induced zone must be smaller than one-half the wavelength of the sound-waves recorded on the carrier.

Furthermore, while under the theoretical conditions described above, maximum efficiency would require a large demagnetizing direct current and large recording currents to permit utilizing the entire straight portion of the descending branch of the magnetization curve for recording practical limitations make this undesirable.

When using perpendicular magnetization, as shown in Fig. 1, the recording flux entering the tape spreads out laterally beyond the zone engaged by the poles, and the increased breadth Z of the induced carrier zone depends not only upon the thickness of the poles P, but also upon the thickness T of the tape. As a result, each recorded tape element leaving the poles is subjected to an additional magnetizing action by the spreading stray field of another recording flux, which distorts the recording effected directly beneath the poles.

In order to make satisfactory records by perpendicular magnetization, a very thin tape must be used so as to reduce to a minimum the lateral spread of the recording flux. Such recording permits operation with a low tape speed, but only thin weak steel tape can be used as a recording medium and the perpendicularly magnetized elements of the thin tape are able to store only little energy.

With longitudinal magnetization, as shown in Fig. 2, the limitations with regard to the thickness of the magnetic carrier are avoided, and either a strong steel wire or a strong steel tape may be used as the recording medium. The thickness of the pole-pieces P and the slot distance Z by which the pole-pieces are offset are so proportioned as to assure that the recording flux magnetizes longitudinally only a very small length of the carrier, while keeping the slot distance Z a minimum.

In operating with longitudinal magnetization, the effect of the leakage flux must be taken into consideration. As shown in Fig. 2, each successive longitudinally magnetized carrier element leaving the zone of the magnets in the direction of the arrow, passes through a zone that is magnetized by the oppositely directed leakage flux L, and its magnetization will be reduced from the remanent value R, along the downward slope of the curve of Fig. 3 to R_1, so that the carrier will leave the zone of the leakage field with the new remanent magnetization R_1'. Accordingly, blotting magnets operating with excessive magnetizing currents impair the subsequent recording process, because the resulting leakage flux reduces the magnetization available for the recording to the straight portion of the descending curve below the point R_1. By designing the blotting magnets for operation with a small leakage flux, this disturbing effect of the leakage flux upon the recording operation may be rendered negligible.

Furthermore, the leakage flux of the recording magnets tends to reduce the magnetization of the recorded tape elements moving through the zone of the leakage flux. By designing the recording magnets to operate with a relatively small demagnetizing direct current, and with sound currents restricted to only a part of the straight portion of the descending magnetization curve below the point R', Fig. 3, the disturbing effect of the leakage flux upon the recording action is rendered negligible.

Although longitudinal magnetization requires a greater length of wire or tape for recording the same length of speech than perpendicular magnetization, recording by longitudinal magnetization is much more practicable. This is due to the fact that all available magnetic sound carriers, such as steel wire or tape, are produced by drawing processes, and drawn steel material can be magnetized to a much greater extent in the longitudinal direction than in the transverse direction. Accordingly, the succession of longitudinally magnetized elements of a tape recorded by longitudinal magnetization in the manner here described supply much greater magnetomotive forces for inducing in the coils of the reproducing magnets large sound-reproducing currents without disturbing noises than could be obtained with perpendicular magnetization.

Magnetic sound recording machines operating in accordance with these principles are now used in most of the European and Canadian broadcasting stations, and are also beginning to enter into the dictating machine field.

A magnetic tape sound recording machine built under the direction of the author for the German and other European broadcasting stations by C. Lorenz Aktiengesellschaft of Berlin is shown in

Fig. 4. This machine makes a continuous recording of 30 minutes. Fig. 5 shows an uncorrected frequency response curve of the reproducing head of this machine. By a suitable corrective network, this response curve can be made uniform between 100 and 8000 cps. A recording made with such a machine will remain intact for several years, and will be unaffected by temperature changes below 250° C.

Summarizing, it may be stated that magnetic recording has the following advantages over other systems: It requires no processing, and the record may be reproduced immediately after it is made without impairing the recording. Each portion of the recorded sound may be repeated as many times as desired without affecting its quality. In distinction from mechanical and photographic recordings, the quality of a magnetic recording may be checked as soon as it is made. Since the recording medium is not subjected to mechanical or chemical changes, the same sound carrier may be used over and over again. Recorded words or sentences may be replaced by others without affecting the remainder of a completed recording. By combining the blotting magnets with the recording and reproducing magnets into a single head, each new recording operation wipes out the prior recording without loss of time and effort. The recording mechanism is not sensitive to external vibrations, and may be used for making records while riding on a train, in an automobile, or in an aeroplane. The simple mechanism can be operated by a child. There is accordingly little doubt that the new magnetic recording devices are bound to find new fields of use in the United States.

BIBLIOGRAPHY

POULSEN, V.: U. S. Patents: 661,619, Original wire recording machine. 873,083, Wire and tape recording with perpendicular magnetization by obliterating magnets and polarized recording magnets. 789,336, Wire spool machine. 873,078, Longitudinal magnetization recording.

POULSEN, V.: "Das Telegraphon," *Annal. der Physik*, **3** (1900), pp. 754–760.

RELLSTAB, L.: "Der Telegraphon," *Electrotechnische Zeitsch.*, **22** (1901), p. 57.

WEST, T. H.: "Der Telegraphon," *Electrotechnische Zeitsch.* (1901), No. 22, p. 182.

STILLE, K.: "Die Elektromagnetische Schallaufzeichnung," *Electrotechnische Zeitsch.* (1930), p. 449.

BEGUN, S. J.: "Telephon-Aufnahme Maschinen zum Emfang von Schnell-Telegraphie," *Telegraphen-Praxis* (1931), No. 5.

BEGUN, S. J.: "Die Diktiermaschine im Grossbetrieb," *Electrotechnische Zeitsch.* (1932), p. 204.

HORMANN, E.: "Zur Theorie der Magnetischen Tonaufzeichnung," *Electrotechnische Zeitsch.*, 9 (1932), p. 388.

MEYER, E., AND SCHULLER, E.: "Magnetische Schallaufzeichnung auf Stahlbander," *Zeits. für Techn. Physik*, **13** (1932), p. 593.

BEGUN, S. J.: "Beitrag zur Theorie der Elektromagnetischen Tonaufzeichnung auf Stahldraht," Dissertation Sonderdruck Studentenhaus Charlottenburg, 1933.

HICKMAN, C. N.: "Delayed Speech," *Bell Lab. Record*, **11** (June, 1933), No. 6, p. 308.

BRAUNMUHL, H. J. VON: "Magnetische Schallaufzeichnung im Rundfunkbetrieb," *Funk* (Dec., 1934), No. 40, p. 483.

FREDERICK, H. A.: "Recording and Reproducing Sound," *Rev. Sci. Instr.*, **5** (May, 1934), No. 5, p. 177.

"Magnetic Recording and Reproducing," *Wireless World*, **34** (Jan., 1934), No. 1, p. 8.

RUST, N. M.: "Marconi-Stille Recording and Reproducing Equipment," *Marconi Review* (Jan., 1934), No. 1, p. 1.

HANSEN, W. H.: "Das Magnetophon," *Electrotechnische Zeitsch.*, **56** (Nov., 1935), p. 1232.

MALLINA, R. F.: "A Mirror for the Voice," *Bell Lab. Record*, **13** (March, 1935), No. 7, p. 200.

SCHULLER, E.: "Magnetische Schallaufzeichnung," *Electrotechnische Zeitsch.*, **56** (Nov., 1935), p. 1219.

VOLK, T.: "Magnetophon, das neue Tonaufzeichnungsgerat der A. E. G.," *A. E. G. Mitteilungen* (Sept., 1935).

VOLK, T.: "Magnetophon, ein neues Tonaufzeichnungsgerat," *Filmtechnik*, **11** (Oct., 1935), p. 229.

HAMILTON, H. E.: "The Blattnerphone—Its Operation and Use," *Electrical Digest* (Dec., 1935), No. 12, p. 347.

BEGUN, S. J.: "Dies neue Lorenz Stahlton-Bandmaschine," *Lorenz Berichte* (Jan., 1936), No. 1, p. 3.

SCHRAGE, W. F.: "Sound Recording on Magnetic Materials," *Radio Craft*, **7** (March, 1936), No. 3, p. 537.

BEGUN, S. J.: "The New Steel Tone Tape Machine," *Electrical Communication*," **15** (July, 1936), No. 1, p. 62.

ICONOSCOPES† AND KINESCOPES‡ IN TELEVISION*

V. K. ZWORYKIN**

Summary.—*A description is given of the theory and performance of the television system based upon the Iconoscope and Kinescope. The cathode-ray transmitting and receiving tubes used in the system are discussed in detail, considering not only the physical principles involved but also the operating characteristics.*

In conclusion, an account is presented of the television project at the Empire State Building (New York), describing the terminal equipment and giving examples of the 441-line picture that can be transmitted and received.

Two extremely important elements in any television system are the pick-up device which converts the light-image into electrical signals, and the viewing arrangement transforming the electrical signals back into visible images. In fact, the success or failure of a television system depends perhaps more upon these two links than upon any other part of the chain. In its present project RCA Manufacturing Company is using the Iconoscope and Kinescope for dissecting and resynthesizing images, and it is the purpose of this discussion to explain the operation of these instruments and point out the reasons for selecting them in preference to other devices designed to serve as pick-up and viewing equipment.

Historically, the development of any form of television had to await a means of converting a light-signal into a corresponding electrical impulse. This step became possible through the discovery of the photoconductive properties of selenium in 1873. Within two years after this discovery, Carey proposed to make use of the properties of selenium in the solution of the problem of television. His suggestion was to construct a mosaic consisting of a great number of selenium cells, in a sense imitating the retina of the human eye. These cells were to be connected to shutters or lamps in corresponding positions on a viewing board. Although the suggestion was made in 1875, the device was not put into operation until 1906, when Rignoux and

*Reprinted from *RCA Review*, I (July, 1936), No. 1, p. 60.

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

† From the Greek *Icon*, meaning an image, and *scope*, signifying observation.

‡ From the Greek *Kineo*, meaning movement.

Fournier used this arrangement to transmit simple patterns and letters. Their mosaic consisted of a checker-board of sixty-four selenium cells. Each cell was connected to a shutter on a viewing screen which was also made up of sixty-four elements in positions corresponding to those in the pick-up screen. When a picture was projected upon the selenium cells the resistance of those illuminated decreased, allowing an electric current to flow which opened corresponding shutters on the viewing screen. A light behind thsese shutters made the reproduced picture visible.

The idea of dividing the picture into elements, converting the illumination on each element into electric current, and sending the signal from each over individual wires is practicable for a small number of divisions or picture elements and for transmission over short distances, but is useless as a means of producing pictures of the standard required of television today.

The next step was proposed by Nipkow in 1884. Instead of using individual wires connecting each picture element, he suggested sending the information from one element at a time over a single communication channel and then reassembling this information again at the viewing screen. This process was to be carried out at such a rate that the picture appeared continuous due to persistence of vision. The means proposed to accomplish this point-by-point transmission was the scanning disk. At the time of its invention the necessary technic of handling and amplifying small currents had not yet been developed so that it was a number of years before this scanning principle could be put to practical use. However, the principle was sound, and the scanning principle has been the basis of all television systems since then.

While this development represents a great step forward, it was attained only at considerable expense of available picture signal. The loss is due to the fact that each element contributes to the picture only for a small fraction of the total time, whereas with the first system suggested each element operated continuously. To make this clear, consider again the simple sixty-four element mosaic used by Rignoux and Fournier. Each photoelectric element was connected to the viewing screen by a separate conductor and the picture to be transmitted was projected continuously upon all the elements, so that a signal current passed through every light-sensitive element all the time. To reduce the scanning system to a comparable case, assume that we have the same mosaic of sixty-four photosensitive elements, but that they are all connected to a common communication channel. The elements are covered with shutters (*i. e.*, the scanning disk) which allow the light from only one element of the picture at a time to reach its corresponding photocell. These shutters are opened one at a time in rotation, covering the entire picture twenty or thirty times a second. Thus each light-sensitive element is operating only for a fraction of the total time, equal to one over the number of picture elements, in this case one sixty-fourth of the time.

In order to regain this lost signal and yet retain the principle of scanning, the development of the Iconoscope was undertaken. To illustrate the method of attack, consider again the sixty-four element array of photocells. Instead of scanning the elements with shutters, assume that each element is connected to the contact points of a switch which connects them in rotation to the main communication channel. Thus the scanning is accomplished by means of a commutator switch.

So far, we have gained nothing over the previous method of scanning, but now if a condenser is placed across each of the photocells in such a way as to accumulate the entire charge released by the action of the light during the time the element is not connected to the communication channel, this charge can be used when the commutator switch again makes contact with this element. Therefore, photoelectric current is being released by every element continuously and the charge is stored in the condenser belonging to that element until it is needed at the end of a scanning cycle.

The reduction of this principle to some practicable form is obviously a difficult problem. The number of individual photocells and condensers required for a 441-line picture with a 4 to 3 aspect ratio will be of the order of 260,000 units, and it is quite apparent that a screen composed of that many conventional photocells and condensers is out of the question.

A solution devised by the author some years ago was to build up a mosaic screen which contained the equivalent of a vast number of photosensitive elements and condensers. This mosaic was mounted in a cathode-ray tube in such a way that an electron beam could be used to commutate the elements. Fig. 1 shows one of these tubes together with its associated circuits, taken from one of the author's early patents.[1] Aside from the advantage gained through the application of the principle of storing the charge on each element for the entire picture time, this tube had the additional advantage that it involved no mechanical moving parts such as a scanning disk, mirror screw, or drum, the scanning being done electrically.

Although the first of this type of tube was built as far back as 1923, many years of research and development had to be undertaken before it was perfected sufficiently to meet the requirements of a satisfactory television system. The history of this development is in-

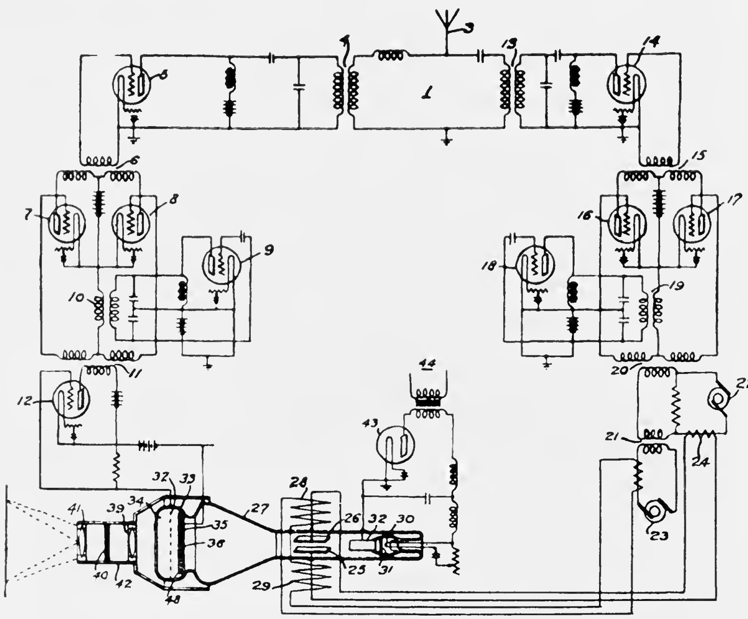


FIG. 1. Cathode-ray tube containing mosaic mounted so as to permit electron beam to commutate elements (taken from U. S. Patent No. 1,691,-324; V. K. Zworykin "Television System").

teresting, but is somewhat outside the scope of this paper, which will be limited to a discussion of the tube as it is today.

The Iconoscope, as this type of tube has been named, is shown photographed in Fig. 2. It consists of an electron gun and photosensitive mosaic enclosed in a highly evacuated glass envelope. The arrangement of these elements is shown diagrammatically in Fig. 3.

The electron gun produces a narrow pencil of cathode rays which serves, as will be shown later, as a commutator to the tiny photocells on the mosaic. The gun is in reality a form of electron projector which concentrates the electrons from the cathode onto the mosaic in a very small spot. The electron optical system consists of two electron lenses formed by the cylindrically symmetrical electrostatic fields between the elements of the gun. Fig. 4 shows diagrammatically the arrangement of this gun, together with the equipotentials of the electrostatic fields making up the electron lenses. Below this diagram is the approximate optical analogue. Details of the gun construction are as follows: The cathode is indirectly heated with its emitting area at the tip of the cathode cylinder. It is mounted so that the emitting area is a few thousandths of an inch in front of an aperture in the control grid. A long cylinder with three defining apertures whose axis coincides with that of the cathode cylinder and con-

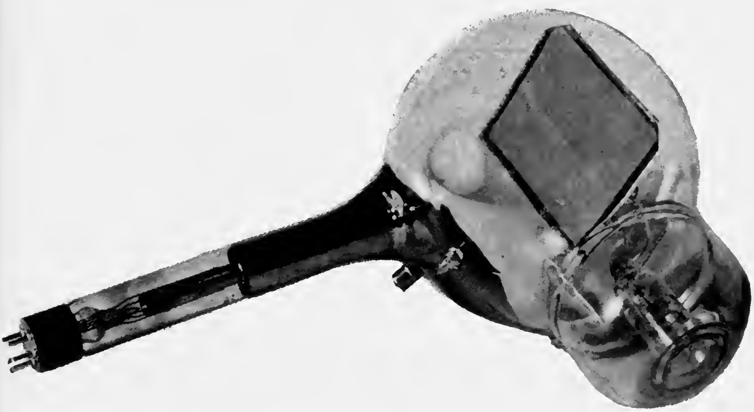


FIG. 2. The Iconoscope.

trol grid serves to give the electrons their initial acceleration, and is known as the first anode. A second cylinder, coaxial with the first anode and of somewhat greater diameter, serves as second anode and gives the electrons their final velocity. The second anode is in general formed by metalizing the neck of the Iconoscope bulb, as shown in Fig. 3. The gun used in the Iconoscope is designed so that it will concentrate a beam current of from one-half to one microampere into a spot about five mils in diameter. Under ordinary operating conditions, a potential of about a thousand volts is applied between the cathode and second anode, and the voltage of the first anode is adjusted until minimum spot size is obtained. The exact value of the beam current to be used will, of course, depend upon the type of picture to be transmitted and the exact conditions of operation.

The beam from the gun is made to scan the mosaic in a series of parallel horizontal lines repeated at thirty cycles per second. This is accomplished by two sets of magnetic deflecting coils arranged in a suitable yoke and slipped over the neck of the Iconoscope. These sets of coils are driven by two special vacuum-tube generators supplying a saw-toothed current wave, one operating at picture frequency and supplying the vertical deflecting coils, the other at horizontal line frequency driving the second set of coils.

The element that characterizes the Iconoscope is the mosaic. It consists of a vast number of photosensitive globules mounted upon a

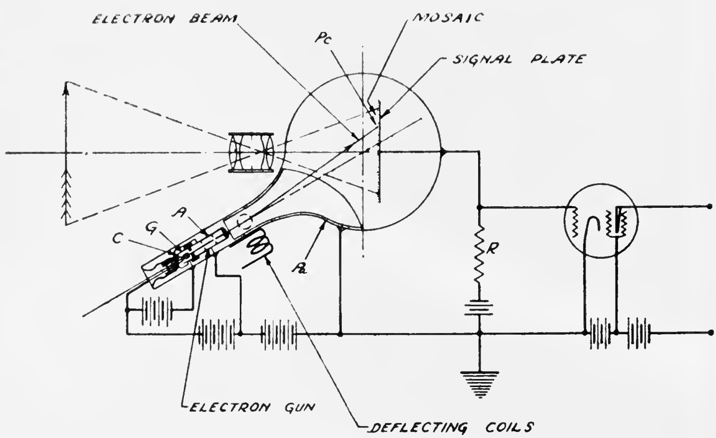


Fig. 3. Arrangement of elements of Iconoscope.

thin mica sheet in such a way that they are insulated from one another. The back of this sheet is coated with a conducting metallic film which serves as a signal plate and is connected to the input of the picture amplifier. The appearance of the mosaic is shown in Fig. 5. Such a mosaic may be formed in a variety of ways. For the standard type of mosaic the silver globules are formed by reducing particles of silver oxide dusted over the mica. Under the proper heat treatment the silver globules reduced from the oxide will not coalesce but will form individual droplets. These droplets are sensitized after the mosaic has been mounted in the tube and the tube evacuated. The sensitization is similar to that used in the ordinary cesium photocell, that is, the silver is oxidized. exposed to cesium vapor, and then heat-treated. The spectral response depends upon the details of the activation schedule and can be varied to meet the operating conditions required of the Iconoscope. The spectral characteristic of the present standard Iconoscope is shown in Fig. 6. It is evident that the Iconoscope with a quartz window is sensitive from well into the infrared, through the visible, and into the ultraviolet. Actual tests have produced images using radiation from 2000Å down to more than 9000 Å.

The mica upon which the silver droplets are mounted serves to in-

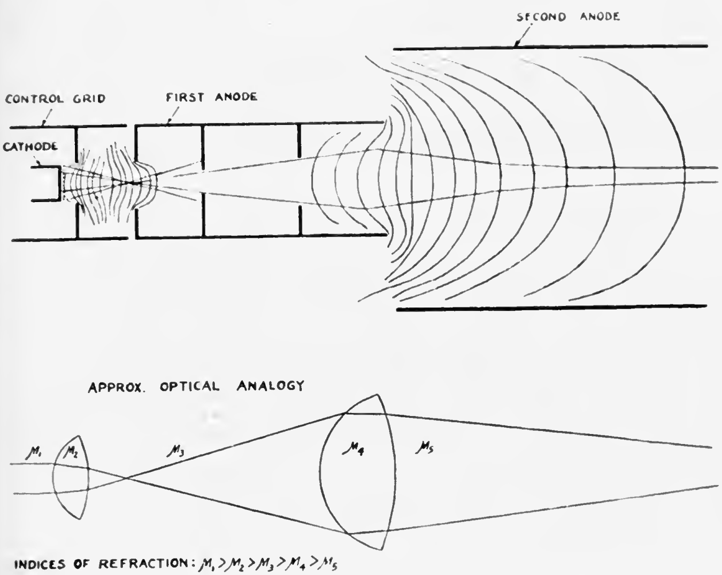


FIG. 4. Diagrammatic arrangement of electron gun.

sulate them from one another and, further, is made thin enough so that the capacity between each globule and the metallic signal plate will be reasonably large. The uniformity of cleavage sheets of mica, together with their excellent insulating properties, low dielectric hysteresis, and low loss make them very suitable for this purpose. Other insulating materials, however, can be used; for example, a thin film of vitreous enamel upon a metal signal plate has proved very satisfactory.

The mosaic is mounted in the tube with the silver beads facing the beam. In order that the optical image may be focused on its front surface, it is placed in the tube in such a way that a normal to its face makes an angle of 30 degrees to the axis of the electron gun.

In essence, the Iconoscope may be thought of as a plain mosaic

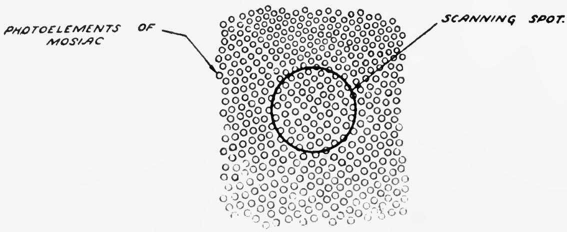


FIG. 5. Appearance of mosaic in Iconoscope.

made up of a great number of individual photocells, all connected by capacity to the common signal plate and commutated by the scanning beam. The fundamental cycle of operation is as follows:

Every silver globule making up the mosaic is photosensitized so

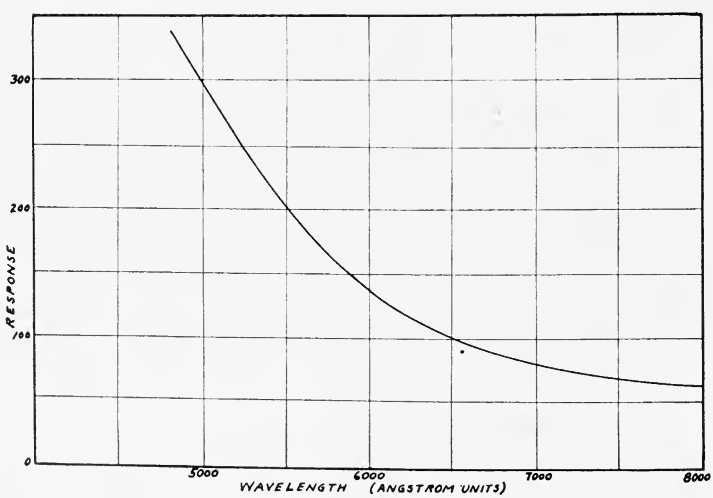


FIG. 6. Spectral characteristic of mosaic.

that when a light-image is projected upon the latter the light causes electrons of a number proportional to the light brilliance to be emitted from each illuminated minute photosensitive area. The resulting loss of electrons leaves each photosensitive area at a positive potential, without respect to its initial condition, which potential is then proportional to the number of electrons that have been released and conducted away, so that the mosaic tends to go positive at a rate proportional to the light falling upon it. As the electron beam scans the mosaic, it passes over each element in turn, releasing the charge it has acquired and driving it to equilibrium. Due to the fact that each element is coupled by capacity to the signal plate, the sudden change of charge of the elements will induce a change in charge on the signal plate and result in a current pulse in the signal lead connected to the amplifier. The magnitude of these pulses will be proportional to the intensity of the light falling upon the scanned element. Thus the

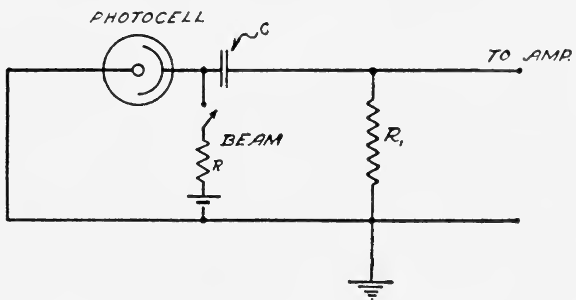


FIG. 7. Equivalent circuit of single element of the mosaic, for storage system.

signal output from the Iconoscope will consist of a chain of current pulses corresponding to the light distribution over the mosaic. This chain can be resynthesized at the receiver into a reproduction of the original image, as will be described later.

To clarify this cycle the equivalent circuit representation of a single element is shown in Fig. 7. The beam is represented by the switch and series resistance *R*. This switch may be considered as being open except at such times as the beam is actually on the element. When the scanning beam moves off the element, the photoemission from it starts to charge the condenser *C*, the rate of accumulating charge being proportional to the illumination of the element. In the next scanning cycle, the beam again sweeps over the element, closing the switch and discharging the element. During this discharging cycle the entire charge accumulated during the time the beam was not on the element must now flow through the input resistor

R_1 generating an emf. which is applied to the input of the picture amplifier.

In designing the mosaic, it is evident that the time-constant of the circuit discharging the condenser C must be small enough to allow it to discharge fully during the time the beam is on the element. This condition requires that $C \times (R_1 + R)$ be less than the time the beam is on the element. In practice, this condition is not difficult to fulfill.

At this point it is interesting to compare the emf. supplied to the amplifier by this storage system with the equivalent voltage from a

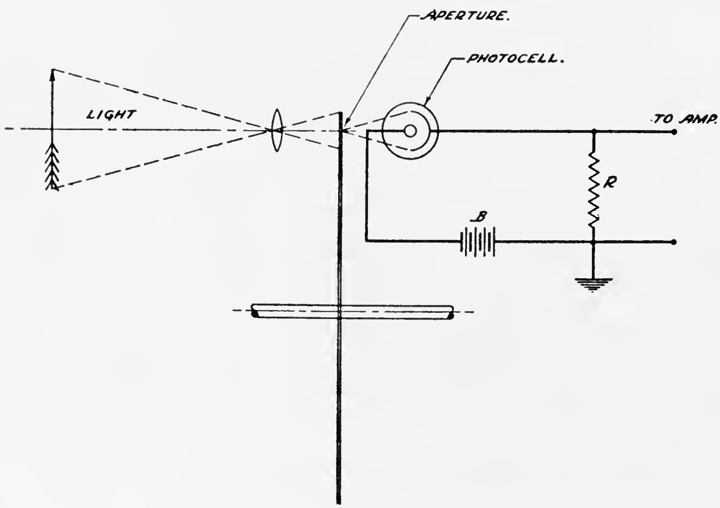


Fig. 8. Equivalent circuit for non-storage system.

non-storage system. The equivalent circuit for the non-storage case is shown in Fig. 8. The current through the input resistor R_2 will be:

$$I_s = \frac{F.s}{n}$$

where F is the light-flux in the picture, s the sensitivity of photo-sensitive elements, and n the number of picture elements. The voltage to the input of the amplifier is:

$$V_2 = \frac{FsR_2}{n}$$

In the storage case the charge accumulated by the element is:

$$Q = \frac{F.s}{n} t_p$$

where t_p is the picture time or $1/N$ for N pictures per second. When the beam strikes the element this charge leaves the condenser, resulting in an average current of

$$i = \frac{Q}{t_e}$$

where t_e is the time the beam is on the element or $1/Nn$. This current is therefore:

$$i = \frac{F.sNn}{nN}$$

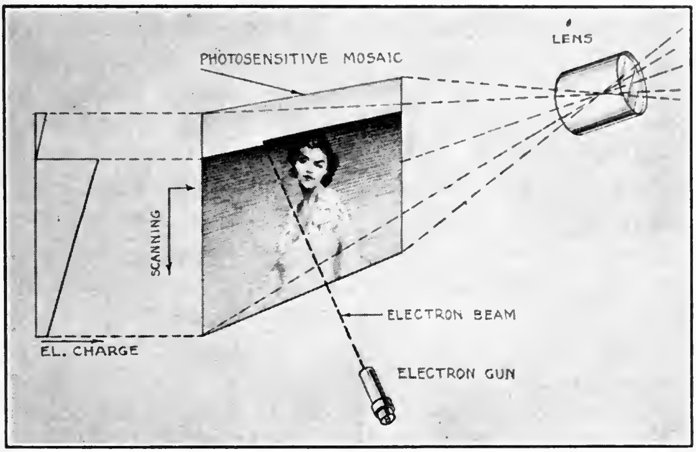


FIG. 9. Pictorial representation of conditions on surface of mosaic.

and the voltage to the amplifier will be:

$$V_1 = FsR_1$$

Comparing the signal voltages generated in the two cases, we see that the ratio is:

$$\frac{V_1}{V_2} = \frac{FsR_1}{\frac{FsR_2}{n}} = n \qquad \text{where } R_1 = R_2$$

Where the number of picture elements is large, as is the case in pictures with good definition, this gain in signal is extremely important. For example, the ratio in the case of a 441-line picture is 260,000 times the signal that could be obtained from the non-storage case.

In order to give a pictorial idea of the conditions on the surface of the mosaic, Fig. 9 is included. It represents the appearance of the charged image on the mosaic if it were visible to the eye. The region just behind the scanning beam is an equilibrium potential and therefore shows no visible image. As we examine the mosaic farther away from the line just scanned, we find that the charged image becomes more and more intense since the elements have been charging for a greater length of time. Just ahead of the scanning beam the image reaches its maximum intensity.

The picture just drawn of the operation of the Iconoscope is very

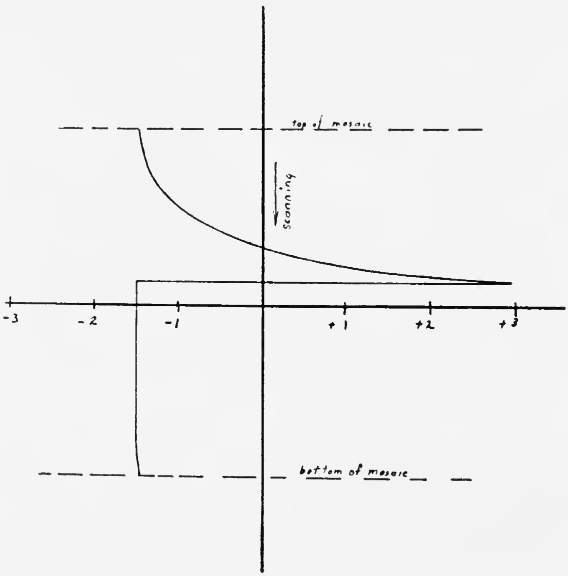


FIG. 10. Cathode-ray oscillograph measurements of potential distribution over mosaic.

much simplified. A number of factors complicate this seemingly straightforward cycle. Among the most important of these complicating factors are the potential distribution over the mosaic and the redistribution of secondary electrons emitted from the elements under bombardment. If the average potential of the mosaic is measured in darkness while it is being scanned, it will be found to be between 0 and 1 volt negative with respect to the electrode which collects the electrons leaving the mosaic; that is, with respect to the second anode. However, the potential is not uniform over the surface of the mosaic. Elements directly under the beam are found to be in the neighborhood of 3 volts positive with respect to the second anode. As we investigate elements which have previously been bombarded, we find them less positive, until at a point one-quarter to one-third of the vertical distance along the mosaic from the point being bombarded, the potential has reached $-1^1/_2$ volts negative with respect to the collector. The rest of the mosaic is found to be at $-1^1/_2$ volts. Cathode-ray oscillograph measurements of the potential distribution over the mosaic shows that it can be mapped somewhat as shown in Fig. 10.

In order to account for the potential distribution over the surface of the mosaic, it is necessary to consider what takes place among the secondary electrons emitted from the cesiated silver elements under bombardment. It is well known that when a cesiated silver surface is bombarded by an electron beam of the order of 1000 volts velocity, a secondary emission of 7 or more times the primary bombarding current can be collected. However, since the mosaic elements are insulated they must assume, when in equilibrium, a potential such that the secondary emission current equals the bombarding current. This potential is found to be about 3 volts positive with respect to the second anode. In the case of the mosaic in darkness it is obvious that the average secondary emission current leaving the mosaic must also be equal to the beam current, since the mosaic is an insulator. Thus it must come to an equilibrium potential such that the average current escaping to the second anode equals the bombarding current.

Perhaps we should digress at this point and discuss more fully the mechanism by which an element acquires this positive equilibrium potential. Measurements of the velocity distribution of the secondary electrons from a bombarded surface show that they can be represented by a distribution curve such as shown in Fig. 11. In the figure the abscissa gives the velocity in electron volts of the emitted electrons, while the ordinates give the current-per-volt range in velocity composed of electrons having a given velocity. If the target is surrounded with an electrode to collect secondary electrons, the current it can collect will depend upon its potential relative to the target. When this collector is at zero potential the current reaching it will equal the total secondary emission as represented by the total area under the curve in Fig. 11. As the collector is made more negative, the current decreases, since some of the electrons leaving will not have sufficient velocity to reach the electrode and will be driven back to the target. The current reaching the collector at some negative potential V_1 will be given by the area under the distribution curve from V_1 to the highest velocity; in other words:

$$i_c = \int_{V_1}^{\infty} f(V)\, dV$$

As the potential of the collector is decreased further eventually it will reach a point where the current collected just equals the current in the primary beam. At this point no current flows in the external lead to the target under bombardment. Experiment shows that for a cesiated surface such as is used to make up the globules on the Iconoscope mosaic, this potential is in the neighborhood of 3 volts. Hence, if an insulated target such as a mosaic element is bombarded, more

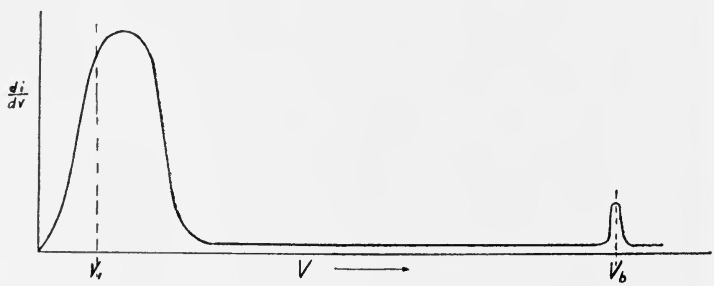


Fig. 11. Velocity distribution of secondary electrons from a bombarded surface.

electrons will leave than will arrive, until the element reaches 3 volts positive, at which potential the element will be in equilibrium and the currents arriving and leaving will be equal.

When the mosaic elements are scanned the secondary emission from them may be divided into three parts, one going to the second anode, another returning to the element itself, and a third being redistributed over the entire mosaic. This latter group which returns to the mosaic comes back as a more or less uniform rain of electrons having a maximum velocity of about $1^1/_2$ volts.

This can be verified by removing a portion of the mosaic and substituting a metal sheet electrode in its place. If the mosaic, except for the substituted portion, is scanned and the current to the metal electrode measured, it will be found to decrease as the potential of the probe is decreased. At $-1^1/_2$ volts negative the current will be dropped to zero.

Let us now consider the operation of the Iconoscope in the light of the phenomena just discussed. In the first place, due to the potential of the mosaic, there is very little electrostatic field aiding the escape of photoelectrons from the illuminated elements. This means that the charging of the globules is dependent in a large measure upon the initial velocities of the electrons. Therefore, the photoelectric emission is not very efficient, and becomes less so as the illumination is increased. It should be remembered, however, that the photoemission occurs during the entire picture time, the charge being accumulated upon the condensers formed by the silver beads and the signal plate. In other systems, since photoemission occurs only during the time a picture element is being scanned, there is a gain of the order of 10^5 to be had by using the storage system, so that even if the above-mentioned photoelectric inefficiency were insurmountable there is still a very great advantage in favor of the Iconoscope system.

As was pointed out in the discussion of the potential distribution, there is a line across the mosaic directly behind the scanning beam that is 3 volts positive with respect to the second anode, while just ahead of the beam the potential is in the neighborhood of $1^1/_2$ volts negative. There is, therefore, just ahead of the scanning beam, a row of elements which have a strong field aiding the leaving photoelectrons. This field very much increases the photosensitivity along this line and gives rise to a phenomenon known as line-sensitivity. This phenomenon can be demonstrated very strikingly in the following way:

The image from a continuously run motion picture film (*i. e.*, by removing the intermittent and shutter from a motion picture projector) is projected upon the mosaic of the Iconoscope. The film is run at such a rate that the frame speed is equal to the picture frequency of the Iconoscope, and in a direction such that the image moves oppositely to the vertical direction of scanning. Under these conditions we find that the Iconoscope transmits a clear image of two frames of the motion picture film although, to the eye, there appears to be only a blur of light upon the mosaic.

Thus we have two sources of signal: one, the stored charge over the entire mosaic surface; the second, from the sensitive line at the scanning beam. At low or normal light intensities, by far the greater part of the signal comes from surface sensitivity; but under high illumination as much as 50 per cent of the signal may come from line-sensitivity.

As was pointed out above, due to the fact that the secondary emission is not saturated, some electrons from the point where the beam strikes the mosaic have not sufficient velocity to leave the mosaic entirely, but return to its surface as a shower of low-velocity electrons. The redistributed electrons act to some extent as a high resistance, short-circuiting the elements, since an element that is more

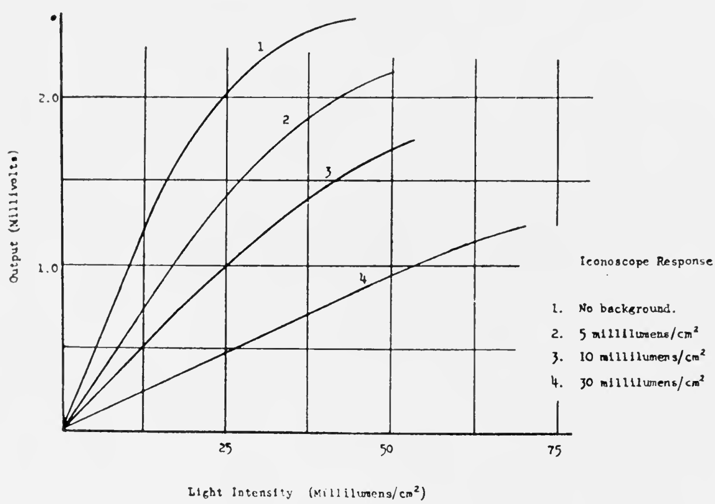


FIG. 12. Response of Iconoscope under various conditions of illumination.

positive than its neighbors tends to receive a greater share of these electrons. This resistance is, in effect, identical with that of the dynamic resistance of a triode tube, and under normal operating conditions is high enough so that it does not produce a very serious loss in efficiency; but under high illumination, where considerable difference in charge between nearby elements may be developed, this shunting resistance may become quite low with the result that there is a fairly large loss of signal.

This redistribution of electrons is, furthermore, responsible for the generation of a spurious signal. It appears as an irregular shading over the picture, even when the mosaic is not illuminated. The cause of this signal is the variation in instantaneous secondary emission current escaping from the mosaic to the second anode. As has been pointed out, the average secondary emission from the mosaic must be unity, but when we consider that a certain fraction of the secondary electrons from the point under bombardment returns to other parts of the mosaic, it is quite apparent that the instantaneous current leaving the mosaic may vary from point to point. This variation is produced by the lack of uniformity of potential and space charge over the mosaic.

It is interesting to note that if a clean sheet of metal is substituted for the mosaic, the spurious signal appears when it is scanned, provided the secondary emission is not saturated. The signal disap-

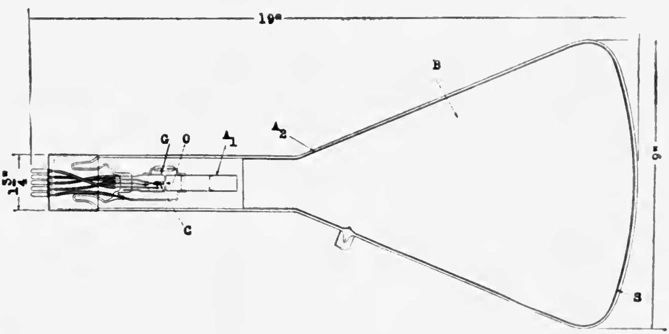


FIG. 13. Diagram of typical Kinescope.

pears, however, if the metal plate is made sufficiently positive or negative with respect to the second anode. Under these conditions, the secondary emission is either saturated or suppressed. In practice the effect of this signal can be eliminated by the introduction of a compensating signal. The spurious signal varies rapidly with beam current, and under conditions of low beam intensity and moderately high illumination it is negligible compared with the picture signal.

So far, the scanning beam has been considered as some sort of commutating switch which sweeps over the mosaic. Actually, the beam does behave in just this way. The beam, when falling upon an element, connects it through a resistance (dynamic, of course) to the second anode. This is obvious when we consider the action of the beam. As has been pointed out, the ratio of secondary electrons to primary electrons from a cesiated silver surface is about 7 when saturated. However, if the bombarded surface is made positive this ratio decreases, reaching unity at +3 volts and one-half at about 10 volts. From curves giving the secondary emission ratio of an element for various collector potentials, together with a knowledge of the beam current, the effective resistance connecting the bombarded element with the second anode can easily be estimated. This resistance

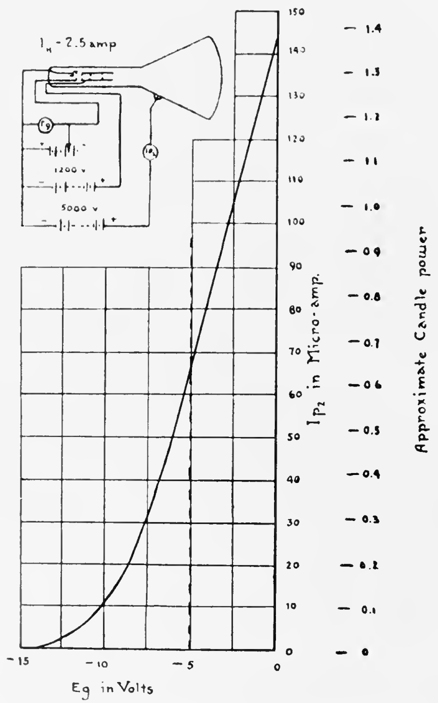


FIG. 14. Typical control characteristic of Kinescope gun.

turns out to be of the order of 10^6 ohms. If the beam current is too weak, it will not fully restore the illuminated element to equilibrium. Considering a stationary picture, and neglecting the effect of the redistribution of scattered electrons, this would not reduce the signal obtained from a given amount of light. However, it would cause a lag and consequent blurring of the image of a moving object. In the actual Iconoscope, because of the role the beam plays in establishing the potential of the mosaic, and because of the shunting effect of redistributed electrons, there is an optimal beam current at which the signal is a maximum for a given condition of light.

Taking into account the various factors tending to reduce the output of the Iconoscope, it is found that the net efficiency of conversion is in the neighborhood of 5 to 10 per cent. In other words, the signal output is about $^1/_{20}$ that which would be expected upon the basis of the light-flux reaching the mosaic, the saturated photoemission of photoelectric elements, and the assumption that the entire photo current is stored by the mosaic. The efficiency of conversion is not constant, but as explained above depends upon the amount of light used. The efficiency is a maximum at low light and decreases as the

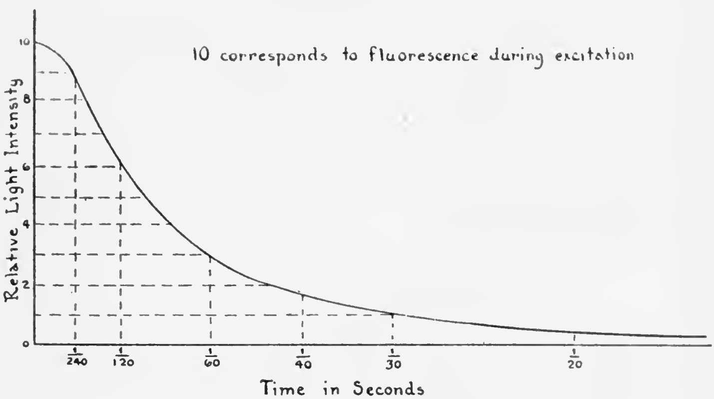


FIG. 15. Phosphorescent decay curve for zinc orthosilicate.

light is increased. This point will be considered again under a discussion of the actual performance of the Iconoscope.

Up to this point we have based our consideration of the relative merits of the storage and non-storage types of systems upon a comparison of signal output alone. The recent development of the secondary emission multiplier makes it necessary to introduce other considerations into this comparison. The electron multiplier provides a means of amplifying a photoelectric current to almost any desired extent without introducing any additional "noise" into the signal. It might seem, therefore, that we could amplify the minute photo current obtained by the conventional scanning system to such an extent that the sensitivity of the two systems would be equal. This, however, can not be done, because even with a perfect amplifying system the statistical fluctuations in the original photo current are amplified just as much as the signal is amplified. Because of this there is a definite limit to the sensitivity of this type of system imposed by the original shot noise in the photo current. In the case of the Iconoscope there is a similar limit, but because the charge representing each picture element is so much greater than in the non-storage case the ideal sensitivity is very much greater. Actually, in the type of Iconoscope described in this paper, the limit of the sensitivity is not set by the statistical fluctuations of the stored charge, but by the thermal noise in the coupling resistor to the amplifier. A quantitative comparison of the limiting sensitivity of the Iconoscope

FIG. 16. Kinescope with 9-inch viewing screen.

used at present, taking into account its inefficiency and imperfections, shows that it is able to operate at one-tenth the light required by a *perfect* non-storage system. This, of course, includes the use of an electron multiplier, and applies to electrically scanned as well as mechanically scanned non-storage systems.

The resolution of an Iconoscope may be limited either by the size of the photoelectric elements or by the size of the scanning beam. The size of the silver globules in the Iconoscope described is many times smaller than a picture element, so that many hundreds of them act together under the scanning spot. The resolution is limited, therefore, by the spot size. At present, the resolution adopted is about 441 lines, but when necessary the beam size can be reduced and the resolution made much higher.

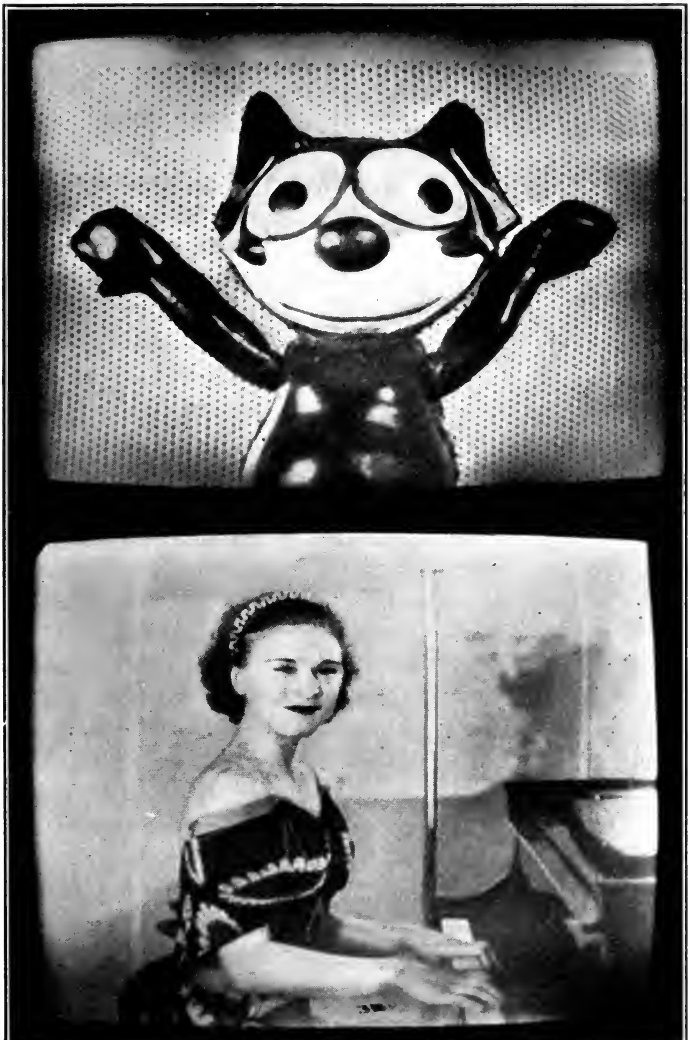


FIG. 17. Televised picture upon the screen of the Kinescope.

FIG. 18. Another televised picture.

The actual response of an Iconoscope under various conditions of illumination is shown in Fig. 12. The output is measured in millivolts across a 10,000-ohm coupling resistance and the light input measured in lumens per square centimeter on the mosaic. The curve showing the greatest response represents the signal output from a small illuminated area when the remainder of the mosaic is in darkness. The other curves of the family show the response from the same area when the mosaic is illuminated with a uniform background of light. The response is not linear, but falls off as the illumination is increased until it reaches a saturation value. The saturation voltage output is nearly constant for tubes of a given design, but the slope of the response curve may vary from tube to tube, depending upon treatment, and is a measure of the sensitivity.

The decrease in sensitivity with illumination is not wholly disadvantageous in that it permits the transmission of a wider range of contrast over a given electrical system than would otherwise be possible. In a sense, this is similar to the compressor-expander systems used in sound recording.

In spite of the complicated manner of its operation and the factors mentioned reducing its efficiency, the Iconoscope is an extremely sensitive and stable device for television transmission. Excellent and consistent results are obtained under widely varying conditions of operation. The practical lower limit to light that can be used to transmit a picture is set by the "noise" in the picture amplifier. Measurements have been made to determine the illumination necessary for satisfactory operation. With an *f*/2.7 lens to focus the image upon the mosaic, an average surface brilliancy of from 30 to 50 candles/sq. ft. on the object viewed gives completely satisfactory transmission. A recognizable image can be obtained from a good Iconoscope with 8 candles/sq. ft. using an *f*/16 lens; that is, with $^1/_{150}$ the illumination mentioned above.

For comparison, the illumination of some scenes commonly met with is given in the following table:

Scene	Location	Date	Time	Weather	Brightness
Beach	Atlantic City	August	2:00 P.M.	Hazy	500
Boardwalk	Atlantic City	August	2:00 P.M.	Hazy	275
Street	Philadelphia	August	2:30 P.M.	Clear	200
Times Square	New York City	November	1:30 P.M.	Rain	40
Street Parade	East Orange	November	10:30 A.M.	Rain	40 to 60

It is evident that perfectly satisfactory outdoor pick-up may be obtained under almost all average conditions of light.

The device used to reproduce the television picture is also electron operated. This tube, which has been named the "Kinescope," is similar to a cathode-ray oscilloscope in many respects. It consists of an electron gun for defining and controlling a cathode-ray beam, and a fluorescent screen which becomes luminous under bombardment from the electron gun. A diagram of a typical Kinescope is shown in Fig. 13.

FIG. 19. A typical studio pick-up camera employing the Iconoscope.

The cathode-ray beam is made to sweep across the fluorescent screen in synchronism with the scanning beam in the Iconoscope which is transmitting the picture. Furthermore, the current in the Kinescope cathode-ray beam is controlled by the signal impulses generated at the Iconoscope. This control acts in such a way that the impulse corresponding to a bright area on the Iconoscope causes an increase in current, while a dark region causes a decrease. There will, therefore, be an exact correspondence both in position and intensity between the fluorescent illumination on the Kinescope screen and the light on the mosaic in the Iconoscope. A picture projected on the Iconoscope will therefore be reproduced by the Kinescope.

The electron gun in the receiving tube is similar in principle to that in the Iconoscope, but is made to handle larger currents and to operate at higher voltages. Furthermore, since the picture is reproduced by modulating the beam current, the control grid is a much more critical item. The control-grid characteristic is determined by a number of factors, such as the grid aperture, the spacing and geometry of the cathode, the first anode, *etc.* Fig. 14 shows a typical control characteristic for a Kinescope gun.

The fluorescent screen is made by coating the flat portion of the glass bulb with a synthetic zinc orthosilicate, very similar to natural willemite. The synthetic material has high luminous efficiency, the light output at a given voltage being proportional to the current striking it. At 6000 volts the material gives nearly 3 candles per watt. The efficiency of light production varies somewhat with voltage used, but at higher beam velocities is nearly constant. This can be seen from the general relation between candlepower P, current intensity I, and applied voltage V, which is given by the equation:

FIG. 20. Console type of television receiver.

$$P = AI(V - V_0)$$

A is a constant depending upon the phosphorescence and V_0 the extrapolated minimum exciting voltage, which proves to be in the neighborhood of 1000 volts.

In addition to its high luminous efficiency, this material does not burn or disintegrate under bombardment with electrons. The phosphorescent properties of a fluorescent material are an important consideration. An ideal substance for television work should emit a constant amount of light for one entire picture frame and drop to zero at the end of this period. If the phosphorescence time is too long, the moving portions of a picture will leave a "trail." For example, the path of a moving ball will be marked with a comet-like tail. On the other hand, if the decay time is too short, flicker becomes noticeable. The phosphorescence decay curve for zinc orthosilicate is shown in Fig. 15.

Fig. 16 shows a photograph of a Kinescope with a 9-inch viewing screen. This is only one of a number of sizes, both larger and smaller, and designs possible for the Kinescope.

Between the transmitting Iconoscope and the reproducing Kinescope there is a chain of electrical equipment involving the picture amplifier, transmitter, radio receiver, and synchronizing system. This field is much too large to cover in this paper and has been treated in detail elsewhere.[2]

In closing, it might be well to illustrate the performance of the systems with some photographs of televised pictures as they appear upon the screen of the Kinescope. These are shown in Figs. 17 and 18. The appearance of a typical studio pick-up camera using the Iconoscope is shown in Fig. 19, while that of a console type television receiver can be seen in Fig. 20.

REFERENCES

[1] ZWORYKIN, V. K.: U. S. Patent No. 1,691,324: "Television System."

[2] ZWORYKIN, V. K.: "An Experimental Television System and Kinescope," *Proc. I. R. E.*, **21** (Dec., 1933), No. 12, p. 1655.

Symposium on an Experimental Television System:

KELL, R. D., BEDFORD, A. V., AND TRAINER, M. A.: "Transmitter," p. 1246.

HOLMES, R. S., CARLSON, W. L., AND TOLSON, W. A.: "Receivers," p. 1266.

YOUNG, C. J.: "Radio Link for Television Signals," *Proc. I. E. R.*, **22** (Nov., 1934), No. 11, p. 1268.

NEW MOTION PICTURE APPARATUS

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

A SINGLE-CHANNEL RECORDING AND RE-RECORDING SYSTEM*

H. I. REISKIND**

When sound motion pictures were first introduced, quite a large number of recording installations were made in the East. Since that time, however, very few completely new recording channels have been installed. Although the old installations have been modernized, it has not always been practicable to include all the operating conveniences that the advances in the recording art indicated as being desirable. For that reason a description of the new installation of RCA recording equipment in the Twentieth Century-Fox Film studio at New York may be in order.

In this, as in all eastern studios, the requirement that the space occupied be kept at a minimum for the facilities furnished, was of extreme importance; and at the same time it was, of course, necessary that the recording and re-recording facilities be on a par with those in the studios on the West Coast.

In discussing this installation an attempt will be made to show the facilities furnished, the schematic equipment layouts, and the general installation methods. Since most of the units used in this installation have already been described in the JOURNAL,[1] this paper will be concerned mainly with the general overall arrangement of the system. The installation consists of a single channel which provides facilities for recording on any one of four stages, with set mixing and headphone monitoring. It is also possible to re-record from four sound-tracks and one or more microphones, using a permanent eight-position mixer installed in the control room in which complete compensation facilities are provided. A complete theater reproducing system is provided for monitoring the re-recording, which may be used also for stage recording when desirable. Smaller compound baffles are provided in the recording room and above there-recording console.

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** RCA Manufacturing Co., New York, N. Y.

Fig. 1 shows the general layout of the studios. The recording and control rooms shown were originally part of stage *D*. The wall between this stage and the control room carries a large double-glass window, 3½ by 7 feet, that can be opened, converting the control room and stage *D* into a monitoring room (Fig. 2). When it is necessary to record on stage *D*, the double windows may be closed and the compound baffle used for monitoring.

The projection machine located upon the level above the control room projects a picture upon a screen above the projection speakers. The projector may also be turned about so as to project a picture upon a screen on stage *A* for orchestra scoring oı similar work. This projector is fitted with a preview attachment that

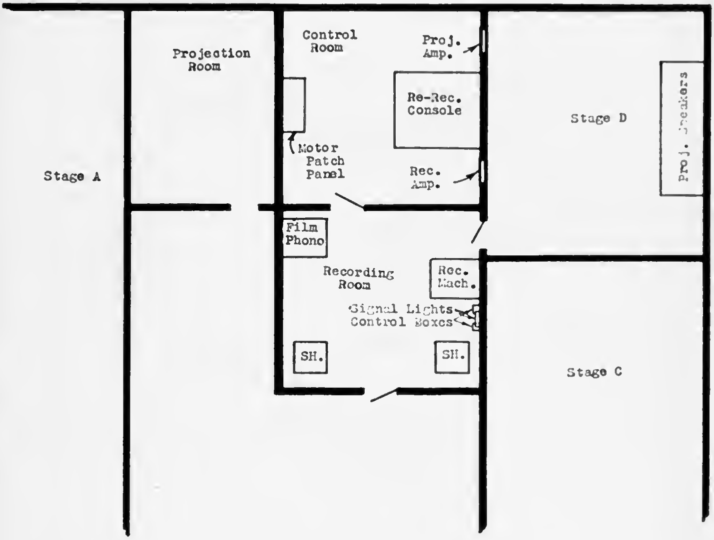

FIG. 1. General layout of the studio, showing control room, recording room, projection room, and three stages.

makes it possible to run separate picture and sound-track on the same machine. Together with the two theater-type sound-heads and the recorder-type film phonograph, a picture can be shown and sound reproduced from four sound-tracks.

The recording and projection amplifier racks are set into the wall, thus saving considerable floor space. This was made possible by the front-servicing construction of these amplifiers. All component parts are mounted upon the front panel, which may be opened on hinges without disturbing any of the wiring. Locating the two amplifiers at the sides of the console brings all the adjustments within reach of the monitor man. The telephone, signal lights, and motor-starting positions are on the right of the recording machine, within easy reach of the operator.

Referring to Fig. 3, the outputs of the four microphone and four phototube pre-amplifiers are fed into an eight-position mixer and compensator. The output of the re-recording console, which will be examined in detail later, is fed to a low-pass filter adjustable to nominal cut-off values of 6000, 8000, or 10,000 cps. The output of the filter is fed to the recording amplifier, the output of which, in turn,

FIG. 2. View of re-recording console, showing double glass window, which may be opened into stage *D*. At the top may be seen the compound baffle used for monitoring, and the window through which pictures may be projected upon the screen in stage *D* from the projection room (on the upper floor at the right, not shown in the picture).

operates the recording galvanometer. Since the internal impedance of the galvanometer varies with frequency, the noise-reduction amplifier and monitoring systems derive their input signal currents from a tertiary winding on the input transformer feeding the output stage of the recording amplifier. The neon volume indicator is fed from a separate output on the recording amplifier through a resistive network incorporated in the recording amplifier. The monitoring amplifier is a-c. operated, and supplies signals to the high-quality head-phones and to the compound baffles through a distribution network. The adjustment of the noise-reduction amplifier, described previously in the JOURNAL, is facilitated by push-buttons upon the front panel.

The monitoring decompensator consists of a resistive network and a single-section filter. The filter introduces a high-frequency loss that closely approximates film-transfer and reproducer-slit loss. By using a standard theater projection amplifier and high-quality theater speakers, the monitoring quality closely approximates the quality of the final print as reproduced in the theater.

The recording machine employs the well known magnetic drive and an optical system having interchangeable intermediate lens barrels. By using these dif-

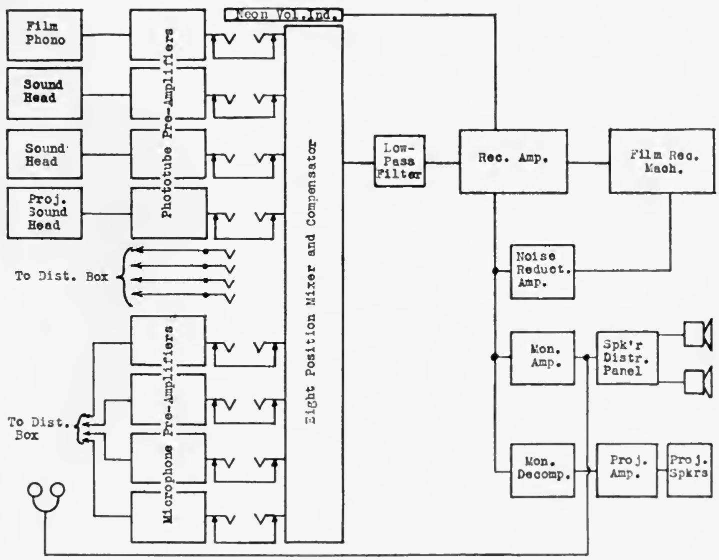

FIG. 3. Set-up of channel for re-recording.

ferent barrels, it is possible to record any of a number of types of track, such as symmetrical variable-width track with bias noise reduction, split-wave (class *B* push-pull), track with shutter noise reduction, and class *A* push-pull. All these types of track are recorded with ultraviolet light, resulting in tracks of much better high-frequency definition. Should it be desirable for any reason, variable-density tracks may also be recorded, using still another intermediate lens assembly.

The film phonograph indicated in Fig. 3 employs the same magnetic drive as the film recording machine. All the sound-heads are of the standard theater type, using rotary stabilizers; and all the machines will reproduce either standard or push-pull track.

Fig. 4 is a diagram of the re-recording console, which consists of the necessary microphone and phototube pre-amplifiers, two four-position mixers with associated compensators, two booster amplifiers, and a combining network. The outputs of the mixers are amplified by the booster amplifiers and combined in the resistance-transformer network. The mixing potentiometers used in both this mixer and in the "tea-wagon" console are bridged-T networks, which have the advantage of maintaining constant impedance regardless of the attenuation setting. The four inputs are coupled to the mixing potentiometers through transformers, and the output is coupled to the transmission line in the same way. This provides for balancing the transmission lines to ground, and reduces the possibility of pick-up and cross-talk. Since the overall master control is seldom used in re-recording, the panels have been laid out with the four mixer knobs in a line at

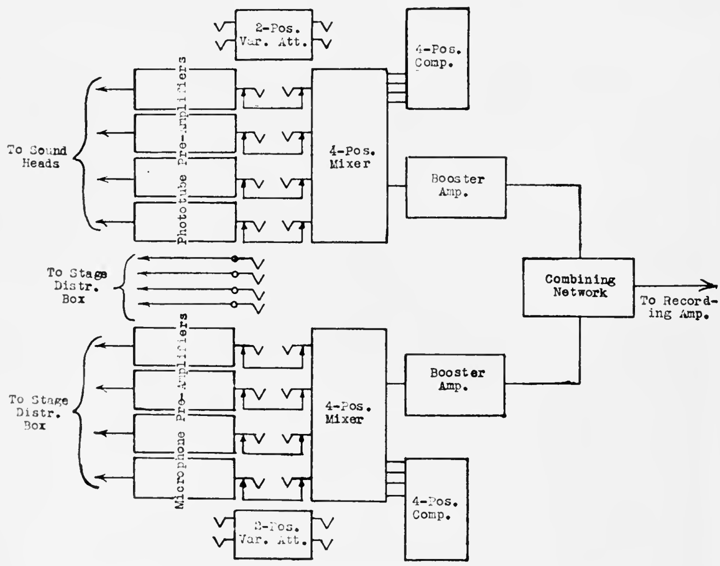

FIG. 4. Transmission diagram of re-recording console.

the bottom, and the master at the top center of the panel where it will be out of the way. *Off-on* key switches are provided for each mixer position, at the top of the panel on either side of the master control. These switches are of the toggle type and have three positions: a central *off* position, and two *on* positions. These two *on* positions differ in that the key locks in place in the forward position, but in the back position it must be held. The back position may be used instead of a push-button control for certain effects such as water splashes, explosions, *etc.*

The units shown as additional attenuators consist of two balanced-H variable attenuators, terminating in jacks which may be patched into any input circuit. They are controlled by key switches identical to those in the re-recording mixer. These attenuators are often useful for obtaining very large level ranges for certain effects, and for providing given amounts of attenuation which may be pre-set and inserted upon cues.

The four-position compensator shown in Fig. 4 provides the mixer man with complete control of the frequency characteristic of each track. In the majority of cases the frequency characteristic should be set by means of formal tests and then left alone; but many cases occur in re-recording in which it is desirable to change the frequency characteristic to correct for poor recording on particular

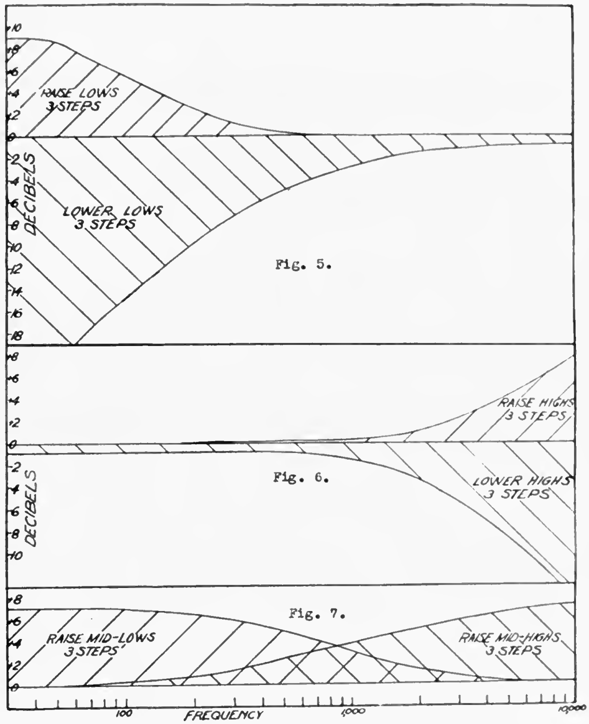

FIG. 5. Characteristic of low-frequency section of four-position compensator.
FIG. 6. Characteristic of high-frequency section of compensator.
FIG. 7. Characteristic of middle-range section of compensator.

takes. The compensator is unique in that the frequency range has been divided into three bands, a separate section of the compensator operating on each of the bands.

Fig. 5 shows the characteristic of the low-frequency section in the positions of maximum compensation. There are two additional steps of "raise low frequencies" and "reduce low frequencies" that are less drastic than the curves shown. The six low-frequency characteristics and a position of zero compensation are controlled by a dial switch.

Fig. 6 shows the characteristic of the high-frequency section of the compensator. Here again three conditions of "raise" and three conditions of "reduce high frequencies" are provided.

Fig. 7 shows the characteristic of the middle-range section, which operates over the frequency band between 200 and 3000 cps. and has proved extremely useful for salvaging very bad recordings. The characteristics of the three sections are all additive, and almost any desired overall characteristic may be attained. A key switch is provided so that the compensator may be inserted into or removed from the circuit. When removed, it is replaced by a fixed pad equal

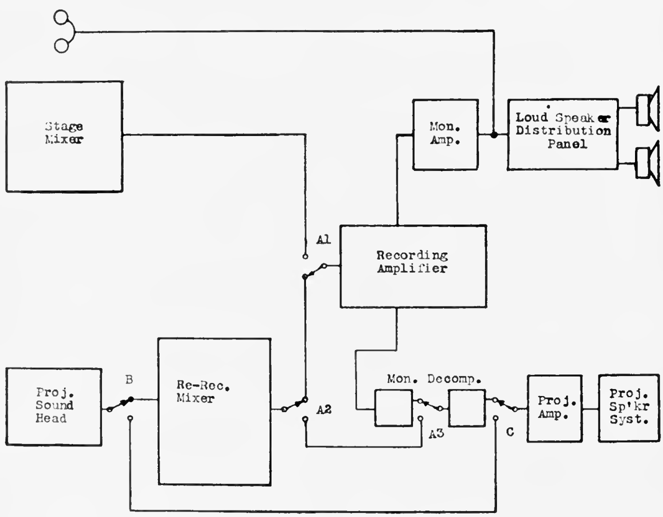

FIG. 8. Switching diagram.

in loss to the insertion loss of the compensator, and thus constant level into the mixer is maintained at all times.

The various units shown in Fig. 4, *i. e.*, mixers, compensators, microphone and phototube pre-amplifier, *etc.*, are all located in the re-recording console. The three sets of amplifiers are mounted in the console on shock-proof shelves, and may be readily removed for servicing since connections to them are made through Cannon plugs and receptacles.

The input to the microphone pre-amplifier comes directly from the stage distribution box, one of which is located on each stage. This furnishes a mounting for three rows of Cannon receptacles. The lines from the microphone pre-amplifiers terminate in one of these rows of receptacles. When it is desired to record a microphone pick-up through the re-recording console, the microphone may be plugged into the proper receptacle in the stage distribution box and the signal thus fed directly to the pre-amplifier. The various pre-amplifier outputs and the mixer inputs appear upon a jack bay which is part of the re-recording console and which allows the selection of any desired mixer. If, because of severe fields upon the stage, it is desired to locate the microphone pre-amplifier nearer the microphone, the pre-amplifier may be removed from the console and plugged into one of the other sets of receptacles on the stage distribution panel. The output of the pre-amplifier then appears upon one of the central sections of jacks and is patched to the mixer. The *B* batteries supplying plate voltage to the microphone, phototube, and booster amplifiers are all located in shielded compartments in the re-recording console.

When mixing on the set is desired, the portable "tea-wagon" console is used. The microphone pre-amplifiers are removed from the re-recording console and inserted into the "tea-wagon" console. This portable console is connected on any stage by using the bottom set of receptacles on the stage distribution panel. The overall circuit arrangement is identical to that used in re-recording, except that, due to the low insertion loss of the portable mixer and compensator, the booster amplifiers are unnecessary. The console provides a mounting for the four microphone pre-amplifiers, volume indicator, and a four-position mixer. Each mixer position has individual high- and low-frequency compensation. Normally the low-frequency compensation is either 9 or 13 db. at 100 cps., and is selected by a three-position key switch. By a change in wiring these values may be changed to 5 and 9 db. The high-frequency compensation begins at approximately 5000 cps. and increases to 10 db. at 10,000 cps.

In order to simplify operation and to change recording equipment set-ups as quickly as possible, it was decided to eliminate jacks and patch cords wherever possible.

Fig. 8 shows, in extremely simplified form, a schematic diagram of the equipment and the switching arrangements. The three switches *A1*, *A2*, and *A3* are, in reality, a single three-position switch mounted at the top of the recording amplifier rack. Switch *C* is mounted in the projection amplifier rack, and switch *B* upon the projection machine. In the positions shown in Fig. 8 the channel is set up for re-recording. The output of the re-recording console is connected to the recording amplifier rack, and the projection system is used for monitoring.

For stage recording, switch *A1* is moved to the *up* position, leaving all the others as shown. This provides the same set-up as in the previous case, merely substituting the portable "tea-wagon" console for the re-recording console. High-quality head-phones are used for monitoring on the stage, a compound baffle is used in the recording room, and the projection system is still connected and may be used for checking orchestral balance or for similar purposes.

In the event that it is desired to rehearse a re-recording while stage recording is going on, switch *A* may be moved to its third position. In this position *A1* remains up, providing a complete recording channel using the "tea-wagon" console, but *A2* and *A3* are in the *down* position. The output of the re-recording console is thus connected to the projection monitor system. The re-recording tracks may then be rehearsed, cues and levels set, and all preparations made for the "take." When the stage recording is finished, all that is necessary is to move switch *A* into its first position, run a few feet to check the overall level, and made the "take."

As a final set-up, switches *B* and *C* may be operated, connecting the projector to the projection amplifier system, thus providing a review room system for running "rushes." Switches were used instead of jacks because they simplify the operation to a great extent, in most cases make fewer contacts necessary in a given circuit than would be the case with jacks, and eliminate any possibility of making incorrect connections with resultant possible impedance mismatch and incorrect frequency characteristic. With this arrangement the circuit is set up correctly or no signal at all comes through.

The motor system operating the recording equipment consists of two standard Selsyn units driven by 3-phase synchronous motors. A motor-patching panel is provided so that any combination of motors may be connected to either of the Selsyn motor-generator sets.

Power supply for the equipment consists of an 8-volt storage-battery for the various amplifier filaments, and *B* batteries for the plates of the three low-level amplifier groups (the microphone and phototube pre-amplifiers and the re-recording booster amplifiers). The remaining plate voltages and the d-c. supply to the recorder lamp, film reproducer lamps, and loud speaker fields are obtained from rectifiers. The plate voltage sources are regulated both for variations in input voltage and output load, and an input regulator is associated with the rectifier supplying the recording lamp current so that variations in a-c. line voltage will not cause density changes in the track.

A signal-light system has been provided for re-recording only. It was felt that the telephone set, with its buzzer mounted in the handset, was sufficient for all signaling purposes connected with stage recording. A telephone patching panel has been provided so that two separate telephone set-ups may be obtained when stage recording is in progress and it is desired to rehearse re-recording work.

A cathode-ray oscilloscope, an oscillator, and a gain-set are used for testing. The oscillator and gain-set are mounted in a dolly so that they may be moved easily to any part of the studio.

The installation was laid out under the direction of Mr. E. I. Sponable, of Twentieth Century-Fox Film Co., and Mr. B. Kreuzer, of RCA Manufacturing Company. The installation work was under the direct supervision of Mr. H. D. Bradbury. Mr. E. B. Keating was responsible for the mechanical design of the re-recording console.

REFERENCE

[1]KREUZER, B.: "Recent Improvements in the Variable-Width Recording System," *J. Soc. Mot. Pict. Eng.*, **XXVII** (Nov., 1936), No. 5, p. 562.

LOOMIS, F. S., AND REYNOLDS, E. W.: "A New High-Fidelity Sound Head," *J. Soc. Mot. Pict. Eng.*, **XXV** (Nov., 1935), No. 5, p. 449.

THE RCA SOUND RECORDING SYSTEM*

M. C. BATSEL AND E. W. KELLOGG**

Motion picture producing studios are the largest users of sound recording equipment. In the few years' time that sound pictures have been produced, there has been a continuous improvement in the product due to developments in operating technic and to improvements in the recording equipment.

In the beginning, the cameraman with his camera was enclosed in a soundproof booth, making it impossible to resort to shots requiring the camera to be moved; and microphones were placed at various places in the sets, requiring the actors to remain within range of the stationary microphones. The stationary camera and microphone were severe handicaps to the motion picture, which depends to a great extent for its effectiveness upon the mobility of the camera.

At the present time, cameras are silenced by means of enclosing cases around the camera itself, known as "blimps." These are larger and more difficult to handle than were the silent cameras. Cameras are being developed that are sufficiently well silenced through improvements in the design to operate without enclosures. Ingenious mountings for the cameras have been designed that make it possible to follow the action effectively.

The microphone is mounted on a "boom" consisting of a long horizontal beam that is supported on a stand equipped with silent casters so it can be easily moved. The beam is made of telescoping tubing so that the length can be adjusted as required, and the beam is pivoted so that the height of the microphone above the floor can be adjusted. The beam is also capable of being rapidly swung about the pivot, and, in addition, provision is made for rotating the microphone mounting on the end of the beam so the microphone may be properly oriented. With the microphone "boom," it is possible for a man stationed on a platform at the controls, where he has a good view of the set, to swing the microphone over the actors as required for proper pick-up of voices or sounds to correspond with the picture being photographed. The recording operation is under the direction of the "mixer," or operator of the volume controls for the microphones used. It is preferable that the mixer be near the set, where he will be in view of the action and within hearing distance of the director.

Since the camera and microphone are moved during the recording operation, it is obviously necessary that the equipment be noiseless in operation. The microphone itself must be capable of being moved through the air quite rapidly without resulting noise.

Sound equipment for use in motion picture studios is required to operate with certainty of results and without delays to production. Due to the expensive personnel and facilities required, delays or failures can not be tolerated. Practically all recording is by the photographic method on film, and the recording is not heard until the following day.

Improvements in the RCA recording system have resulted both from develop-

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

ments in the studios where the equipment is used and in the research laboratories. The laboratories, through studies of fundamentals, have discovered methods of improving the system, while the operating engineers in the studios in coöperation with RCA engineers have developed features which have made for convenience in operation and increased flexibility and designs to meet the many special and new requirements which the rapidly developing sound picture art requires.

A recording system is made up of a number of items of equipment, some of which are used in other fields, such as broadcasting and sound amplification. The major items discussed in the following paragraphs point out some of the requirements of motion picture application.

MICROPHONE

Alexander Graham Bell's first telephone, built in 1876, employed an electromagnetic microphone. A few years later, the carbon microphone was invented, and up to about 1916 had no competitors for either a commercial or high-quality service. In 1916, E. C. Wente developed the condenser microphone, which was a great step forward from the standpoint of quality and constancy. The great fault of the carbon microphone is its hiss. It is also subject to large variations in output and is very easily overloaded. Condenser microphones are very insensitive compared with carbon microphones, but with amplifiers available, this has not been a paramount consideration, and until the advent of the RCA ribbon microphone, the condenser microphone has been employed for practically all high-quality work, such as sound recording and broadcast transmitters.

Among the drawbacks of the condenser microphone is the fact that its directive properties vary considerably with frequency. Thus, up to about 2000 cps. it responds almost equally to sounds from all directions. At higher frequencies it becomes more and more directive. This fault can be overcome by reduction in size, but this measure is at the price of serious loss in sensitivity. The shape of the condenser transmitter as usually built also results in a decided peak in the response at about 3000 cps. The condenser microphone is expensive to construct, requiring extreme refinements, and has presented a serious problem in insulation in order that the circuit shall not be noisy. Its output impedance is so high and its actual power putput so small that it is practically necessary to couple it by very short leads to the grid of an amplifier tube, preferably a screen-grid tube. The output can not practically be transmitted any distance prior to amplification. These faults in the condenser transmitter made it desirable to develop a new form of high-quality transmitter, and in developing the present ribbon microphone, H. F. Olson reverted to the general principles of Bell's original transmitter, except that instead of moving a piece of iron close to the poles of a polarized electromagnet, a conductor is moved through a magnetic field and voltage is induced in the conductor.[1] This was not a new idea, but the type of conductor and method of construction resulted in a directive magnetic microphone having properties previously unattained.

The moving conductor consists of an aluminum ribbon 0.0001 inch thick by 0.2 inch wide and 2 inches long between supports. It is provided with shallow transverse corrugations which increase its flexibility, the ribbon being under only sufficient tension to keep it in a proper position between the poles of the field magnet. The ribbon is so thin and light that the air in its vibratory movements can more easily move the ribbon than flow around it, so that it follows the movements of the air particles almost perfectly. In other words, the amplitude of its movement is practically equal to that which the air would execute were no microphone present. The air itself provides sufficient damping for such a light object and no tendency to resonate appears. In order that the vibrations of the ribbon may be as nearly as possible the same as would occur in air without the microphone, the field magnet structure is cut away so as to present the minimum obstruction to the movements of the air. From 70 to 2500 cps. the response is uniform. Above 2500 cps. the effect of the mass of ribbon becomes measurable and the output is down about 2 decibels at 10,000 cps. This departure from the ideal flat response is smooth and is readily compensated in the amplifier. Since the single conductor can generate only a very low voltage, a step-up transformer is provided. The transformer is built into the microphone unit. The transformer is protected from external fields by a suitable shield, while the exposed circuit of the ribbon is balanced against such fields by splitting the conductor and providing a return conductor each side of the ribbon. The ribbon and magnet are enclosed in a wind-shield of silk cloth and perforated metal. Fig. 1 shows a model *144-A* microphone. The fact that the ribbon microphone responds to the velocity of air movements rather than to air wave pressure, has led to its being termed a "velocity microphone."

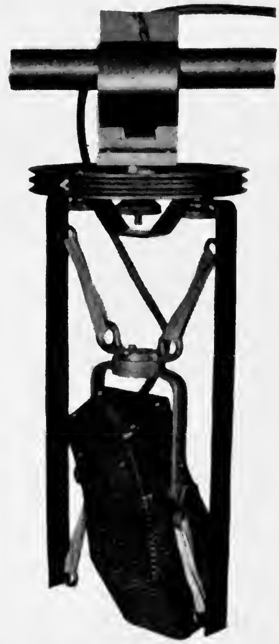

FIG. 1. Velocity microphone, in mounting generally used in motion picture studios.

The ribbon microphone presents no insulation trouble, and the fact that it can operate directly into a transformer makes it possible to transmit the output over distances up to several hundred feet through shielded cable, and therefore to place the microphone amplifier in the most convenient location, which is ordinarily at the mixer. The extremely smooth natural response (which, however, was obtained only after considerable development in which the ribbon itself and the form of the pole-pieces were varied) and complete avoidance of resonance meant higher fidelity than had been obtainable with the condenser, but the most important practical advantage of the new microphone lies in its directive property. Only one side of the diaphragm of the condenser is exposed to free air, and pressure variations are experienced by the diaphragm, whatever the direction of the passing sound-wave. It is only because the body of the microphone casts a sound-shadow that the condenser microphone shows any directive properties whatever. On the other hand, the ribbon microphone is entirely symmetrical, and the movements of the diaphragm depend upon the direction of travel of the sound-wave. If the sound comes from directly in front, maximum response results. If the sound comes from directly behind the microphone, the phase of the diaphragm movements is reversed (with respect to the pressure variations in the wave). If the sound comes from the side, no ribbon movements result. The complete absence of response to sounds coming from 90 degrees to the normal (whether coming from directly above, below, or either side) and the reduction in response for intermediate directions means that the velocity microphone, when adjusted for equal sensitivity for sounds coming from directly in front, picks up less of the sound coming from random directions than is the case with a pressure-operated microphone like the condenser. If sounds come equally from all directions, the

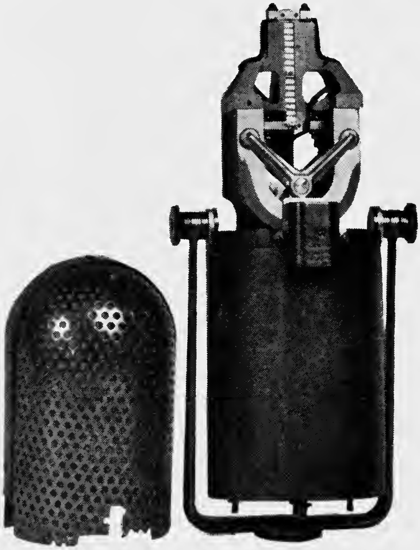

FIG. 2. Unidirectional microphone with shield removed.

average response of a ribbon is only one-third of that of a non-directional unit having the same sensitivity for sound coming from directly in front. The echoes which make the reverberation in a fairly live enclosure, approximate the condition of arrival from random directions, so that on the average the ribbon microphone picks up only one-third of the reverberation which a non-directional microphone would pick up. The decreased response to reverberation makes it possible to place a ribbon or velocity microphone about 70 per cent farther away from the source of sound than a non-directional microphone can be placed, without too much reverberation.

When a person with normal hearing is listening to sounds, his binaural sense enables him to discriminate against sound coming from random directions in favor of the sound that he wishes to hear. The benefit of this discrimination is lost in all single-channel recording and reproduction. Far less reverberation can therefore be tolerated for microphone pick-up than would be acceptable in direct listening. The reduction in reverberation is obtained by placing the microphone closer to the original source of sound. In general, it has been necessary to place pressure microphones so close to the source that there is a loss of balance unless the sources are confined to a very restricted space. It has therefore been necessary, when recording orchestras, to employ several microphones, while in recording sounds for motion pictures, the microphone must either be moved to follow the action or several microphones must be employed. In motion picture work, it is of course necessary to keep the microphone out of the field of the camera. By acoustic treatment of the sound stages where most of the pictures are made, echoes from the more distant walls have been largely suppressed, and it is possible to obtain satisfactory sound pick-up with pressure type microphones, but

FIG. 3. Unidirectional microphone, disassembled.

there are many situations in which reverberation or other unwanted sounds constitute a problem, and the ability to locate a velocity microphone considerably farther away is a decided advantage. Ability to work at greater distance simplifies the problem of avoiding the field of the camera, gives better perspective, makes it less necessary to follow the action closely by moving the microphone, and tends to give a more natural quality to such reverberation as is recorded.

The directive properties of the ribbon microphone have been found to be extremely helpful, but the form of the directivity curve can be still further improved. One hundred per cent sensitivity for sounds coming from a direction opposite to the original sound is not desirable, while the forward directivity is, if anything, a little too sharp for convenience in recording some scenes in pictures. A wider angle of pick-up from the general forward direction is needed to cover the action better without making it necessary to turn the microphone. The improved directive characteristic is now available through a recent development (also the work of H. F. Olson) which has given us the unidirectional ribbon microphone.[2] By suitable shielding of one side of the ribbon, it can be made into a pressure-operated device. If a pressure unit and a velocity unit can be made almost to coincide in position and adjusted to equal output for sounds coming from the forward direction, and their output voltages added, there results a directive curve

FIG. 4. Console type of mixer.

which shows zero response from the rear, 50 per cent response (in voltage) at 90 degrees, and full response from the front. The total energy picked up from random sounds is again only one-third of what it would be with a non-directional device having the same forward sensitivity, while the forward directivity is broadened so that an angle of 90 degrees may be covered with little variation in sensitivity. The combination of two such units is provided by clamping the ribbon near its mid-point and providing a shield behind one portion. This shield must produce practically no acoustic reaction on the back of the diaphragm. In other words, it must imitate free air devoid of sound. This result has been obtained by means of a column of air about 20 inches long with loosely packed absorbent material sufficient to prevent resonance in the air column. The tube is in the form of a coil to minimize space requirements. Figs. 2 and 3 show the form of the unidirectional microphone and something of its construction. The form of the pole pieces is similar to that of the bidirectional or simple ribbon microphone.

In the pressure microphone, called the "inductor microphone," an aluminum conductor is mounted on an extremely light paper diaphragm about $^1/_2$ inch wide by 3 inches long. This conductor is moved between magnet poles very much as in the case of the ribbon microphone, except that the conductor of the inductor microphone can be in the form of a round wire instead of a ribbon, and the magnet poles can therefore be brought close together, thus giving a stronger field and

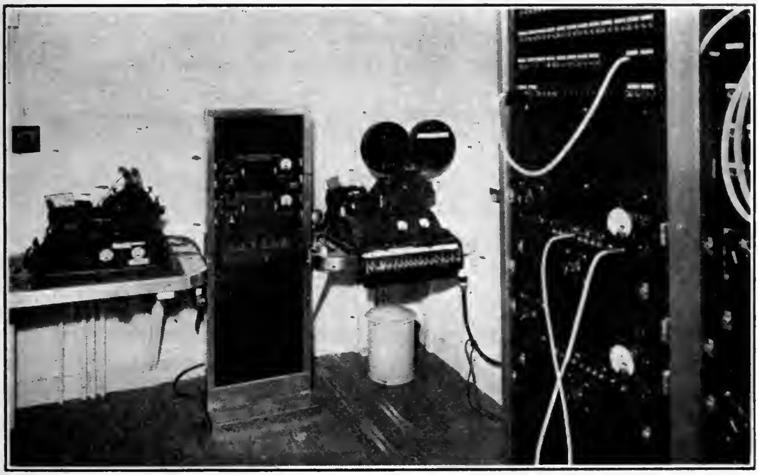

FIG. 5. Recording room used for musical scoring.

increased sensitivity. The space behind the diaphragm is completely enclosed (which makes the inductor microphone a pressure-operated device). By the employment of damping material, and by suitable design of the chamber, the air behind the diaphragm is made so to resist the motion of the diaphragm that it will have a velocity proportional to the instantaneous pressure of the sound pressure wave, thus giving the desired relation for uniform response. It is useful for outside work, since it is less affected by wind. Its response curve is not as smooth as that of the ribbon.

MIXERS AND AMPLIFIERS[3]

For many purposes, it is desirable to employ several microphones—sometimes for picking up the sound from widely separated points; sometimes for introducing special sound effects, and sometimes for emphasizing certain sources of sound with a local microphone, as, for example, bringing out the voice of a singer accompanied by an orchestra.

The requirements for an ideal mixer are that any adjustment of the level of sound contributed by any one microphone shall not affect that of any of the others (or in other words, independent adjustments), and that no adjustments should alter the impedance match of either the incoming or outgoing circuits. This second feature is necessary since the response characteristics of many pieces of equipment depend upon the impedance with which they are connected. Fig. 4 shows a console type of mixer such as is ordinarily used on sound stages. No mixer can be made to comply with all these conditions and provide adjustable attenuation without throwing away considerable power. Since the level of the unamplified microphone output is already low, especially when faint sounds are being recorded, it is desirable from the standpoint of avoidance of disturbances by stray electric and magnetic fields and possible noise from the mixer contacts, to provide some amplification between the microphone and the mixer.

It has been found possible by careful design and shielding to transmit the microphone output considerable distances through cable. This makes it possible to locate the microphone amplifier adjacent to the mixer, rather than at the microphone.

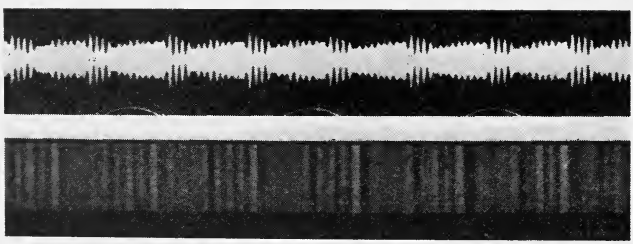

FIG. 6. Variable-width and variable-density sound-tracks.

The microphone output is stepped up to 250 ohms' impedance. The other end of the cable is connected to a transformer having a high step-up ratio and the voltage is applied to the grid of an amplifier tube. The amplifiers used in this location are two-stage, using a screen-grid tube and a triode. The compensation for the slight droop in the microphone response, which has already been mentioned, is incorporated in the microphone amplifier.

Compensation is provided in the mixer to introduce the desired amount of low-frequency attenuation, and some high-frequency attenuation, if needed, to give the best overall effects when speech is being recorded. Since voices are usually reproduced at abnormally high levels, they give the impression of an unnatural quality which it has been found possible to offset by certain modifications in the frequency characteristics of the system.

The output of the mixer is fed to the main amplifier, the output of which operates the recording galvanometer. This amplifier increases the power level from the mixer by approximately 80 decibels at maximum volume control setting. This is sufficient for operation of the recorder galvanometer. Provision is made in the circuit arrangement for connections to the monitoring circuits and noise-reduction equipment. A vibrating reed type of hummer is included in the amplifier case and can be connected in the circuit to provide a substitute for sound pick-up as a convenient means for adjusting the galvanometer and noise-reduction system. The inclusion of the hummer as well as a meter for testing purposes eliminates several extra panels formerly used for mounting the equipment required for adjustment and tests.

The amplifier is very compact, but sufficiently rugged to withstand the jars and dust to which it is subjected when mounted in automobile trucks, which often make long trips over rough roads into dusty locations.

SOUND-TRACK

There are fundamentally two types of photographic sound record. In one the actual shape of the wave is shown as in an oscillogram. The area to one side of the line that marks the shape of the wave is preferably as black as it can well be made, while the other should be as clear as possible. In the other type of record, the transparency of the film changes from point to point, but no change in shape is indicated. Sound-tracks of both kinds are shown in Fig. 6. Many sound recordings have been made by mixtures of these two systems, but in modern high-quality systems, the effort is to make the track distinctly of one type or the other, since the photographic requirements differ radically, and what is best for one is not best for the other. The type of sound record first mentioned is usually described as "variable-width," while the second is called a "variable-density" record.

In reproduction, the record or sound-track is passed through a sharply focused beam of light which has the form of an extremely narrow rectangle where it strikes the film. This rectangle or slit image is about 0.001 wide by 0.084 inch long. As the film passes through this light-beam, the amount of light that gets through to the photocell varies in proportion to the width of the clear area, if the record is of the variable-width type, or in proportion to the translucency if the record is of the variable-density type.

Present RCA equipment can be readily adapted to make either type of record. The relative merits of the two systems[4] have been the subject of prolonged controversy. The principal arguments are the following:

Advantages of the Variable-Width System

(*1*) Less distortion, especially of low-frequency and high-amplitude sounds.

(*2*) Less critical to exposure and development. (The extremely close control of photographic and laboratory conditions required for low distortion in the case of variable-density records, has been a constant source of trouble.)

(*3*) Higher photocell output. (A variable-density record, if so printed as to transmit more than 25 per cent of the incident light, on the average, gives rise to bad distortion, owing to the photographic characteristics of the film.)

(*4*) Less ground-noise of "hiss"type resulting from graininess of the negative and print films.

(*5*) The form of the recorded wave is evident to the eye, and anything wrong can be more readily discovered or diagnosed.

Advantages of the Variable-Density System

(*1*) Lower ground-noise of the type that results from dirt and scratches on the release print.

(2) Quality of reproduction less affected by imperfections in the reproducing optical system.

The first RCA Photophone recording optical systems were so designed that a single trace of the sound-wave was produced, the area on one side of the sound-track being black and the other clear, as shown at *A*, Fig. 7. In 1932, the form of the track was changed to that shown at *D* or *E*, in which the clear area is in the middle of the track and the wave shape is traced symmetrically on both sides of the middle.[5] This new form of variable-width track presents certain advantages which will be explained in connection with ground-noise reduction, and also re-

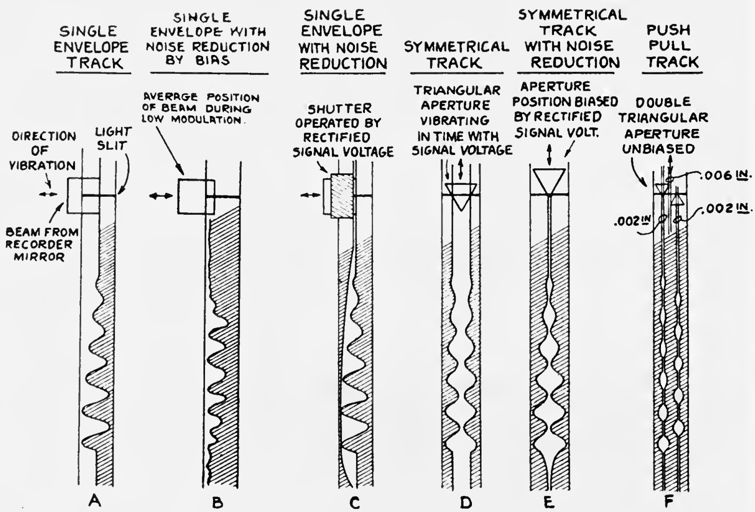

FIG. 7. Variable-width sound-tracks produced by different recorders.

sults in less distortion in case the angle of the reproducing light-beam with respect to the film is not accurately adjusted.

Still another form of sound-track of the variable-width type is shown at *F* in Fig. 7. This is a push-pull system.[6] Positive and negative half-waves are recorded as separated transparent areas on the two sides of the track. The reproducing light-beam is split, and one part directed to one cathode and the other to the other cathode of a double photocell. The two photocell elements are connected to a push-pull transformer. The push-pull track affords important advantages on the score of ground-noise and the avoidance of certain forms of distortion. Since it requires a special reproducing system, its use has so far been confined to making master records rather than theater release films, although the latest RCA reproducing sound-heads are designed so that a simple conversion device can be applied and change-overs quickly made.

RECORDING OPTICAL SYSTEM[7,8]

The variable-width sound-track has been compared to an oscillogram of the sound-wave. It is, in fact, a miniature oscillogram, differing in form from the ordinary oscillogram only in size and in the fact that the area on one side of the wave outline is black. It was natural in view of the similarity, that the first galvanometers to be used should have been the same as oscillograph vibrators, modified only in detail and in the form of the magnet structure to suit the apparatus. Fig. 8 shows the arrangement of the optical elements in the present recording optical system, and Fig. 9 the assembly. The filament of a small high-intensity incandescent lamp L is imaged by condenser lens C on the galvanometer mirror G. Close to the condenser lens is a diaphragm, or mask, M, with an opening, A, of suitable shape. Near the galvanometer mirror is a lens B, which produces an image, D, of the opening A at the plane of the slit S. If the condenser lens is properly designed and adjusted, the spot of light D is

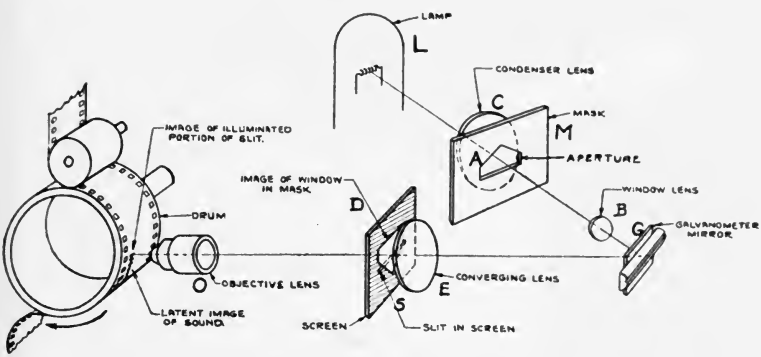

FIG. 8. Elements of the optical recording system.

uniform in intensity. Rotation of the galvanometer mirror causes the spot D to move, and illuminate more or less of slit S. Were a film placed directly behind this slit and voice currents passed through the galvanometer, a sound-track would be recorded on an enlarged scale. Objective lens O produces a reduced image of the illuminated portion of the slit. The lens E serves to direct all the light which passes through the slit into the objective lens O. The perfection of the slit-image on the film is an important factor in recording high-frequency sounds. An even finer or narrower light-beam is employed for recording than for reproduction. The present physical slit is $1^3/_4$ mils wide, and the objective lens forms an image $^1/_{7.5}$ of this size, or $^1/_4$ mil wide on the film. Since all the light which passes through the slit is concentrated into the small image upon the film, the intensity within this image is very high, the brightness being such that it is possible to get adequate exposure during the extremely brief time that a given point on the surface of the film is within the light-beam, or in $^1/_{72,000}$ second.

Ever since the beginning of variable-width recording there has been pressure for increasing the amount of light that the optical system can concentrate into this slit-image on the film. The proportions of the optical system may be varied within wide limits, and, assuming proper design, the question of how much light can be concentrated upon the film always comes back to the same factors—

How bright is the source (in candle-power per square mm. of projected area)?

How large is the mirror, and does the filament image occupy all of the mirror surface?

How large a solid angle can the slit be made to subtend from the mirror?

The size of the mirror and the intensity of the image upon it determine the candle-power of the beam of light which leaves the mirror. The angle subtended by the slit, multiplied by the candle-power of the mirror, regarded as a source, gives the number of lumens passing through the slit. The mirror vibration swings the light-spot *D* across the slit in such a way that various lengths of slit are illuminated. Obviously, the larger the angle that the slit subtends at the mirror, the farther the mirror must swing in order to move the light-spot far enough to cover and uncover the entire slit. In the earlier forms of optical

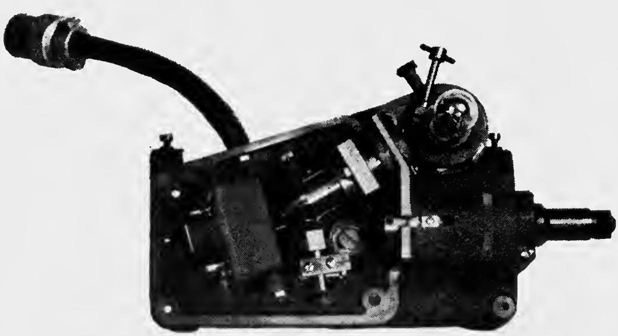

FIG. 9. Recording optical system, with cover removed.

system the aperture *A* was rectangular, and the galvanometer, which was of the oscillograph vibrator type, with its axis vertical, caused the light-spot *D* to move horizontally or parallel to the slit. One of the important improvements which gave more light was to turn the mirror axis horizontal and swing the light-spot across the slit instead of lengthwise, and provide for varying the length of the illuminated portion by imaging an aperture of triangular shape.[9] If the aperture is made in the form of a triangle with its vertex at the middle, the present form of symmetrical track (Fig. 6*B* or Fig. 7*D* and *E*) is produced. The more acute the angle of intersection of the edge of the light-spot and the slit, the smaller is the actual movement of the light-spot required, and therefore, the closer can the slit be placed to the mirror, with resultant increase in the light passed. It is not desirable to make this angle extremely acute because when this is done the end of the illuminated portion becomes less sharp on the film. The angle can be made sufficiently acute to afford a gain of 3 or 4 to 1 in light-intensity at the film.

VARIABLE-DENSITY RECORDING WITH THE RCA OPTICAL SYSTEM

If, instead of a triangular opening at *A*, a rectangular aperture were employed, so that the entire slit is illuminated at all times, and if a dark glass of suitably graded density were placed in this aperture, the slit illumination would change in intensity only, as the image of this glass "wedge" moves up and down in response to the mirror vibration. The result would be a variable-density track on the film. A simpler expedient than the glass wedge serves the same purpose. A horizontal mask edge is located at such a position that it is out of focus at *D*, appearing as a soft-edged shadow, or penumbra. Conditions can be so chosen that the light-intensity within this penumbra decreases linearly from full brightness to zero, which exactly meets the requirements for variable-density recording. The

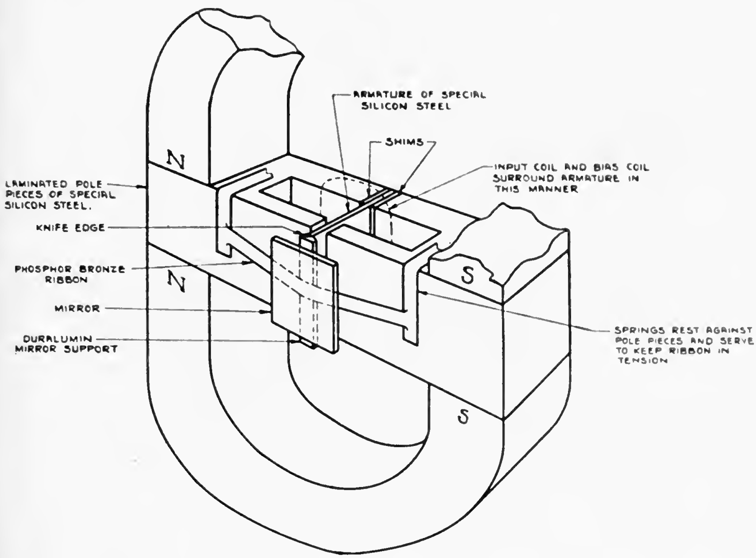

FIG. 10. General construction of magnetic galvanometer.

RCA variable-density system avoids a certain form of distortion that has been well recognized as inherent in the usual "light-valve" form of variable-density recording system, and which results from the fact that the light-valve controls the exposure by varying the width of the slit-image on the film.[10]

MAGNETIC GALVANOMETER

A second important improvement consisted in the development of the present form of galvanometer which has superseded the oscillograph vibrator type. In the present type, which was developed by G. L. Dimmick,[11] and which is illustrated in Fig. 10, an armature of silicon steel vibrates between pole-pieces of laminated silicon steel. A permanent magnet provides the polarization. The moving end of the armature is sharpened to provide a knife-edge which engages a groove in a duralumin block in the form of a short half-round bar, on the flat side of which the mirror is mounted. A ribbon 0.001 by 0.006 inch of phosphor-bronze, under tension, is so arranged as to act as a pivot as well as to hold the duralumin block against the knife-edge. The effective center of rotation of this block or mirror carriage is only 0.020 inch from the knife-edge, and the result is that a small displacement of the latter causes a large rotation of the block with its mirror. Damping is provided by small blocks of rubber clamped against the armature just behind the pole-tips, by a *U*-shaped metal piece which serves as a load. The damper does not affect the amplitude of vibration at low frequency, but the mass of the metal piece and elasticity of the rubber blocks combine to form an anti-resonant system which provides strong damping at the frequency at which the armature would otherwise have a large resonance peak.

The great advantage of the magnetic galvanometer is its ability to swing a large mirror. The mirror used is 0.1 by 0.125 by 0.005 inch thick, which provides ten times the area of the mirrors employed in the oscillograph galvanometers. This results not only in an increase in the amount of light leaving the mirror, about in proportion to the increase in area, but the relative amount of stray light from the edges of the mirror (which was formerly a serious problem) is greatly reduced, enabling the new galvanometer to give cleaner and sharper images, as well as far more light. The mirror can swing through about the same angle as the oscillograph vibrator, and requires about the same power to operate.

By a series of refinements in design and materials, the galvanometer has been steadily improved, giving flatter response, more uniform behavior, and less hysteresis and wave-shape errors. The natural frequency of the armature when driving the mirror is about 9000 cps. There is a slight peak at this point, and at higher frequencies the amplitude falls rapidly. This characteristic is found in nearly all apparatus in which the mass plays a part in limiting the high-frequency response. It is not regarded as a drawback since in practically all sound reproduction it has been found desirable to attempt to reproduce or transmit all frequencies up to a certain definite upper limit and cut off the response sharply at this point. Although of delicate construction, the moving elements are so light that the galvanometer is decidedly rugged. It can stand heavy overload without injury, being protected at about 200 per cent amplitude by saturation of the armature and pole-pieces, which limits the forces that can be produced magnetically.

GROUND-NOISE REDUCTION

When a film is run through a reproducing system the light is modulated not only by the photographic image on the film, but by accidental variations in transparency. Some of these variations are due to inherent graininess of the film.[4,12,13,14] If, for example, two equal microscopic areas that have the same exposure are examined, they will be found to differ slightly in the number and size of developed silver grains, and therefore in the amount of light which they will transmit. Over larger areas these differences tend to average out, so that the difference between the total transmission through two fairly large areas is an extremely small fraction of that total. In other words, the variations in average density over large areas that have had the same exposure are practically nothing; but in scanning a sound record an extremely small area is in the light-beam at one time, and the variations due to the accidental distribution of grains become appreciable in comparison with the total light transmitted.

A second cause of noise is dirt and abrasions on the film. Utmost care in handling the film is required for best results. All good laboratories carry out their film processing in rooms that are ventilated entirely with filtered and washed air. All machines through which film must be run must be designed so that as far as possible nothing comes in contact with the film within the picture area or the sound-track.

A dirt speck on the blackened part of the sound-track has little effect, for little light gets through for it to modulate. A similar speck in the clear area may produce a loud click. It is therefore desirable to have as little clear film as possible. In order to accomplish this result, L. T. Robinson, of the General Electric Company, proposed biasing the recording galvanometer by means of rectified current in such a way that the clear area of the film was just sufficient to accommodate the recorded waves.[15] The difference that this makes in the recorded sound-track may be seen by comparing tracks *A* and *B* of Fig. 7. C. R. Hanna, of the Westinghouse Electric and Manufacturing Company, worked on the same idea, and provided rectifying and biasing arrangements which were used in the earlier photophone recordings.[16]

The sound-track shown in Fig. 7*B* is open to objection because when the modulation is small the waves are all recorded near one edge. It is unfortunately true of many reproducing optical systems that the quality and intensity of the slit-image becomes poorer toward the ends. There are also many machines in which the film is not sufficiently well guided, and weaves slightly from side to side. Under such conditions, there is a possibility that small waves recorded at the extreme edge of the sound-track will not be well reproduced or may be even cut off. To obviate this difficulty, H. McDowell, Jr., of RKO, reduced the width of clear film, not by biasing the galvanometer, but by providing a separately actuated shutter which moved back and forth in front of the slit in such a way as to permit the illumination of only so much as is required for the modulation.[17, 18] The resulting track is shown at *C*, Fig. 7. Fig. 7 shows also the light-spot and shutter relations for producing the various tracks. The adoption of the symmetrical track shown at *D*, Fig. 7, and produced by moving a triangularly shaped light-spot across the slit instead of a rectangular light-spot parallel to the slit, made it possible to revert to the simpler arrangement of biasing the galvanometer in accordance with the modulation. For full modulation, the light-spot moves up and down about a mean position such that half the slit is, on the average, illuminated. When the modulation goes down, the light-spot moves upward as shown in Fig. 7*E*, so that the slit crosses the triangle near the tip, and only a short section of slit near the middle is illuminated.

The slowly varying current for biasing the galvanometer is supplied from a special amplifier and rectifier known as the "ground-noise reduction amplifier."[3, 19] The input to this unit is taken from a tertiary winding on the interstage transformer preceding the output stage of the main amplifier. The audio-frequency input voltage is applied, through a volume control, to the grid of the first tube, and the output of the second stage operates the rectifier. The output of the rectifier is arranged to increase the negative bias on an output tube, the plate current of which biases the galvanometer. Thus, at zero modulation the plate current is maximum, the exact value being adjusted to bias the galvanometer until a very small fraction of the track width is illuminated. As the modulation increases, the plate current falls, and the galvanometer returns toward the mid-position at which maximum modulation can be accommodated. The galvanometer is set for mid-position with zero plate current, and the volume control of the ground-noise reduction amplifier is adjusted so that the output tube will be biased to cut-off or zero plate current when the modulation is about 75 per cent of maximum. This insures definiteness of the galvanometer position for high modulation, which is very important. If anything should go wrong with the ground-noise reduction amplifier, the most likely result would be that the plate current would fall, or perhaps become zero. This would do no harm except cause some increase in ground-noise.

Distortion will occur if the tip of the triangular light-spot actually crosses the slit. With the galvanometer biased so that the tip is near the slit it is obvious that vibration in one direction is in danger of producing distortion, while there is abundant room for movement in the opposite direction. This relationship justifies the use of a half-wave rectifier, and correct polarity relations must be preserved between the ground-noise reduction amplifier and the recording galvanometer.

Since the changes in galvanometer bias must be such as to accommodate peak amplitudes rather than rms. values, the rectifier should as nearly as possible be designed to give a rectified voltage proportional to the peaks of the irregular audio-frequency waves. This can be closely approached in the case of a practically unloaded rectifier, or one loaded only with the grid of an amplifier tube. A resistance-capacity filter between the rectifier and the grid of the output tube eliminates audio-frequency voltages from the latter, and also limits the rate at which the bias can increase; and a discharge resistance allows the tube bias to come back slowly toward the zero modulation setting when the modulation decreases. It is obvious that in case of a sudden increase in modulation the unmasking must take place quickly. At the same time this unmasking involves a change in the amount of light passing through the sound-track. If this change takes place above a certain rate, a thumping sound is heard in reproduction. Therefore, the rectifier is designed so that the maximum rate of opening is limited. The closing of the track after the sound has decreased in intensity is made quite gradual, since it is not desirable to have the track width continually changing in an attempt to follow every little change in amplitude. The actual opening and closing times are about 0.014 and 0.25 second, respectively, when the modulation is suddenly changed from zero to full value and back.

The narrowing of the clear track gives about a 10-db. decrease in ground-noise when the modulation is low. This means a 10-db. increase in the useful volume range, since the faintest sound that can be satisfactorily recorded must be louder than the ground-noise by a certain definite margin, while the loudest sound recorded must not overshoot the track. In order that ground-noise due to the graininess of the film may be kept at minimum, it is important that the black areas be as dense as possible and the clear areas free from fog, and that the line that divides the two shall be as clean and sharp as possible. If this line of division is soft it means that there is a certain amount of gray film, and gray film produces more noise of this type than either clear or black film. Improvements in the lenses employed in the recording optical system, the availability of a galvanometer that can swing a large mirror, and the use of the recently developed front surface aluminum coated mirrors have all contributed to sharper images and cleaner outlines of the sound-track. The sharp outline makes it possible to set the minimum track width still closer, to keep down the ground-noise due to abrasions and specks on the film.

RECORDING MACHINES

Whether or not they have recognized the cause, there are few who have listened to music reproduced from records of any kind, who have not suffered (a form of torture greater or less in proportion to one's musical appreciation) from the

FIG. 11. Type *PR*-4 recorder, showing flywheel and driving magnet.

"twangy," out-of-tune, and Hawaiian guitar effects that result from speed fluctuations in recording and reproducing machines. These fluctuations and the disturbances in sound quality which they produce, have been dubbed "wows." Disturbances that occur at a rapid rate are termed "flutter," "ripple," or "gurgle." Sometimes the rapid fluctuations result in an outright treetoad trill, and sometimes simply in muffled and "wheezy" tones.

Engineers concerned with the earlier developments that eventuated in the exploitation of sound-pictures by RCA Photophone,* seem to have recognized that a film can not be moved at constant speed by means of a sprocket.[20] A disturbance in speed in the nature of a tooth ripple inevitably results.

For many purposes, the departure from constant speed which this tooth ripple introduces is not serious, but in sound reproduction it results in a serious impairment in quality, depending, of course, upon the degree of misfit between the sprocket and the film. Some misfit is inevitable, since films originally perforated with a certain pitch are subject to shrinkage which varies all the way from $^1/_4$ to $1^1/_2$ per cent. This tooth ripple can be avoided if the film is carried on a smooth

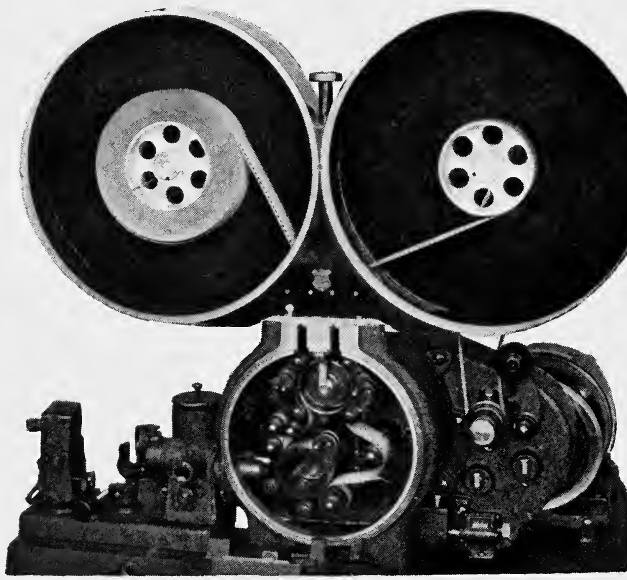

FIG. 12. Recorder, showing normal film loops.

drum against which it is held by friction (usually provided by a soft-tired, spring-mounted pressure roller), the recording or reproducing light-beam being arranged to strike the film where it is supported by the drum, and the drum being driven at as nearly constant speed as possible. In the various laboratory machines constructed in the earlier development of the Photophone system, smooth drums were consistently employed, and these were almost without exception connected to flywheels to minimize fluctuations. Film may be propelled through other parts

*The pioneer work of C. A. Hoxie, of Schenectady, deserves special mention in this connection. Contributions of C. L. Heisler and E. D. Cook, of Schenectady, of C. R. Hanna, of the Westinghouse Company, and others, should also be recognized.

of the machine, such as the picture projector, or withdrawn from the supply reel or controlled where it enters the take-up magazine by means of sprockets, but at the recording or reproducing point its speed is under control of the drum. Practically all other manufacturers of recording and reproducing machines have until quite recently ignored the impossibility of obtaining satisfactorily constant speed for sound work if the film is driven at this point by a sprocket. Even the recording machines have recorded directly on sprockets, great refinement being introduced in the attempt to rotate the sprocket at constant speed, but the benefit being thrown away by the inherent pulsations that the sprocket teeth impart.

Unfortunately for the performance of the earlier machines of the drum-and-

FIG. 13. Magnetic drive recorder; type *PR-23*.

flywheel type, this expedient by itself does not give constant speed. The sprockets, which are necessary in all machines that must run synchronously, propel the film at a rate that may be measured in terms of perforations per second. This happens to be 96 per second, which corresponds to 1.5 feet per second when the film is first perforated, but would be 1 per cent less when the film has shrunk by that amount. Therefore, the speed of the drum, which depends entirely upon the linear speed of the film, can not be determined in advance. The drum must be permitted to find its own speed, and the loops of film between it and the sprockets must in some way control the drum speed. The simplest arrangement is to drive the drum by means of the film. With such a drum drive, speed irregularities occur because:

(*1*) The tension on the film is often so great that slipping on the drum occurs, even though the film is held against the drum by a pressure roller.

(2) If the film is at all tight, it is incapable of acting as an elastic link and taking up the slight pulsations imparted to it by the sprocket that does the pulling, and the inertia of the drum and flywheel are not sufficient to iron out the irregularities without the coöperation of flexibility, any more than a heavy body can give a smooth-riding automobile without springs or rubber tires.

(3) The flexibility in the driving system and loop of film, combined with the inertia of the flywheel attached to the drum, produce an oscillatory system, which is found to have very little damping, and the slightest irregularity in speed at the sprocket (provided this irregularity has a periodicity nearly that of the oscillation system) causes large fluctuations in drum speed. This is analogous to the well known "hunting" of synchronous motors, in which the magnetic field is an elastic means of imparting torque to the armature, and this elasticity forms an oscillatory system in conjunction with the armature inertia. In synchronous motors the tendency to hunt is controlled by grids in which currents are induced and energy dissipated whenever an oscillation takes place. Or, again using the automobile analogy, shock absorbers are needed as well as springs and a reasonably heavy body.

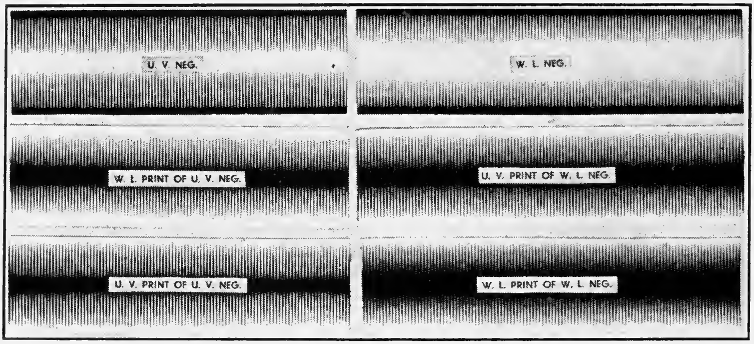

FIG. 14. Direct enlargements of 9000-cycle recordings comparing white light and ultraviolet recording and printing. (The halftone screen causes an appearance of modulation which the original photographs do not show.)

A recorder[20] that employed the principle of electromagnetic damping was brought out in 1930. In this recorder, a copper flange is mounted on the flywheel and this reacts with a multipole magnet, currents being induced in the flange in proportion to the velocity of the relative movements between flange and magnet. Fig. 11 is a photograph of the recorder from the motor side, showing the flywheel and magnet.

Any steady or continuous speed difference between the magnet and the flange exerts a continuous torque, while oscillatory motions produce an alternating component of torque which resists or damps the oscillations. The damping effect is practically independent of the steady torque effect. A stationary magnet would tend to damp out oscillations, but would have the undesired effect of resisting the continuous rotation and thereby of imposing a heavy load upon the film which acts as a driving belt. In the magnetic drive, as embodied in the *PR-4* and all subsequent models of Photophone studio recorders, the magnet is connected to the driving motor and driven at about 10 per cent higher speed than the drum.[21] By this expedient the continuous component of torque due to the difference in mean speed is caused to help rotation instead of producing a drag. Enough torque is supplied to the drum shaft by the magnet to overcome the bearing friction and relieve the film of the work of rotating the drum. As the magnet current is increased, the loop of film that pulls the drum is gradually relieved of its steady tension until this becomes zero, and with still higher magnet current, the slack film is thrown into this loop and the loop above the drum begins to exert a retarding tension. Conditions for guiding the film are better when the film approaching the drum is under a slight tension. The recorders are therefore operated with more than enough magnet current to overcome friction losses. Before a recording is made a piece of "daylight film" is run through the recorder and the magnet current is adjusted to the value that throws the slack film into the lower

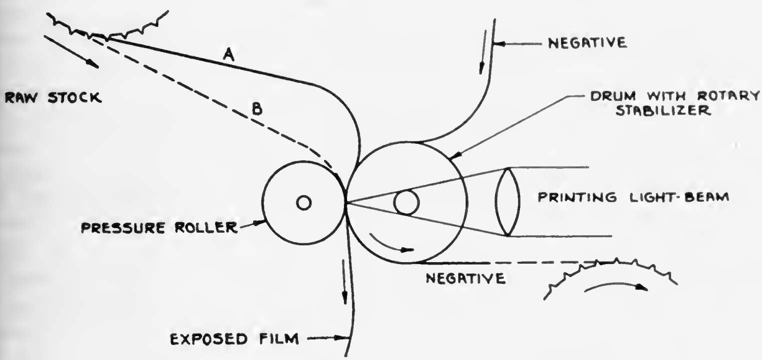

FIG. 15. Principle of the non-slip printer.

loop (film leaving the drum) and the upper loop under very slight tension, such that it forms an easy bow (see Fig. 12) which possesses a high degree of flexibility but can still exert enough tension to effect the final control of the drum speed. Such a loose loop of film can transmit little or no disturbance from the sprocket. During starting, the lower film loop is under tension for accelerating the drum, but the magnet assists in the acceleration. When the drum is up to speed the film loops are relieved of tension, and with the oil films in the bearings established, the drum almost floats along, held at constant speed by its flywheel with no appreciable forces to disturb the speed constancy. The oscillation produced by starting dies out in a few seconds. The path of the film and location of all guiding rollers has been carefully worked out to facilitate the formation of easy film loops, to lay the film upon the drum accurately directed and guided, to prevent edgewise movements or weaving, and to insure its lying snugly against the drum at the recording point. Fig. 12 is a front view of the *PR-4* recorder, showing the drum and film path. The film loops shown are fairly representative of conditions during running. Fig. 13 shows the most recent type of magnetic drive recorder.

FILM RESOLUTION PROBLEM

Early photographic sound recordings were extremely deficient in high-frequency response. Some of this fault was due to imperfect optical arrangements which failed to confine the light-beam in recording or reproduction to the desired narrow rectangle. At the standard speed of 90 feet per minute, a 9000-cycle wave is only 0.002 inch long. Obviously, to record such a wave or to reproduce it, the light-beam must be extremely fine. Its width should be a small fraction of a wavelength. Only a properly designed and corrected lens will produce the required sharp images of this size. Extreme care is necessary in manufacturing the actual slit which is imaged on the film, and stray light of all kinds must be carefully avoided.

Analyses have been made of the effect of employing a light-beam whose width is a considerable fraction of a wavelength.[22, 23] The harmful effect in loss of high-frequency response is much more serious in recording than in reproduction, and results not only in loss of high frequencies, but in a form of distortion analogous to rectification, whereas in reproduction the only harm is in the loss of high frequencies. In the earlier equipment it was not feasible to reduce the width of the recording slit image below 0.001 inch, because there was not enough light available to expose the film. In the case of a reproducing machine too much sacrifice of photocell illumination results in trouble from microphonics, hum, and other disturbances. Reproducing machines still employ a one-mil slit image, which gives about 65 per cent response at 9000 cps. In recording, advantage has been taken of every improvement that increases the light-intensity or film sensitivity, to reduce the size of the slit-image. It has been found that there is some gain in resolution as this width is reduced even beyond the present $^1/_4$-mil width. The gain from further reduction, however, is extremely small, especially in view of the limitations of the resolving power of the film itself.

A film emulsion consists of minute crystals of silver bromide dispersed in a layer of gelatin. Both are transparent, but the index of refraction of the silver bromide crystals differs from that of the gelatin, with the result that light is refracted whenever it passes from one medium to the other. This results in diffusing or scattering the light just as drops of water in a fog or crystals of ice in a snow bank diffuse light. The light which strikes a minute area of the surface of a film therefore diffuses in all directions, with the result that the image spreads beyond the nominally exposed areas.[12, 24, 25] Astronomers take advantage of this spreading of the image, and estimate the amount of light from a star by the size of the spot on the film rather than by its blackness. In sound recordings, the diffusion of light in the film emulsion has qualitatively the same effect as that of recording with a wider slit-image. The most important improvements in recording, with respect to high-frequency response, have been the result of developments which have made it possible to reduce this spread of the image. At first it was necessary to employ the most sensitive films available, namely, picture negative film. This is relatively coarse-grained and has less resolution than the positive type. Before commercial exploitation of the Photophone system was undertaken, progress in the improvement of the optical system had made it possible to expose picture positive to the desired blackness or density with a $^3/_4$-mil slit-image. It happened that this film was the best of all available commercial emulsions. It has high resolving power, fine grain, and is inherently a high-contrast film, which helps to give good resolution and sharp edges in a variable-width recording system. This was extremely fortunate for the reason that picture positive is the type of film used in largest quantities and is therefore the cheapest of the various films manufactured. The high resolving power of standard picture positive is also fortunate in that this is the film on which the sound-track must finally be printed.

Film manufacturers have devoted a great deal of effort to the production of still better sound recording films. The most important practical result of these developments has been a film that is considerably faster than the picture positive, while having equal resolution. Advantage has been taken of this improvement to narrow the recording light slits. Certain extremely fine-grain emulsions have been developed which show considerably higher resolution than the picture positive, but these fine-grain films require some ten times more exposure to give a satisfactory density, and they have not come into use. Some advantage has been shown, in experimental films, from the use of antihalation backings which reduce the light reflected from the back surface of the film. This expedient, however, has been rendered practically unnecessary by the most recent important development, namely, ultraviolet recording.

Extensive studies have also been made of the effects of various developers and to determine the optimum exposures and degrees of development.[26]

ULTRAVIOLET RECORDING[27]

The most striking improvement in film resolution that has been made is probably the recent advent of ultraviolet recording. The benefits gained are probably more than would have been anticipated. Some reasons for the improvement are understood, but how much each factor contributes is a question. It is well known that lenses exhibit greater resolving power with light of short wavelength than with longer wavelengths, assuming the lens in each case to have been corrected for the wavelength used. A higher degree of lens correction is possible if the light is restricted to a narrow range of wavelength than if a wide band is employed. In ultraviolet recording, the visible rays are almost completely excluded by the No. *584* Corning filter employed. On the other hand, the limitations of the tungsten lamp and the transmitting properties of the special glass used in the lenses determine the limit on the short-wave side, so that the entire exposure is produced by light within the range of 350 to 400 millimicrohms. It has been found that the tungsten lamps used in RCA recording systems radiate enough ultraviolet light to record on some of the sound recording films that are now available. Only by certain changes in the optical system, however, has it been possible to obtain enough ultraviolet light from a tungsten lamp to give the high negative densities which have been found to give best results. These densities are greater than have been found best for white light recording, very high contrast being possible with the ultraviolet system.

The second factor that makes for higher resolution with ultraviolet light is the fact that the emulsion itself absorbs ultraviolet light very strongly. Therefore, the light which strikes the surface of the film, although it is scattered by the silver halide grains as in the case of white light recording, does not spread as far. This confines the image to the surface. A high density or high degree of film blackening can be obtained only by heavy exposures, but this means that all the grains in the immediate vicinity of the exposed surface are rendered developable, whereas with enough white-light exposure to produce the same density, only a part of the grains in this region would be used and the remainder of the density would be contributed by developed grains farther within the emulsion and to either side. Fig. 14 shows enlargements of a 9000-cycle wave as recorded and printed with ultraviolet light and with white light. The difference can not be shown fully in a halftone reproduction, but the filling-in between the waves, resulting in an apparent reduction of amplitude, is clearly shown. The clean, sharp edges of the ultraviolet recording make for reduced ground-noise, higher response at high frequency, and reduced distortion of the kind mentioned as rectification, or change in average transmission when a high-frequency wave is recorded. The use of ultraviolet light results in about the same improvement in the printing operation as in the recording, provided the printer maintains the films in close contact.

THE NON-SLIP PRINTER[28]

Picture printers have for years operated on the plan of running both negative and raw stock around a large sprocket with the negative inside. Light is thrown on the films from a lamp on the other side of the sprocket, the sprocket being cut away to permit the light to pass. Since the two films are wrapped around the sprocket with the raw stock on the outside, the travel of the raw stock is slightly greater than that of the negative. By choosing the proper sprocket diameter, this can be made to compensate for the fact that the negative will on the average have shrunk, and therefore be somewhat shorter for the same number of sprocket holes than the fresh film on which the print is being made. This crude approximation to correction for shrinkage of negative in excess of that of the raw stock, has sufficed for picture printing, and until recently, for sound printing, but each improvement that reduces the imperfections resulting from one cause makes the faults of some other operation more apparent. It has been known for a long time that there was some loss due to slipping in the sprocket type of printer, but only recent refinements have compelled widespread attention to this fault.

A number of years before the industry recognized the need of better sound printers, A. V. Bedford, realizing that here was a fault that would sooner or later have to be corrected, began experimenting with a printer which operates on a different principle.[29] R. V. Wood, independently, but at a later date, worked on the same principle.[30] Bedford had previously suggested the same idea for application to projectors. He had found that if the film is driven by a drum rotating at constant speed and is held against the drum by a pressure roller (the pressure roller being free to find its own speed) the actual linear speed of the film could be varied within a limited range by merely changing the direction from which the film approaches the point at which it is pinched between the drum and pressure roller. This direction was made to vary automatically in proportion to the length of the loop of film between a sprocket and the drum. Provided the surface speed of the drum were *approximately* equal to the mean linear speed at which the sprocket propelled the film, the loop would gradually change in length until the angle of approach was correct to make the film speed at the two points exactly equal, after which the device would continue to run under constant conditions. The same principle is applicable to a printer. In this case, the negative film is wrapped around the drum and the outer surface of the negative film is the speed to which the raw stock must adjust itself. The drum is driven by the negative film, and since the negative film may vary in shrinkage, the actual drum speed may differ from one negative to another, and the raw stock in each case finds a certain loop length and angle of approach that enable it to pass through this point of contact at exactly the right speed and without any slipping. Fig. 15 indicates the arrangement of the essential features.

The principle of operation may be thought of in terms of stretching or compressing the raw stock. It is not necessary to stretch or compress the entire film in order that it may be maintained in non-slipping contact with the negative and still pass exactly the same number of sprocket holes per minute. It is necessary only that the surface in contact be stretched or compressed, and this, it will be readily recognized, is accomplished by bending. The actual curvature of the raw stock at the point where it is gripped between the rollers is altered by a change in the direction from which it approaches.

The improved resolution obtained from the use of the non-slip printer is not due solely to the absence of slipping, but also to the better contact. In a sprocket printer the films must be allowed to slip slightly, and therefore can not be held very tightly. In the non-slip printer they are held in firm contact. To realize the benefit of this principle, the printing must be done at the point where the films are held together. The printing light is therefore supplied in the form of a beam about 0.005 inch in width, and the optical system is adjusted to make the light strike the film at exactly the right position. Small speed variations at the drum would not produce "wows" in the case of a non-slip printer since the negative and print must move together, but slight variations in print density might result. The well known "rotary stabilizer" (which is essentially an oil-damped flywheel) is employed to insure speed constancy at the drum.

RE-RECORDING

A large proportion of the sound recorded for motion pictures is re-recorded before printing on the release print. This is done for the purpose of adjusting loudness levels, introducing extra sound effects, and other matters pertaining to editing the sound. For a number of years it was the general practice to run the original sound record through an ordinary sound picture projector, the output from which was supplied to a recorder. The speed constancy of sound projectors has not been what it might be, and serious impairment of quality has been the result. RCA Photophone furnishes re-recording equipment in which the reproduction, as well as the recording, takes place on a drum with magnetic drive, thus performing both operations at the most constant speed obtainable. The reproducing optical system has special adjustments by which some faults in original negatives can be corrected if necessary and, of course, a light-beam of the best obtainable quality and uniformity is employed. The re-recording console is provided with a mixer, so that sounds from several records or from a recording plus an orchestra, or the voice of an announcer, can be mixed at whatever relative levels are desired. A very flexible system of compensation also is provided so that sounds being re-recorded may have their very high- or low-frequency components boosted or lowered by various amounts to give whatever is found to be the best overall result.

REFERENCES

[1] OLSON, H. F.: "The Ribbon Microphone," *J. Soc. Mot. Pict. Eng.*, **XVI** (June, 1931), No. 6, p. 695.

[2] OLSON, H. F.: "The Ribbon Microphone," *J. Acoust. Soc. Amer.*, **III** (July, 1931), No. 1, p. 56.

OLSON, H. F., WEINBERGER, J., AND MASSA, F.: "A Unidirectional Ribbon Microphone," *J. Acoust. Soc. Amer.*, **V** (Oct., 1933), No. 2, p. 139.

OLSON, H. F.: "A Unidirectional Microphone," *J. Soc. Mot. Pict. Eng.*, **XXVII** (Sept., 1936), No. 3, p. 284.

[3] READ, S., JR.: "RCA Victor High-Fidelity Film Recording Equipment," *J. Soc. Mot. Pict. Eng.*, **XX** (May, 1933), No. 5, p. 396.

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

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

[6] DIMMICK, G. L., AND BELAR, H.: "An Improved System for Noiseless Recording," *J. Soc. Mot. Pict. Eng.*, **XXIII** (July, 1934), No. 1, p. 48.

[7] HARDY, A. C.: "The Optics of Sound Recording Systems," *Trans. Soc. Mot. Pict. Eng.*, **XII** (Sept., 1928), No. 35, p. 760.

[8] SACHTLEBEN, L. T.: "Characteristics of Photophone Light-Modulation System," *J. Soc. Mot. Pict. Eng.*, **XXV** (Aug., 1935), No. 2, p. 175.

[9] KELLOGG, E. W.: U. S. Patent No. 1,740,406.

[10] SHEA, T. E., HERRIOT, W., AND GEOHNER, W. R.: "The Principles of the Light-Valve," *J. Soc. Mot. Pict. Eng.*, **XVIII** (June, 1932), No. 6, p. 697.

MILLER, B. F.: "Harmonic Distortion in Variable-Density Records," *J. Soc. Mot. Pict. Eng.*, **XXVII** (Sept., 1936), No. 3, p. 302.

[11] DIMMICK, G. L.: "Galvanometers for Variable-Area Recording," *J. Soc. Mot. Pict. Eng.*, **XV** (Oct., 1930), No. 4, p. 428.

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

[13] HARDY, A. C., AND JONES, L. A.: "Graininess in Motion Picture Negatives and Positives," *Trans. Soc. Mot. Pict. Eng.*, **VI** (May, 1922), No. 14, p. 107.

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

SANDVIK, O., HALL, V. C., AND GRIMWOOD, W. K.: "Further Investigation of Ground-Noise in Photographic Sound Records," *J. Soc. Mot. Pict. Eng.*, **XXII** (Feb., 1934), No. 2, p. 83.

[15] ROBINSON, L. T.: U. S. Patent No. 1,854,159.

[16] HANNA, C. R.: U. S. Patent No. 1,888,724.

[17] MCDOWELL, H., JR.: U. S. Patent No. 1,855,197.

[18] KELLOGG, E. W., AND BATSEL, C. N.: "A Shutter for Use in Reduction of Ground-Noise," *J. Soc. Mot. Pict. Eng.*, **XVII** (Aug., 1931), No. 2, p. 203.

[19] KREUZER, B.: "Noise-Reduction with Variable-Area Recording," *J. Soc. Mot. Pict. Eng.*, **XVI** (June, 1931), No. 6, p. 671.

[20] KELLOGG, E. W.: "A New Recorder for Variable-Area Recording," *J. Soc. Mot. Pict. Eng.*, **XV** (Nov., 1930), No. 5, p. 653.

[21] KELLOGG, E. W.: U. S. Patents Nos. 1,892,554; 1,899,571; and RE 19,270.

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

[23] STRYKER, N. R.: "Scanning Losses in Reproduction," *J. Soc. Mot. Pict. Eng.*, **XV** (Nov., 1930), No. 5, p. 610.

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

[25] SANDVIK, O.: *J. Opt. Soc. Amer.*, **XIV** (Feb., 1927), No. 2, p. 169; **XVI** (April, 1928), No. 4, p. 244; **XVII** (Aug., 1928), No. 6, p. 107.

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

[27] DIMMICK, G. L.: "Improved Resolution in Sound Recording and Printing by the Use of Ultraviolet Light," *J. Soc. Mot. Pict. Eng.*, **XXVII** (Aug., 1936), No. 2, p. 168.

[28] BATSEL, C. N.: "A Non-Slip Sound Printer," *J. Soc. Mot. Pict. Eng.*, **XXIII** (Aug., 1934), No. 2, p. 100.

[29] BEDFORD, A. V.: U. S. Patent No. 1,754,187.

[30] WOOD, R. V.: "A Shrinkage-Compensating Sound Printer," *J. Soc. Mot. Pict. Eng.*, **XVIII** (June, 1932), No. 6, p. 788.

BOOK REVIEWS

"**Color Cinematography**"; Adrian Bernard Klein, *American Photographic Pub. Co.*, Boston, Mass., 1936; 337 pp.

A long needed book and one that should be enthusiastically received. The author has boldly attempted to include in 337 pages all the theoretical, historical, economic, and aesthetic aspects of color photography as they should apply and as they have been applied to the professional motion picture field.

After a 21-page historical sketch, the author launches into the theory of the complete problem of reproducing in the mind of an observer the effect of the original object, condensing it into 88 pages. Then follows chapters on additive and subtractive processes in which all those of importance are given in as great detail as was available to the author at the time of writing. Perhaps the greatest value to be derived from the book by a serious student of color photography will come from the careful analysis of these processes. Major Klein, although frankly and openly biased on the question, has presented reasons why most of them can never succeed, and his analyses merit careful consideration.

Chapter IV is devoted to the optics of beam-splitting cameras for obtaining color-separation negatives, and Chapter V covers the use of the so-called bi-pack system for achieving the same result. In Chapter VI the author returns to the theory of analysis and synthesis, giving a somewhat more consistent treatment of the question than space permitted in the first hasty survey; and in Chapter VII under the heading of *Phenomena of Color Vision and the Making of Films in Color*, he discusses after-images, color fatigue, simultaneous contrast, color and spatial harmony, color standards, color scores and the future, economically and aesthetically. An appendix reprints the *Glossary of Color Terms* of the Color Committee of the Society of Motion Picture Engineers.

The book is well written, contains a wealth of valuable material, and at the same time is pleasant reading Considering the nature of the task and the space available, the author must be complimented upon the quantity of material included. The beginning student of the subject, however, will do well to read slowly and consider carefully as he reads. The facility of Major Klein's writing, we are afraid, may lead many into feeling that they know all about the subject after one reading, and so perhaps tend to increase the number of inexperienced experts that the Major so justly condemns.

To mention an omission in a book of this sort is little short of injustice, and yet, after a rather frightening discussion of the effects of after-images and color fatigue, it rather surprised the reviewer to find no mention of a subject that has caused much more confusion in practice—the problem of psychological white. It is well known in physiological optics that an untrained—and perhaps also a trained—observer tends to accept as white the general illumination of his surroundings. A layman, confronted in daylight surroundings with a picture that reproduced exactly the hue, contrast, and saturation of the room in which he spent the previous evening would simply denounce the picture as obviously ridiculous. The same holds for a picture taken half an hour before sundown. On the other hand, he would *not* insist that artificial light is not at all yellow. The problem becomes, then, one of reproducing what the person who sees the picture *thinks he would have seen* if he were present. By the same reasoning it seems to the reviewer that the situation in the theaters is somewhat less of a problem than it appears to the author of this book. If the sequences are correctly *balanced* for color, then there is a very considerable range of color-temperature through which the color of the projection light may vary without unpleasant consequences, provided only that it remains constant during the entire picture!

We were surprised to learn on page 103 that all color negatives should be developed to a gamma of about 0.65, and that an observer whose color response is not normal would not enjoy a motion picture in natural color—but enough, it is a good book.

R. M. EVANS

"Cine Titling Simplified"; H. B. Abbott, *Link House Publications, Ltd.*, London, 1936; 83 pp.

An amateur film without titles is usually rather uninteresting, and the author comments aptly in his introduction—"Every cine film that is worth taking is worth editing and titling." He also points out that the book is not intended to cover the subject of editing; only that of titling. Styles of letters are discussed, and various commercial titling outfits are described. Chapters deal with size and design of title cards, camera distances, and supplementary lenses. If he so desires, the amateur may develop his own title films, and directions for this are included. Special effects are covered in the closing chapter. The handbook is well illustrated and indexed.

G. E. MATTHEWS

"Documentary Film"; Paul Rotha, *Faber & Faber, Ltd.*, London, 1936; 272 pp.

According to the publisher's review, the word *documentary* has the connotation, *providing evidence*. The documentary film, therefore, is intended to provide evidence of the subject matter of the world in which we live, "its climates, peoples, occupations, and problems." The *Times* (London) defines it as "the art of skilled and faithful reporting, depending for its success upon the ability to use the camera to build up an interesting and dramatic picture of the life led and the work done in the world of everday reality."

The book is divided into four sections, as follows: *I.* Introduction to Cinema; *II.* The Evolution of the Documentary; *III.* Some Principles of Documentary; *IV.* Documentary in the Making. An appendix lists the documentary directors and their films. There are 63 illustrations from documentary films.

G. E. MATTHEWS

OPEN FORUM

Correspondence is invited from readers of the Journal on any subjects relating to the contents of the Journal, the welfare and conduct of the Society, or the technical interests of the motion picture industry. The publication of such material is at the discretion of the Board of Editors.

March 14, 1937

Society of Motion Picture Engineers
Gentlemen:

During the past year or two, the awkwardness of the rather cumbersome term "black-and-white," when frequently and unavoidably used in the current literature pertaining to color motion pictures, has become increasingly obvious, and perhaps the time has now arrived when an abbreviation may logically be proposed, with the chances favoring its general adoption.

In various industries—mentioning only one class of human activity—abbreviations necessitated for reasons of facility, of some very frequently used technical terms, have become familiar to the public, while their originals have either lapsed into disuse, or were never generally known. For instance, the popularly quoted letters "T.N.T." refer to trinitrotoluene; a tongue-twister and memory test. Other familiar abbreviations that come to mind readily are: a-c., d-c., rpm., U.S.P.; and it may be said, incidentally, that while the man in the street is compelled to recognize a-c. and d-c. as specifications when buying electrical appliances, yet, more often than not, he is unable to explain just what they represent. These abbreviations fit very well on name-plates, labels, bills, receipts, advertisements, and in the extensive technology of industry.

As color in motion pictures, and concurrently, still photography, becomes more widespread, its literature (scientific, technical, patent, philosophical, topical, and legal) increases in volume and is definitely handicapped by the necessarily frequent use of the horse-and-buggy term "black-and-white," for which there is no apt substitute in a shorter expression such as monochrome, monotone, black-tone, uncolored, non-color, and the like. These inept terms have all been used haphazardly and indecisively. To explain—monochrome describes photographic images of a single continuous color-tone of any given color, as well as "black-tone." Monotone is also a misnomer; it applies in elocution. A like error would be to suppose that radiograph is included in the terminology of wireless communication, whereas it denotes X-ray negative.

The abbreviation "b.w." ought to be included in a future revision of the SMPE Color Glossary, as a proposed term, to be coupled in use with other names, *e. g.*, camera, laboratory, department, division, lighting, negative, production, picture, photograph, photography, printer, print, positive, image, film, projection, version, *etc.*—whenever color photography forms the topic, partly or wholly, of a technical article, a patent, or other literature. The "b.w. negative" may appear superfluous, inasmuch as colorfilm negatives (termed in other branches of photography as color-separation negatives), are just as free of apparent coloration. Nevertheless, both types of finished negative must be separately distinguished at one time or another. Additionally, there is such a thing as a multicolored negative, in at least one obscure process, which exhibits coloring completely within the confines of each individual frame of the negative. The "b.w. version" of a colorfilm production obviously means release prints as printed from a selected color component of the colorfilm negative, or from a dupe thereof.

A term complementary to "b.w.," denoting color motion picture, has yet to be proposed, and very likely may well turn out to be the already existing coined word colorfilm, the use of which can be traced twenty years back to the demonstration of "Colorfilms" at Wurlitzer Hall, New York City, the evening of November 16, 1916. The word finds present-day use in the title of a concern promoting a lenticulated colorfilm process.

MICHAEL ROBACH

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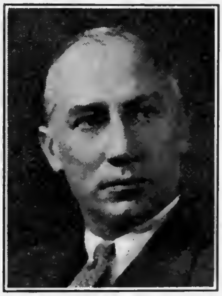

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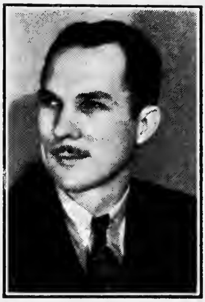

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SPRING, 1937, CONVENTION

SOCIETY OF MOTION PICTURE ENGINEERS

HOLLYWOOD-ROOSEVELT HOTEL

HOLLYWOOD, CALIF.

MAY 24th–28th, INCL.

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Headquarters

Headquarters of the Convention will be the Hollywood-Roosevelt Hotel, where excellent accommodations are assured. A reception suite will be provided for the Ladies' Committee, and an excellent program of entertainment will be arranged for the ladies who attend the Convention.

Special hotel rates, guaranteed to SMPE delegates, European plan, will be as follows:

One person, room and bath	$ 3.50
Two persons, double bed and bath	5.00
Two persons, twin beds and bath	6.00
Parlor suite and bath, 1 person	9.00
Parlor suite and bath, 2 persons	12.00

Room reservation cards will be mailed to the membership of the Society in the near future, and everyone who plans to attend the Convention should return his card to the Hotel promptly in order to be assured of satisfactory accommodations. Special garage rates will be provided for SMPE delegates who motor to the Convention.

Railroad Fares

The dates of the Convention have been chosen in order that delegates may avail themselves of the summer tourists' rates, which go into effect May 15th. The following table lists the railroad fares and Pullman charges:

City	Railroad Fare (round trip)	Pullman (one way)
Washington	$126.20	$20.50
Chicago	86.00	15.75
Boston	144.25	22.25
Detroit	101.70	18.00
New York	138.35	21.75
Rochester	119.95	19.25
Cleveland	105.65	18.00
Philadelphia	133.10	21.00
Pittsburgh	113.05	18.75

The railroad fares given above are for round trips, forty-five day limits. Arrangements may be made with the railroads to take different routes going and coming, if so desired, but once the choice is made it must be adhered to, as changes in the itinerary may be effected only with considerable difficulty and formality. Delegates should consult their local passenger agents as to schedules, rates, and stop-over privileges.

New streamlined trains will be operating from Chicago to Los Angeles and San Francisco, making the trip to Los Angeles in 39 hours. Special fares are levied on these trains.

Semi-Annual Banquet

The Semi-Annual Banquet of the Society will be held at the Hotel on Wednesday, May 26th. 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.

Inspection Tours and Diversions

Arrangements have been made to visit several of the prominent Hollywood studios, and passes will be available to registered members to several Hollywood motion picture theaters. Arrangements may be made for golfing and for special trips to points of interest in and about Hollywood.

Ladies' Program

An especially attractive program for the ladies attending the Convention is being arranged by Mrs. K. F. Morgan and Mrs. P. Mole, *hostesses*, and their Ladies'

Committee. A suite will be provided in the Hotel, where the ladies will register and meet for the various events upon their program.

Points of Interest

En route: Boulder Dam, Las Vegas, Nevada; and the various National Parks.

Hollywood and vicinity: Beautiful Catalina Island; Zeiss Planetarium; 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 SMPE motion picture exhibit); Mexican village and street, Los Angeles.

TENTATIVE PROGRAM

MONDAY, MAY 24th

9:00 a. m. **Registration;** *Blossom Room.*

10:00 a. m. to 12:00 p. m. *Blossom Room;* **Business and General Session.**

Opening Remarks by President S. K. Wolf. (*10 Min.*)

Report of the Convention Committee; W. C. Kunzmann, *Convention Vice-President.* (*5 Min.*)

Report of the Membership Committee; E. R. Geib, *Chairman.* (*5 Min.*)

Report of the Papers Committee; G. E. Matthews, *Chairman.* (*5 Min.*)

"Progress in the Motion Picture Industry;" Report of the Progress Committee; J. G. Frayne, *Chairman.* (*20 Min.*)

Report of the Historical Committee; E. Theisen, *Chairman.* (*10 Min.*)

"Soft X-ray Motion Pictures of Small Biological Specimens;" H. F. Sherwood, Kodak Research Laboratories, Rochester, N. Y. (*Demonstration.*) (*15 Min.*)

"Educational Film Progress and Problems;" S. K. Wolf, Erpi Picture Consultants, Inc., New York, N. Y. (*Demonstration.*) (*25 Min.*)

12:30 p. m. *Florentine Room;* **Informal Luncheon.**

For members, their families, and guests. Brief addresses by prominent members of the industry.

2:00 p. m. to 5:00 p. m. *Blossom Room;* **Studio Session.**

"The London Film Studios at Denham, England;" L. Fermaud and J. Okey, London Film Productions, Ltd., Denham, Middlesex, England. (*20 Min.*)

"The Evolution of Special Effects Photography from an Engineering Viewpoint;" F. W. Jackman, Hollywood, Calif. (*Demonstration.*) (*25 Min.*)

"Special Engineering Problems in a Motion Picture Studio;" W. Strohm, Twentieth Century-Fox Film Corp., Hollywood, Calif. (*20 Min.*)

"A New Viewpoint on the Lighting of Motion Pictures;" G. Gaudio, A.S.C., Hollywood, Calif. (*Demonstration.*) (*25 Min.*)

"Recent Developments in Motion Picture Set Lighting Equipment;" E. C. Richardson, Mole-Richardson, Inc., Hollywood, Calif. (*15 Min.*)

"Light-Weight Stage Pick-Up Equipment;" L. D. Grignon, Paramount Productions, Inc., Hollywood, Calif. (*15 Min.*)

8:00 p. m. to 11:15 p. m. **Studios of Universal Pictures Corporation,** Universal City, Calif. (*Special Evening Demonstration*) "How Motion Pictures Are Made."

8:00 p. m. **Assemble on Stage 10.**

8:10 p. m. Cartoon—*Oswald* or *Meenie Miney & Mo.*

8:20 p. m. Welcome to Universal—Charles R. Rogers, *Vice-President in Charge of Production.*

8:23 p. m. "Reading a Story for Production;" Martin Murphy, *Production Manager.* (Story conference, shooting scripts, scheduling players and equipment.)

8:35 p. m. "Prescoring for Musical Pictures;" Bernard Brown, *Chief Music and Dubbing Mixer.* (*Demonstration.*)

8:50 p. m. **Adjourn to production stage.**

9:05 p. m. "Set Design from Script to Stage;" illustrated by the set used for remainder of this program, John Harkrider, *Set Designer.*

9:15 p. m. "Production Handling of Lighting Equipment;" Frank Graves, *Chief Electrical Engineer.* (*Demonstration.*)

9:25 p. m. "Lighting for Long Shots and Close-Ups;" Joe Valentine, *Cinematographer.* (*Demonstration.*)

"Sound Pick-Up on a Production Basis;" William Hedgcock, *Production Mixer.* (Close-ups, long shots, mike shadows.)

"The Director's Problem;" Edward Buzzell, *Director.* (*Demonstration.*)

10:15 p. m. **Return to Stage 10.**

10:30 p. m. Projection of "dailies" made in the demonstration above.

10:35 p. m. "Editing Motion Pictures;" Maurice Pivar, *Chief Editor.* (*Demonstration.*)

10:55 p. m. "Setting Music to Motion Pictures;" Charles Previn, *Musical Director.*

11:15 p. m. "Assembling a Final Sound-Track;" Edwin Wetzel, *Dubbing Mixer.* (*Demonstration.*)

TUESDAY, MAY 25th

10:00 a. m. to 12:30 p. m. *Blossom Room;* **Color Session.**

"Color Print Processes;" O. O. Ceccarini, Metro-Goldwyn-Mayer Studios, Culver City, Calif. (*45 Min.*) A comprehensive exhibit of color stills by various studios and leading color photographers throughout the country will be on display in the Hollywood-Roosevelt Hotel in conjunction with Mr. Ceccarini's paper.

"The New Agfacolor Process;" Agfa Ansco Corporation, Binghamton, N. Y. (*25 Min.*)

Report of the Color Committee; J. A. Ball, *Chairman.* (*10 Min.*)

"Advanced Technic of Technicolor Lighting;" C. W. Handley, National Carbon Co., Cleveland, Ohio. (*20 Min.*)

"Some Lighting Problems in Color Cinematography;" T. T. Baker, Dufaycolor, Inc., New York, N. Y. (*Demonstration.*) (*20 Min.*)

2:00 p. m. to 5:00 p. m. *Blossom Room;* **Instruments Session.**

"Twenty Years of Development in High-Frequency Cameras;" H. Joachim, Zeiss-Ikon Aktiengesellschaft, Dresden, Germany. (*25 Min.*)

"A High-Precision Sound-Film Recording Machine;" H. Pfannenstiehl, Bell Telephone Laboratories, Inc., New York, N. Y. (*20 Min.*)

"A Dynamic Light-Valve;" E. Gerlach and H. Lichte, Klangfilm G.m.b.H., Berlin, Germany. (*25 Min.*)

"A Dubbing Rehearsal Channel;" H. G. Tasker, Universal Pictures Corp., Universal City, Calif. (*25 Min.*)

"An Automatic Sound-Track Editing Machine;" G. M. Best, Warner Brothers Pictures, Inc., Burbank, Calif. (*15 Min.*)

Symposium on Transmission Meters.

"A Transmission-Measuring System Utilizing a Graphic Recording Meter;" W. W. Lindsay, Jr., General Service Studios, Hollywood, Calif. (*10 Min.*)

"A New Instrument for Producing Automatically a Graphic Record of Audio-Frequency Characteristics;" A.D. MacLeod, Tobe Deutschmann Corporation, Canton, Mass. (*10 Min.*)

"A Continuous Level Recorder for Routine Studio and Theater Measurements;" G. M. Sprague and J. K. Hilliard, Metro-Goldwyn-Mayer Studios, Culver City, Calif. (*10 Min.*)

"A Curve-Plotting Transmission Meter;" L. A. Aicholtz, Universal Pictures Corporation, Universal City, Calif. (*10 Min.*)

"A Curve-Plotting Transmission Meter;" L. D. Grignon, Paramount Productions, Inc., Hollywood, Calif. (*10 min.*)

8:00 p. m. to 10:30 p. m. **Metro-Goldwyn-Mayer Studios,** Culver City, Calif. (*Special Evening Demonstration.*)

Projection and discussion of outstanding films illustrating (*1*) Sound Quality, (*2*) Color, (*3*) Special Effects, (*4*) Unusual Photography. Arranged by the technicians of the Hollywood studios.

WEDNESDAY, MAY 26th

10:00 a. m. to 12:30 p. m. *Blossom Room;* **Acoustics and Sound Session.**

"Recent Progress in Acoustics;" V. O. Knudsen, Professor of Physics and Dean of Graduate Study, University of California, Los Angeles, Calif. (*25 Min.*)

"Mathematical Relations between Grain, Background Noise, and Characteristic Curve of Sound-Film Emulsions;" W. J. Albersheim, Electrical Research Products, Inc., New York, N. Y. (*25 Min.*)

"Improved Noise-Reduction System for High-Fidelity Recording;" H. J. Hasbrouck, J. O. Baker, and C. N. Batsel, RCA Manufacturing Co., Inc., Camden, N. J., and Hollywood, Calif. (*25 Min.*)

"A Device for Direct Reproduction from Variable-Density Sound Negatives;" W. J. Albersheim, Electrical Research Products, Inc., New York, N. Y. (*25 Min.*)

"Sound Pick-Up Methods for Motion Pictures;" J. P. Maxfield and A. W. Colledge, Electrical Research Products, Inc., New York, N. Y. (*25 Min.*)

2:00 p. m. to 5:00 p. m. **Visit to Twentieth Century-Fox Film Corporation, Beverly Hills, Calif.**

7:30 p. m. *Blossom Room;* **Semi-Annual Banquet.**

Short addresses by eminent members of the industry; names to be announced later.

Introduction of stars and prominent guests.

THURSDAY, MAY 27th

10:00 a. m. to 12:00 p. m. **Open Morning. Studio Visits May Be Arranged through Local Committee.**

1:10 p. m. to 5:00 p. m.

Blossom Room; **Laboratory and Projection Session.**

"Changing Aspects of the Film Storage Problem;" Capt. J. G. Bradley, National Archives, Washington, D. C. (*20 Min.*)

"Report of the Projection Practice Committee;" H. Rubin, *Chairman.* (*25 Min.*)

"A Wide-Range, Linear-Scale, Photoelectric Cell Densitometer;" W. W. Lindsay, Jr., General Service Studios, Inc., Hollywood, Calif., and W. V. Wolfe, RCA Manufacturing Co., Inc., Hollywood, Calif. (*25 Min.*)

"Standardization of Photographic Density;" C. Tuttle and A. M. Koerner, Kodak Research Laboratories, Rochester, N. Y. (*20 Min.*)

"Objective Quantitative Determination of Graininess in Photographic Emulsions;" A. Goetz, Associate Professor of Physics, California Institute of Technology, Pasadena, Calif.

"Sound-Track Blooping;" F. D. Williams, Williams Laboratory, Hollywood, Calif. (*20 Min.*)

"Toning Positive Film by Machine Method;" J. M. Nickolaus, Metro-Goldwyn-Mayer Corporation, Culver City, Calif. (*20 min.*)

"Fixing Baths and Their Properties;" J. I. Crabtree, H. Parker, Jr., and H. D. Russell, Kodak Research Laboratories, Rochester, N. Y. (*20 Min.*)

8:00 p. m. to 10:30 p. m.

Blossom Room; **Meeting of the Research Council and the Technician's Branch of the Academy of Motion Picture Arts and Sciences;** William Koenig, *Chairman*, Research Council; Major N. Levinson, Vice-Chairman, Research Council and *Chairman*, Technicians Branch.

Members and guests of the SMPE are cordially invited.

"Coöperative Technical Program of the Research Council of the Academy of Motion Picture Arts and Sciences;" W. Koenig, *Chairman*, Research Council. (*20 Min.*)

"The Work of the Committee on Standardization of Theater Sound Projection Equipment Characteristics;" J. K. Hilliard, *Chairman.* (*25 Min.*)

"Standard Density Measuring Device for Release Printing Laboratories;" L. E. Clark, *Chairman*, Committee on Improvement in Release Printing Quality. (*25 Min.*)

"Screen Illumination in Relation to Picture Quality;" J. O. Aalberg, *Chairman*, Screen Illumination Committee. (*25 Min.*)

"Camera Noise Analysis Tests and an Account of the Establishment of Standard Methods for Measuring Camera Noise;" V. E. Miller, *Chairman*, Silent Camera Committee. (*25 Min.*)

"Observations on Hollywood Production in Relation to the Production of Army Training Films;" R. T. Schlosberg, *Capt. U. S. Army Signal Corps.;* now on duty as a student with the Academy of Motion Picture Arts and Sciences. (*25 Min.*)

FRIDAY, MAY 28th

10:00 a. m. to 12:30 p. m. *Blossom Room;* **Apparatus Symposium and Manufacturers' Announcements.**

"The Super Simplex Pedestal;" J. Frank, Jr., International Projector Corporation, New York, N. Y. (*15 Min.*)

"A Film Mutilator Machine;" O. F. Neu, Neumade Products Corporation, New York, N. Y. (*Demonstration.*) (*15 Min.*)

"Complete Cue-Mark Elimination Plus an Automatic Change-Over;" S. A. McLeod, Los Angeles, Calif. (*15 Min.*)

"Magnetic Recording-Reproducing Machine for Objective Speech Study;" S. J. Begun, New York, N. Y. (*Demonstration.*) (*15 Min.*)

"Infrared Negative as Applied to Special Effects Photography;" G. W. Hough and W. Leahy, Agfa-Ansco Corporation, Hollywood, Calif. (*Demonstration.*) (*15 Min.*)

"Laboratory Equipment for the Smaller Laboratory;" Arthur Reeves, Hollywood, Calif. (*15 Min.*)

"Two New Emulsions for Duplicating Work;" Eastman Kodak Co., Hollywood, Calif.

"Cine Kodak Model *E;*" L. R. Martin, Eastman Kodak Company, Rochester, N. Y. (*15 Min.*)

2:00 p. m. to 5:00 p. m. *Blossom Room;* **Sound Equipment Symposium.**

"Present Aspects in the Development of 16-Mm. Sound;" A. Shapiro, The Ampro Corporation, Chicago, Ill. (*20 Min.*)

Report of the Non-Theatrical Equipment Committee; R. F. Mitchell, *Chairman.* (*10 Min.*)

"The SMPE Test Film for 16-Mm. Sound-Film;" M. C. Batsel, RCA Manufacturing Co., Inc., Camden, N. J. (*Demonstration.*) (*10Min.*)

"A Sound Kodascope;" E. C. Fritts and O. Sandvik, Eastman Kodak Company, Rochester, N. Y. (*Demonstration.*) (*25 Min.*)

Report of the Standards Committee; E. K. Carver, *Chairman.*

Report of the Sub-Committee on Film Perforation; J. A. Dubray, Chairman. (*20 Min.*)

"A Combination Picture and Non-Slip Ultraviolet Automatic Printer;" O. B. Depue, Chicago, Ill. (*Demonstration.*) (*20 Min.*)

"Recent Advances in Recording Galvanometers;" G. L. Dimmick, RCA Manufacturing Co., Inc., Camden, N. J. (*20 Min.*)

"The RCA Recording System and Its Adaptation to Various Types of Sound-Track, with Demonstration of Recent Recordings of the Class *A* Push-Pull Type;" G. L. Dimmick, RCA Manufacturing Co., Inc., Camden, N. J. (*20 min.*)

"A Linear Decibel Scale Volume Indicator;" F. G. Albin, United Artists Corp., Hollywood, Calif. (*15 Min.*)

8:00 p. m. to 10:00 p. m. *Blossom Room;* **Television Session.**

"RCA Developments in Television;" Ralph R. Beal, *Research Supervisor*, Radio Corporation of America, New York, N. Y. (*1 Hour.*)

ABSTRACTS OF PAPERS FOR THE HOLLYWOOD CONVENTION MAY 24–28, 1937

The Papers Committee submits the following abstracts of papers for the consideration of the membership. It is hoped that the publication of these abstracts will encourage attendance at the meeting and facilitate better discussion of the papers.

G. E. MATTHEWS, *Chairman*

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L. N. BUSCH	M. E. GILLETTE	P. R. VON SCHROTT
O. O. CECCARINI	E. W. KELLOGG	H. C. SILENT
A. A. COOK	R. F. MITCHELL	H. G. TASKER
L. J. J. DIDIEE	W. A. MUELLER	I. D. WRATTEN
	E. C. RICHARDSON	

Local Committee

W. A. MUELLER, *Chairman*
L. A. AICHOLTZ, *Secretary*

C. N. BATSEL	E. C. RICHARDSON	H. C. SILENT
O. O. CECCARINI		H. G. TASKER

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

Further renovation of obsolete sound and picture equipment and continued expansion of studio floor space and facilities were noted during the past year. Another stimulant to the aroused interest in color processes was given by the announcement of a new three-color subtractive process. A multi-layer emulsion contains components in the three separate layers which react with the developing solution to produce dye images *in situ* in the layers. The completely unblimped camera has still to be adapted for modern sound pictures but a number of refinements were introduced in mechanisms and lenses. A growing tendency to use less general illumination and more effect lighting was noted.

Push-pull recording announced a year ago has made rapid inroads against previously employed systems. One type of light-valve uses four ribbons for recording all push-pull tracks. Following the lead of the Fletcher two-way horn development, systems incorporating the fundamental principles of this reproducer came into widespread use. Commercial equipment for push-pull recording with ultraviolet radiation was installed in several production centers here and abroad. The use of non-slip printers was extended considerably as a further laboratory refinement.

In the 16-mm. field, new emulsions were made available for ordinary and color photography, and several new cameras and projectors were announced. A gradual but definite invasion of the 35-mm. field was noted as equipment for use in small auditoriums was being adopted. Such installations would probably not compete directly with 35-mm. equipment but would augment such equipment.

Summaries of the motion picture progress in Great Britain, Germany, and Austria are appended to the report.

"Soft X-ray Motion Pictures of Small Biological Specimens;" H. F. Sherwood, *Eastman Kodak Co.*, Rochester, N. Y.

Soft x-rays have been used in radiographing leather, textiles, paper, biological specimens, *etc.* The most recent application is in recording soft x-ray motion pictures directly on the film, using a special emulsion having a high sensitivity to soft x-rays. Radiographs were made at a speed of 16 frames per second.

The camera used was a universal model *C*, with the lens removed and a piece of infrared gelatin filter (Wratten No. *87*) covering the gate to protect the film from light, and at the same time, to furnish a support for the subject. The camera shutter absorbs the soft x-rays from the tube during the short exposures between frames, thus allowing continuous operation of the tube.

A special form of x-ray tube fitted with an extremely thin window is required for the production of radiation suitable for radiographing thin subjects.

Soft x-ray motion pictures of the yellow meal worm show peristaltic waves, gas bells leaving the stomach through the mouth, and the effects of various anesthetic vapors upon the internal movements.

"Educational Film Progress and Problems;" S. K. Wolf, *Erpi Picture Consultants, Inc.*, New York, N. Y.

During the past year the educational sound-film has shown greater progress than in any previous year since its inception. In September, 1936, it overcame a possible crisis when a 16-mm. standard was adopted and ratified at Budapest by the International Standards Association. The increase in production of films and sale of projection apparatus and films has more than doubled any previous year's activities in Europe and in this country. Abroad the 16-mm. educational film has been subsidized and assisted in a number of ways. In Hungary, Germany, and other countries, school children are taxed to support the production of educational sound-films. In some countries educational sound-films are being exhibited on entertainment programs. Objective experiments have been continued with new productions, adding to the already overwhelming evidence of the fact that the film-taught student acquires and retains more than the student instructed without films. Production technic, particularly in the field of technical animation, has shown remarkable improvement.

Producers in coöperation with school authorities have developed a utilization program properly integrating the films into the curricula, training the teachers, and organizing a complete audio-visual program as contrasted to the former less organized use of films.

While there has been continued improvement in the engineering development of the educational film medium, there remain many unfinished problems that must be solved before the educational film can realize its full pedagogical and commercial potentialities. The quality requirements of the teaching film are substantially the same as those of the entertainment film. The mechanical and optical requirements are more severe. The educational film already feels the need for a color process, which thus far is not available. Different negative and print materials will probably be necessary for educational pictures. Better light-sources for the 16-mm. projection will be required. The operation of the projection equipment must be simplified if it is to be used as a universal classroom teaching tool. The noise created by the operation of present projectors is distracting, and must be reduced to a level not in excess of 40 decibels. This presents a real acoustical engineering problem. The responsibility for the solution of these problems lies with the motion picture engineers, and offers a real challenge to the profession as well as a great opportunity.

The educational film needs the whole-hearted support of the entire motion picture industry, and, in particular, that of the major producers, whose wealth of educational material will give a great impetus to educational films. Perhaps the greater immediate need of the educational film is more adequate distribution.

"Denham Studios of London Film Productions, Ltd.;" L. C. Fermaud and J. Okey, *London Film Productions, Ltd.*, Denham, Middlesex, England.

The studios occupy 28 acres of a 165-acre estate in Buckinghamshire, about 17 miles from the center of London. Fine gardens stretching to the edge of dense woodland provide a natural setting that can be adapted easily for exterior photography. There are seven stages, totalling 120,000 square-feet of floor area. Two stages are 250 by 120 by 45 feet (high); two are 125 by 120 by 45; and three are 120 by 80 by 35. Details of the foundation and wall construction are given. The main reviewing theater is designed for reviews and for scoring; for the latter the reverberation period can be adjusted to 0.8 second and for the former, 1.5 seconds.

A description is included of the various shops that service the studios, not only for set construction but also for equipment. The Metal Shop, for example, has turned out over 700 lamps for set lighting, two optical printers, a projection printer, a stop-motion machine, and a rear projector.

In the sound stages, only the dubbing channel is of the permanent type. A brief description is given of the portable sound channels, the camera department, and the processing laboratories. Two automatic developing machines, capable of developing 480 and 1000 feet per hour, are available for film processing. Automatic mixing equipment is used for preparation of solutions.

The electrical power plant is described and details are included on fire protection, water supply, and sewage disposal.

"The Evolution of Special-Effects Photography from an Engineering Viewpoint;" F. W. Jackman, *A.S.C.*, Hollywood, Calif.

The development, and particularly the present status, of special-effects photography is discussed. In the early days, special-effects photography, or "trick camerawork," as it was called then, was not only mechanically crude, but was treated virtually as a matter of "black magic." The desired effects, although achieved more frequently by luck than by skilled intent, were almost invariably held as the closest of trade secrets—or more correctly, as personal secrets of the cameraman.

With the general advancement of the business and of the individuals therein, this condition has vanished to a large extent. Today there are definite, well-established classifications of this type of photography, governed by laws as positive as those covering any other branch of engineering. In building a bridge, for instance, the structural engineer knows that if a given load is to be carried, the supporting members must be of certain specifications. In the same way, the special-effects photographic engineer knows that if a certain effect is to be had, the components of his shot must be properly coördinated. In a miniature, a known scale in the model, combined with equally known factors of lens, camera, speed, *etc.*, will combine to produce a natural effect, while any deviation from any of these will appear artificial. The same holds true of the back-ground projection composite process, optical printing, and the like. In a word, the modern special-effects cinematographer who succeeds is the one who tackles his problems from an engineering, rather than a wonder-working point of view.

"Special Engineering Problems in a Motion Picture Studio;" W. Strohm, *Twentieth Century-Fox Film Corporaticn,* Beverly Hills, Calif.

The Engineering Department at the Twentieth Century-Fox Film Corporation Studios is responsible for the various technical operations of the studio, which can be classified under the headings of Air-Conditioning, Plumbing, Foundry Mechanical, or Electrical activities.

The responsibilities enumerated above cover a considerable portion of the technical activities of a studio, and a great deal of effort is required to take care of the routine matters that arise each day. However, the interesting work of this department lies in the special engineering problems that arise in the production of motion pictures. A solution of these problems is made much more difficult because they must always be solved satisfactorily in a very short space of time. Also, due to the motion picture requirements, commercial equipment is usually not satisfactory, and suitable equipment must be designed and built in the studio.

This paper describes some of the various engineering problems that have been encountered in the production of motion pictures at this studio.

"A New Viewpoint on the Lighting of Motion Pictures;" G. Gaudio, *A.S.C.*, Hollywood, Calif.

The lighting of motion pictures is discussed, with relation to a new technic developed by the author and employed in several recent productions, notably *Anthony Adverse* and *The Life of Emile Zola.*

The use of artificial lighting for motion picture scenes originated with attempts to imitate the flat overall illumination produced by daylight on the early "daylight stages." When the concepts of modelling and effect lighting were introduced, they were regarded merely as adjuncts to an overall flat general lighting. They have, in the main, so continued until today, despite the great advances made in optics and sensitive materials.

The author holds that under modern conditions, this technic is faulty. He has therefore dispensed with the so-called "general lighting," and has for some time done all his lighting with various types of spotlighting units. This enables him to light more precisely; to accommodate his effects and his equipment to the physical requirements of modern production technic; and to achieve more natural effects upon the screen.

The paper will be illustrated by motion pictures showing scenes discussed in the paper, from recent productions and possibly from some earlier productions.

"Recent Developments in Motion Picture Set Lighting;" E. C. Richardson, *Mole-Richardson, Inc.,* Hollywood, Calif.

The basic principles of motion picture set lighting are outlined and the technic of "key" lighting, employed by most cinematographers, is discussed.

Several new types of lamps that have found extensive use are described in detail. Technical data regarding them are presented along with information regarding their application in cinematography.

"Light-Weight Stage Pick-Up Equipment;" L. D. Grignon, *Paramount Productions, Inc.*, Hollywood, Calif.

In the past year and a half light-weight microphones and new pick-up equipment have been made available. This paper describes certain apparatus designed and built to take full advantage of the newly acquired features. The apparatus described in the paper consists of a fish-pole type of microphone boom with accessories and a complete stage pick-up unit.

The microphone boom is readily adaptable to a number of pick-up conditions where light weight, small size, and ease of handling are necessary.

The stage pick-up unit is readily portable and of relatively small weight and size. It includes the pick-up amplifier, booster amplifier, and power supply, with a small amount of storage space. It completely replaces the large type of monitoring booth previously employed. The weight of the unit being about 300 pounds, a great saving in operating costs is effected and greater simplicity of operation achieved.

"Color Print Procsses;" O. O. Ceccarini, *Metro-Goldwyn-Mayer Studios*, Culver City, Calif.

Color photography applied to publicity stills represents a very valuable asset for the motion picture industry. The demand for high-quality results and speed places color stills in a special class of their own, and therefore the discussion of the various methods for obtaining color-separation negatives is carried out essentially upon the basis of these requirements. For the production of sample prints on paper, many of the available methods are discussed, such as carbon, carbro, dye transfer, chemical toning, *etc.*, emphasis being placed upon the methods that are capable of giving results most suitable to the needs of motion picture industry. The general discussion and the extensive bibliography should be found valuable by those who wish to study the subject of color photography in greater detail.

"The New Agfacolor Process;" *Agfa Ansco Corp.*, Binghamton, N. Y.

A survey of the history of monopack or multilayer photographic color processes is given, including the coloring methods of greatest importance at the present time. These are: (*a*) silver dye-bleaching methods and (*b*) silver dye-coupling methods. Silver dye-coupling methods appear to be most promising, and have been successfully applied to monopack films according to two distinct principles.

In one method, color-forming compounds are added to the developing solutions. Color separation in this method depends upon control of the speed at which bleaching solutions penetrate superposed emulsion layers.

In the second method, employed in the new Agfacolor process, the different color-forming substances, instead of being added to the developing solution, are incorporated in emulsions that are coated in superposition so that three differently colored images are simultaneously formed in a single development. The metallic silver is subsequently removed by solvents leaving only pure dye images.

This new process is based upon the pioneer work on color-forming methods of R. Fischer who, before the World War, developed the process substantially as it is now being used. The contributions made by Agfa in improving this process are the perfection of dyestuff coupling components better than those available to Fischer, improved methods of preventing diffusion of the color-forming compounds, and methods of precisely controlling the manufacture of multilayer film upon a large scale, so that the present film is the practical expression in commercial form of Fischer's process.

Report of the Color Committee; J. A. Ball, *Chairman.*

The Eastman perforation, although adopted by the Society as a standard for positive and negative film, has certain disadvantages for use in connection with color processes and for background projection. The reasons for these limitations are analyzed, and a proposal is made that the important advantages of the Eastman filleted rectangular shape be retained in a perforation, the dimensions of which are the same as those of the Bell & Howell perforation. Such a perforation would fit existing Bell & Howell registering pins.

The use of a photocell having most of its sensitivity outside the visible spectral region imposes an added burden to those working upon color sound processes. Search is urged for a cell that would have all the advantages of existing caesium cells but with its chief sensitive response in the visible range.

The term "Direct Color Developer Process" is recommended for a color process wherein non-diffusing color-formers in the emulsion (multiple-layer) combine with the oxidation products of the developer to form insoluble dyes. A process of this type was introduced recently by Agfa.

"Advanced Technic of Technicolor Lighting;" C. W. Handley, *National Carbon Co.*, Cleveland, Ohio.

Within the past several months the technic of lighting Technicolor motion pictures has changed from more or less flat, evenly illuminated sets of high light level to a method whereby the cinematographer now uses a much lower level of general illumination and has greater freedom with the use of "modelling" lamps.

Recent developments in arc lamps for use in Technicolor lighting are discussed. The changed technic of lighting, made possible by the new equipment and the laboratory advancements, is briefly explained. The uses of each type of illuminant, diffusion screens, black screens, and other lighting-control devices are described. An explanation is given of the part taken by the chief set electrician, or "gaffer," in lighting motion picture sets.

"Some Lighting Problems in Color Cinematography;" T. T. Baker, *Dufaycolor, Inc.*, New York, N. Y.

In an additive process of color photography it is generally conceded that the primaries used are blue-violet, green, and orange bands of the spectrum, which overlap to some extent in the transmissions, and are not narrow and sharply divided. It is also well known that the latitude in exposure of a color-screen process is smaller as compared to that of black-and-white negative stock. Underexposures will frequently tend to excessive blue, and overexposures to some other predominant color, these effects being in some measure due to differences in the shapes of the foot and shoulder of the characteristic curves of an emulsion when exposed to light of the three spectral areas used. But overexposure will always result in a dilution of the colors. This is due to the invasion of each primary into its neighbor's territory. There is thus a color saturation latitude in the screen or matrix, as distinct from a true emulsion latitude. The object of this paper is to discuss a method of calculating the approximate range of light-intensities that can be used in studio lighting while maintaining the most correct color balance of which any particular additive color process may be capable.

In the case of Dufaycolor film, a wedge spectrogram representing average exposure is taken, the steepness of the wedge being of a suitable range, such as from a density of 0 to 2.5. This spectrogram, on development and reversal, shows the peaks throughout the wedge spectrum as completely saturated, (*i. e.*, 100 per cent of the reseau or matrix saturation). But as any particular spectral zone is followed from the peak downward, toward the base-line, it is seen that as the image approaches the base-line, and therefore approaches maximum exposure, the color becomes diluted and may even turn to white.

This is caused by the fact that, upon overexposure, a scatter effect carries the light effect behind (say) a green element into the region of neighboring blue and red elements, so that the resultant color is reseau-green plus *some* blue and red, totalling reseau-green plus white. This effect is found to be accentuated in reseau composed of less saturated color elements.

By measuring from the peak to the position in any ordinate in the spectrogram where distinct dilution of the color becomes apparent, the permissible range of light intensities on the set can be computed from the difference in log opacity of the two points on the ordinate.

Diagrams of the apparatus used and samples of the spectrograms are included in the paper, and practical examples of still and motion picture films will be shown as demonstrating the advantage of keeping the light-intensity range of the subjects photographed within that indicated by the spectrograms.

"Twenty Years of Development in High-Frequency Cameras;" H. Joachim, *Zeiss-Ikon Aktiengesellschaft*, Dresden, Germany.

The construction of the high-frequency camera of the Zeiss-Ikon Company has behind it twenty years of development. The original model was designed by H. Lehmann and appeared upon the German market in 1917 as the Ernemann high-frequency camera. The principle of this apparatus is based upon optical compensation, to which end a reflecting drum with exterior mirrors was employed as compensating element. Films exposed with these machines exhibited a frequency up to 500 pictures per second.

The new model, which first appeared upon the market in 1930, is likewise constructed upon the principle of mirror compensation, with the difference that instead of the exterior mirrors a reflector drum is supplied with mirrors on the inside according to the patents of Professor Thorner.

In this way an extraordinarily simple driving mechanism has been obtained, as well as a specially compact form; so that with a holding capacity of approximately 60 meters of standard 35-mm. film, the size of the camera does not exceed the dimensions of a normal cine camera. The latest model permits an exposure frequency of about 1500 pictures per second.

The camera is therefore suited for practical use in technical photography of all kinds. It can be equipped with certain intermediate lenses for close-ups or with a supplementary distance tube for distance exposures. For photographing micro high-frequency films a particular apparatus has been developed.

In order to evaluate the exposures, a time-marking device is made use of, in which a glow-lamp, controlled by an electric tuning-fork, produces the time records on the film at periods of $^1/_{1000}$ sec.

The method of operating the camera, and several new and older films produced with the high-frequency filmer, will be demonstrated.

"A High-Precision Sound-Film Recording Machine;" H. Pfannenstiehl, *Bell Telephone Laboratories, Inc.*, New York, N. Y.

In this recording machine an improved type of sprocket drive mechanism is employed to propel the film at a constant velocity at the recording light-beam. In addition to the film drive and control mechanisms, the recorder is provided with several accessory devices to facilitate operation and thereby reduce the cost of sound-film production.

These accessory devices consist of a slater, which photographically records the "take" number of the record in the sound-track area; an electromagnetically operated punch mechanism, which punches an identifying notch or hole in the film; an electromagnetically operated shutter arranged to cut off the recording light-beam at an extremely high speed so that a definite and sharp cut-off point is produced on the sound-track that may be used for synchronizing purposes; and a switch mechanism to control automatically various operations of the machine in their proper sequence.

The recorder may be equipped with any of the optical systems required for recording sound on single, double, or other types of sound-track. Associated with the optical system is a photoelectric cell and amplifier unit by means of which direct monitoring of the sound being recorded may be done.

All mechanisms and devices are enclosed within the housing of the recorder and are accessible for operation. All manual controls are located upon a panel convenient to the operator on the front of the base of the recorder. Provision is made also for remote control of such devices as the slater, punch, shutter, *etc.*, as well as the starting and stopping of the machine.

This recorder may be used with either the Bell & Howell or Mitchel film magazines. The machine was developed by the Bell Telephone Laboratories in cooperation with Electrical Research Products, Inc., to meet current studio requirements.

"A New Dynamic Light-Valve;" E. Gerlach and H. Lichte, *Klangfilm G.m.b.H.*, Berlin, Germany.

A description of a new type of dynamic light-valve with oil-camped mirror used in the *Eurocord* recording equipment. Damping by oil, though influenced by temperature, is compensated automatically.

"A Dubbing Rehearsal Channel;" H. G. Tasker, *Universal Pictures Corp.*, Universal City, Calif.

Preparation of sound effects, music and, dialog tracks for the dubbing process requires accurate synchronism of each sound with the corresponding action. This is ordinarily accomplished by a preliminary step in which the synchronism of one sound-track at a time is checked against the action in a moviola, in which the picture is seen through a small viewing lens.

The image being small, the accuracy with which synchronism may be checked is not good. Hence this is followed by a final step, in which the synchronism of all tracks is checked during rehearsals in the dubbing room proper. Owing to the ponderous character of the dubbing machinery the latter process is quite slow and laborious.

This paper describes the form and use of a machine that permits accurate synchronism of the various sound-tracks with the corresponding action, but with all the mechanical freedom of the usual moviola.

The machine will accommodate six sound-tracks, with provision for controlling the output level from each, and may be instantly started, stopped, or reversed. The mechanical design facilitates threading and easy displacement of any sound-track by a known amount to bring it into synchronism. The action is projected upon a screen $4^1/_2 \times 4$ feet in size, which enables accurate observation of the degree of synchronism attained.

"A Transmission-Measuring System Utilizing a Graphic Recording Meter;" W. W. Lindsay, Jr., *General Service Studios, Inc.*, Hollywood, Calif.

The need for a graphic record of transmission measurements has been recognized for many years.

The requirements that this system attempts to fulfill are as follows:

(*1*) The equipment must be stable, rugged, and simple to operate, and the recording portion of it must be portable and operated by alternating current.

(*2*) The response must be independent of frequency from 35 to 10,000 cps., ±0.2 db., and the effects of line voltage changes must also remain within these limits.

(*3*) Effects of turn-over and wave-form errors, together with interference from stray magnetic fields at power supply frequencies, must be reduced to a minimum.

(*4*) A linear decibel scale, and a logarithmic frequency change of oscillator output with respect to time, are desirable.

(*5*) There should be accurate marking of the completed record in terms of the oscillator frequency dial calibration.

The first three requirements have been satisfactorily met, the fourth not at all, and the fifth partially so.

Experimentation with most of the generally known circuits, as well as several of our own, led us to believe it difficult to obtain a strictly linear decibel scale and at the same time provide the required degree of stability, simplicity of operation, freedom from line-voltage changes, or tube replacements. Space limitations and lack of a suitable commercially available condenser prevented adopting a logarithmic frequency change with respect to time. A cam arrangement is the most simple solution of this problem.

It has been found that the simple method of engaging the oscillator dial driving pinion at the beginning of the record has been entirely satisfactory for use as a frequency fiducial for the application of the transparent chart (which is marked in decibels and in frequencies corresponding to the oscillator dial calibration) to the graphic record.

A commercial audio oscillator and booster amplifier have been modified to provide uniform output, the frequency control being driven by means of a synchronous motor and gear train.

A high-impedance input, Class *A*, push-pull amplifier system is connected to a full-wave, approximately square-law tube rectifier, the d-c. output of which is connected to the recording meter. Tube heaters are in series across the 110-volt line, and the line voltage supply is obtained by a voltage-doubling circuit without power transformer or filter chokes. By simple means, this amplifier system has been made independent of frequency over the range of 35 to 12,000 cps.

The applications to which the equipment have been put are as follows:

(*1*) Gain runs of all kinds, including amplifiers, microphones, loud speakers, light-valves, frequency films, *etc.*

(*2*) A recording microdensitometer has been achieved by using a modulated light-source, moving the sound-track past a scanning aperture, and recording the amplified variations due to the density changes.

(*3*) As a recording volume indicator the instrument has been useful in studying recording and re-recording signal amplitudes.

(*4*) The recording meter alone has been used for making direct current or voltage records of various transient phenomena.

"A New Instrument for Obtaining Automatically a Graphic Record of Audio-Frequency Characteristics;" A. D. MacLeod, *Tobe Deutschmann Corp.*, Canton, Mass.

The requirements of the acoustical engineering profession for a practical tool to be employed in analysis of audio-frequency characteristics of such electro-acoustic devices as microphones, audio transformers, loud speakers, and amplifiers, and in the determination of sound pressure *vs.* frequency as affected by baffle and cabinet design, are met by the newly developed Tobe Audi-O-Graph. This instrument incorporates the following features, which have been found essential for a usable tool: (*1*) It is entirely self-contained; (*2*) is reasonably portable; (*3*) covers an adequate frequency range; (*4*) produces a permanent record; (*5*) is fully automatic; (*6*) is provided with a means for rapidly checking the whole or any portion of the record; (*7*) its recording characteristics are essentially the same as those that have been adopted as standard for acoustical measurement.

The construction, operating principle, and practical application of the instrument are discussed in detail.

"A Continuous Level Recorder for Routine Studio and Theater Measurements;" G. M. Sprague and J. K. Hilliard, *Metro-Goldwyn-Mayer Studios*, Culver City, Calif.

The use of the continuous level recorder as used in a recording plant to check its daily operation is described.

The recording equipment consists essentially of the commercial Esterline-Angus, 5-milliampere recorder driven by a synchronous clock motor which has a large number of rates of paper speed. The motor is operated from a linear rectifier which, in turn, may be operated either directly from the equipment to be measured or from a logarithmic amplifier. The recorder is used to calibrate microphones, loud speakers, review room characteristics, networks, and general transmission characteristics.

"Curve-Plotting Transmission Meter;" L. A. Aicholtz, *Universal Pictures Corp.*, Universal City, Calif.

An automatic curve-drawing transmission-measuring equipment is described, similar to those developed by Metro-Goldwyn-Mayer, General Service Studios, and Paramount, which form the subjects of separate papers.

An interesting feature of the device is the use of a vacuum tube "compressor" circuit to obtain a volume scale that is approximately linear in decibels over a range of 30 or more. Since this "compressor" circuit is of the peak voltmeter type, it is arranged in push-pull to eliminate wave-form discrepancies that might otherwise arise due to mis-poling the circuits under test.

Another feature of interest is the provision of an 80-db. sending gain control in steps of 10 decibels, which greatly facilitates the use of the equipment in straight-away transmission tests.

Circuit diagrams, photographs, and transmission characteristics of the equipment are given, together with sample curves made with the apparatus.

"Recent Progress in Acoustics;" V. O. Knudsen, *Professor of Physics and Dean of the Graduate School, University of California,* Los Angeles, Calif.

Some recent developments in acoustics, especially in Germany, Russia, and in the author's laboratory, are reviewed.

Experiments by E. Meyer, of Berlin, help to clarify the differences between geometrical and diffuse reflections of sound in rooms, and reveal the nature of some of the errors inherent in reverberation measurements. Meyer also describes special absorbent materials, as thin wood panelling or stretched oilcloth, which are selectively absorbent for low frequencies.

S. Rschevkin, of Moscow, describes a method for prolonging, diminishing, or otherwise modifying the reverberation in a room by means of Helmholtz resonators.

A new electroäcoustical device for the artificial production of vowels, by K. W. Wagner, of Berlin, is capable of generating typical German vowels that can not be distinguished from the originals. The oscillogram and sound spectrum of the artificial vowel resemble more closely the oscillogram and sound spectrum of the original vowel than do two sets of oscillograms and sound spectra of the same vowel "picked up" at two different microphone positions in the same room. The experiments reveal the nature of sound distortion caused by reflections from the boundaries of a room; they also show that the ear tolerates considerable distortion.

The paper concludes with a review of some recent work undertaken by the writer, including resonance in rooms, the acoustical design of broadcasting studios, and vistas in musical acoustics.

"Sound Pick-Up Methods for Motion Pictures;" J. P. Maxfield and A. W. Colledge, *Electrical Research Products, Inc.,* New York, N. Y.

The proper recording of sound requires not only the requisite pick-up technic but suitable acoustic surroundings to enable its most flexible use.

The paper, therefore, discusses first the acoustic requirements of sound picture stages, sets, *etc.*, with special reference to scoring, whether before or after taking the picture.

With this background, various methods that have been developed for obtaining and controlling the desired amount of acoustic perspective are treated. In particular, consideration is directed to the factors for which quantitative values have been determined. A discussion of the practical means for using these quantitative factors is given.

Preliminary information on the application of these technics to stereophonic recording and reproduction is discussed.

"Mathematical Relations between Grain, Background Noise, and Characteristic Curve of Sound-Film Eulsions;" W. J. Albersheim, *Electrical Research Products, Inc.,* New York, N. Y.

Computations and measurements show that the background noise of film can be interpreted as the superposition of two types of noise: first, surface noise, and second, grain noise. The surface noise power decreases with the square of specular transmission; the grain noise power reaches a maximum at 50 per cent transmission. Accordingly, it is found that under the conditions of variable-width recording the surface noise is predominant; for variable-density recording, the grain noise is the main factor. The average area of the grains or grain clusters can be calculated from the signal-to-noise ratio; their average volume from the total weight of silver per square centimeter at a given density. For equal grain sizes, surface exposure such as obtained by ultraviolet illumination is definitely noisier than penetrating exposure.

Upon the basis of random three-dimensional distribution of sensitized grains and of the quantum theoretical findings of previous investigators, the shapes of H&D curves were calculated. The assumption that a halide grain is sensitized by a single photon leads to a toe shape that is more rounded than those found in practice. The actual shape of the characteristic from toe to shoulder is accounted for by the assumption that it takes two photons to sensitize a silver halide grain. It is expressed by the equation:

$$D = \frac{D_\infty}{\ln \tau}\left[\epsilon^{-e\tau} - \epsilon^{-e} + \int_\tau^1 \epsilon^{-x}\frac{dx}{x}\right]$$

in which τ represents the translucence of the unexposed emulsion to the actinic light.

The experimental fact that the straight portions of H&D curves obtained from the same emulsion at various gammas originate from a single point which is depressed by bromide content is explainable by taking into account the fact that the emulsion contains silver halide grains of more than one size and speed.

"An Improved Noise-Reduction System for High-Fidelity Film Recording;" J. O. Baker, C. N. Batsel, and H. J. Hasbrouck, *RCA Manufacturing Co., Inc.*, Camden, N. J., and Hollywood, Calif.

This recently developed method for making noiseless film records uses a twin mask shutter and replaces the familiar biased galvanometer and displaced zero line. The new noise-reduction arrangement was developed for either standard RCA symmetrical sound-track or class *A* push-pull, which is rapidly gaining favor because of its numerous advantages. These include cancellation of "zero shift" or distortion of the sibilants, and the elimination also by cancellation of any sounds caused by action of the ground-noise system such as shutter "thumping." The ground-noise timing can be successfully speeded up.

When combined with ultraviolet light the new optical system and noise-reduction method are capable of producing records of extreme quietness and great brilliance, free from sibilant distortion and other extraneous noise. More consistently good recording is possible because maintenance of the equipment is made easier and more accurate by means of precision adjustments.

As compared with previously used shutter systems, an appreciable decrease in ground-noise is now achieved by extremely sharp focusing of both shutter masks and the recording aperture, which are all in effectively the same plane, avoiding the "soft" focus image experienced when a shutter is positioned as close as possible but not sufficiently close to the mechanical slit. Placed where it is, the new shutter also greatly reduces the amount of light falling upon the galvanometer at low modulation levels so that less stray light enters the slit and there is a minimum chance of fogging in the clear unmodulated portions of the sound negative.

Since the shutter edge images are perpendicular to the mechanical slit, the photographic sharpness is greater than could be realized were the edges at a more acute angle to the slit, as would be the case with a single mask of triangular shape.

A new optical monitoring system is introduced providing easy and accurate observation of both the speech modulation and ground-noise reduction action at the same time. The light-spot is larger and can be focused sharply upon the card. More light is provided, making visible instantaneous amplitudes not regularly repeated and of high frequency, known as "fringe." These high-frequency peaks, although very dim, are frequently observed, extending well beyond the body of the modulation.

"A Device for Direct Reproduction from Variable-Density Sound Negatives;" W. J. Albersheim, *Electrical Research Products, Inc.*, New York, N. Y.

Variable-density negatives exposed on the toe of the H&D curve have been known to be superior in brilliance and high-frequency response to the average sound-print, although they show some harmonic distortion. Variable-density negatives recorded on the straight-line portion of the characteristic are highly distorted, but show a remarkably low background noise level.

In order to eliminate the negative distortion, the playback apparatus should produce the same type of compensating distortion that occurs in a straight-line print; that is, the output should be a negative power function of the input. The exponent, called apparatus gamma, should be variable, to fit the variations in negative gamma. Preferably, the apparatus should be capable of reproducing prints as well as negatives. These purposes are achieved in the negative playback unit, *RA-222*, by four distinct steps:

(*1*) An essentially linear input stage usable for reproduction of prints.

(*2*) An exponential feedback stage which converts the output of the first stage into a logarithmic form.

(*3*) A linear, variable-gain stage which reverses the polarity and provides gamma control.

(*4*) An exponential output stage which converts the logarithmic response into the desired power function.

The possibility of reproducing straight-line variable-density negatives opens up the following fields of use:

The quality of newsreels and other rush shows can be judged before printing.

The correct gamma of newsreel negatives can be estimated from the best setting of the reproducer gamma control.

Release negatives can be obtained by re-recording directly from the original negatives, with a saving of time, printing expense, and with improved sound quality.

To obtain highest quality of reproduction for special first-run showings, the sound-track may be a negative directly re-recorded from the original without intervening printing process.

All these uses have been successfully made of the negative playback unit. It is a self-contained, a-c. operated apparatus, which can be adapted to the existing types of film reproducers. By a single switching operation it can be set for the reproduction of positive prints or of negatives. A calibrated control makes it adjustable to the reproduction of variable-density negatives of a wide range of gamma. In addition, gain control and adjustable low-frequency equalization have been provided.

The results are being demonstrated by reproduction from typical variable-density noise-reduction negatives to show the increased clarity, volume range, and freedom from noise-reduction "hush-hush."

"Changing Aspects of the Film Storage Problem;" J. G. Bradley, *Division of Motion Pictures and Sound Recordings,* The National Archives, Washington, D. C.

Photographic film records are taking on new values. Business concerns, libraries, government agencies, and private collectors are beginning to realize the future value of photographic records. The hope that such records may be preserved over a long period of time has given impetus to storage plans, both in terms of chemical preservation and fire prevention. Volume to be stored is increasing rapidly. Federal Government's interest in aerial photography has resulted in an undreamed of volume of aerial film maps and additional government agencies making use of motion pictures. The volume in government circles alone will shortly exceed one hundred tons. The principle of unit isolation and unit application of cooling agent seems most logical in the prevention of film fires.

Report of the Projection Practice Committee; H. Rubin, *Chairman.*

Among the projects under consideration by the Committee during the past six months are those of screen brightness; its desirable values and methods of measuring it; the question of using a visual test-pattern for checking screen illumination; revisions of the projection room plans; questions of projector motors and take-ups, and difficulties incident to the starting of projector motors; requirements of sound screens; and a recently initiated survey of theaters throughout the United States to determine not only existing conditions of projection, but also for the purpose of establishing a set of recommendations regarding theater structures.

"A Wide-Range, Linear-Scale, Photoelectric Cell Densitometer;" W. W. Lindsay, Jr., *General Service Studios, Inc.,* Hollywood Calif.; and W. V. Wolfe, *RCA Manufacturing Co., Inc.,* Hollywood, Calif.

The need for an instrument having a wide range of density and linearity of scale calibration has been recognized for some time. The more general types of instrument involve the balance of two illuminated spheres by visual observation, and are therefore to a large extent dependent upon the skill and fatigue of the observer.

Various forms of photocell densitometers have been built and are in general use in most studios. The majority of these instruments utilize a meter with a scale calibrated in density or per cent transmission. Physical factors impose a scale calibration that becomes rapidly congested as the higher density end is approached.

The writers undertook the construction of a densitometer along different lines, involving the use of a modulated light-source, a stable high-vacuum photocell, and an amplifier having essentially constant gain, in conjunction with a precision attenuator containing a linear decibel scale, and a multiplier. The amplifier has band-pass characteristics, to eliminate harmonics and power supply frequencies. An indicating meter of rugged construction is used.

The instrument operates as follows: The photocell is placed in the operating position; the gain of the amplifier is adjusted so that the zero density point on the attenuator scale reads reference meter deflection; then the unknown density is inserted, and the amplifier gain readjusted to read the reference meter deflection again. By suitable calibration, the gain of the amplifier may be interpreted in terms of density.

The apparatus has been in use, giving satisfactory performance, for a period of two years. During the past year, the addition of a Raytheon voltage regulator has reduced line voltage fluctuations to a minimum.

A historical résumé, the discussion of theoretical factors, density standards, and limitations of the instrument, together with details of the various mechanical and electrical features that were used to improve its performance, conclude the paper.

"Standardization of Photographic Densitometry;" C. M. Tuttle and A. M. Koerner, *Kodak Research Laboratories*, Rochester, N. Y.

It is desirable that all laboratories dealing with photographic problems shall be in agreement upon the significance of the term "density," and that the means for numerical determination of this value shall be specifiable.

In different optical systems, the apparent "light stopping power" of a given photographic image specimen will vary because of the manner in which the sample reflects, scatters, and absorbs light. Since the numerical value obtained depends upon the characteristics of the optical system used in the densitometer, it becomes necessary to specify the optical system to be used as a reference standard. Because it may be definitely specified, the integrating sphere is suggested as the light collector for this standard optical system. Precautions that must be followed in the use of the sphere for this purpose are enumerated.

It is shown that once some standard optical system is adopted, several other types of optical systems may be employed in practical instruments if the calibration of these instruments is made under actual working conditions with photographic images previously measured in the system adopted as standard.

The paper concludes with a discussion of the interrelationships of $\log_{10}$ apparent opacity as determined in several optical systems commonly used in densitometry.

"The Objective Quantitative Determination of the Graininess of Photographic Emulsions;" A. Goetz, *California Institute of Technology*, Pasadena, Calif.

A graininess meter as an instrument for the objective and quantitative determination of the density fluctuations of photographic emulsions is described. The instrument, specially designed for this purpose, produces a microphotometric record of a uniformly exposed area in terms of relative transparency fluctuations (T/T_m; T_m = mean transparency). The resolving power of the optical system is larger than the individual grain size, so that granularity as well as graininess is recorded. Unlike the usual microphotometric records, the records are produced in such a way that they can directly undergo a process of partial integration in a photoelectric integrator designed for the purpose. Thus a record of the distribution of transparency fluctuations is directly obtained. In addition to this the sum total of fluctuations can also be obtained. The former, however, is chosen to determine a measure of the graininess in the form of a logarithmic average obtained by a simple graphical method which weighs the size of the fluctuation in approximation to the subjective impression. The average of the transparency fluctuations relative to the mean transparency of the specimen thus obtained is used as the expression for the graininess.

The graininess meter has been applied to the following problems: The graininess-density diagrams of various commercial negative and positive film materials; the effect upon the emulsion by the variation of the mode of development; the quantitative measurement of the increase of graininess in contact prints with respect to the graininess qualities of the negative materials from which the print is made; the effect of the optical nature of the printing light upon the graininess increase of the print.

"Sound-Track Blooping;" F. D. Williams Co., Los Angeles, Calif.

A demonstration of the various methods of blooping sound-track films, with special emphasis on the "flash" method. A series of drawings and film exhibits will be used to show a direct comparison of the methods and explain the value and qualities of each system of blooping.

"Toning of Positive Film by Machine Method;" J. M. Nickolaus, *Metro-Goldwyn-Mayer Corp.*, Culver City, Calif.

A description of the toning of the entire release of the Metro-Goldwyn-Mayer production *The Good Earth*, using a modified developing machine.

"Fixing Baths and Their Properties;" J. I. Crabtree, H. Parker, and H. D. Russell, *Kodak Research Laboratories*, Rochester, N. Y.

In addition to removing the unreduced silver halides from an exposed and developed emulsion, the fixing bath should (*a*) arrest development immediately, and (*b*) harden the gelatin film so as to prevent excessive swelling during washing and reduce mechanical injury during handling.

The fixing agent usually consists of sodium or ammonium thiosulfate, or a mixture of sodium thiosulfate with ammonium chloride. The bath also contains an acid (usually acetic acid) to arrest development, sodium sulfite which inhibits the precipitation of sulfur, and potassium or chrome alum which tans the gelatin.

The addition of developer carried into the fixing bath tends to cause the precipitation of aluminum sulfite, but this can be prevented by (*a*) revival of the bath with acid at intervals, or (*b*) the addition of boric acid which also extends the *p*H range over which effective hardening is obtained. The exhaustion point at which revival should occur may be determined with *p*H indicators.

Various fixing bath formulas are included and their properties discussed in terms of (*a*) developer capacity, (*b*) sludging and scumming propensity, and (*c*) hardening life.

"The Super Simplex Pedestal;" J. Frank, Jr., *International Projector Corporation*, New York, N. Y.

This new pedestal embodies a number of unique features, including spirit-level; lamp house table, with universal joints permitting accurate adjustment; sufficient mass to assure steadiness of the projected picture; support arms for various makes and types of sound-head attachments; spacers to permit the use of existing port holes; and a lateral adjustment device.

"Cine Kodak Model *E*;" L. R. Martin, *Eastman Kodak Co.*, Rochester, N. Y.

Simplicity of operation and control in this camera is obtained by using a single-plane film path, with the supply reel above and ahead of the take-up reel. The mechanism is built as a unit with all the controls mounted upon the frame. A single-claw pull-down is used, driven by an eccentric. The camera operates at three speeds: 16, 32, and 64 pictures per second. Standard equipment includes an $f/3.5$, 20-mm. fixed-focus lens. A feature of the camera is the addition of a supplementary film-footage scale adjacent to the field of the finder.

"A Film Mutilator Machine;" O. F. Neu, *Neumade Products Corp.*, New York, N. Y.

To circumvent the film pirate who for years has been exhibiting film productions in various parts of the world without properly compensating the producers, a film mutilator has been developed.

The film mutilator housing is constructed of cast iron; steel rippers in an aluminum mutilating jaw perforate the film as it passes through brass film-guides and rollers. Each frame is perforated, completely destroying the pictures and sound-track, making it absolutely impossible to reprint, duplicate, or exhibit the film. There are two models having four types of perforations: single perforation in frame; double-staggered perforations in frame; double perforations, one in frame, the other in sound-track; triple perforation, double-staggered in frame, the other in sound-track. One model is hand driven, the other motor driven. The film is fed automatically into a slot in the left side of the housing, passes over the mutilator hub and perforators, and out through a slot on the other side.

"Complete Cue-Mark Elimination Plus An Automatic Change-Over;" S. A. McLeod, *Automatic Change-Over Co.*, Los Angeles, Calif.

The vexing problem of cue-marking, both by producers and projectionists, is well known to all. Defaced cue-marked films have not only been costly and troublesome to the producers and projectionists, but, most important of all, have resulted in poor picture presentation to the theater-going public.

Elimination of all cue-marks or any need of them, plus an automatic, electric transfer to the oncoming projector is now possible through the use of an automatic change-over mechanism which automatically performs the following operations: (*1*) gives a buzzer warning; (*2*) starts the oncoming motor; (*3*) changes over the dowsers; (*4*) changes over the sound.

Two trigger fingers or levers attached by means of a side plate to the reel, set by the projectionist between the film windings, predetermine the timing. The unwinding film, releasing each finger, causes an impulse to be carried mechanically by means of pawls to two half-round plunger shafts in the magazine's hollow axle or spindle shaft. This spindle supports at its outer end a switch housing, enclosing two mercury switches. The mechanical impulse by means of the plunger shafts is here converted into an electrical impulse.

These electrical impulses are then carried to a main control cabinet mounted upon the wall between the projectors, conveniently accessible to the projectionist, and embodying automatic electric interlocks, relays, solenoids, and features for controlling the operations. The regular controls remain unaltered, allowing a return to the old "manual or visual" controls if desired. The entire unit may be adapted to all present makes of standard projection equipment, and the film trigger plates may be quickly attached to standard reels.

"A Magnetic Recording-Reproducing Machine for Objective Speech Study;" S. J. Begun, New York, N. Y.

A small sound recording machine that utilizes the magnetic method has been developed. This machine is especially adapted for students, speakers, singers, and others who wish to improve themselves along their particular line of endeavor.

The machine utilizes an endless steel tape as sound carrier. The recording time is approximately thirty seconds. The steel tape is moved over four rolls on the edges of a metal framework. The amplifier, loud speaker, and the mechanical parts for driving the steel tape are built inside the framework, and all are encased in a portable cabinet. Switches are provided upon a panel for operating the amplifier and the motor. A plug connects the microphone to the machine. Normally the machine is set for reproduction, but when the push-button is pressed for only an instant, it is possible to record for thirty seconds. After this interval has elapsed, the push-button falls back into its original position and the machine continues to reproduce until the push-button is again pressed and a new record made. An indicating system is used in conjunction with the push-button to mark off the recording time. As the method of magnetic recording is used, it will not be necessary to change the steel tape during the life of the machine. The circuit is so designed that making a new record automatically wipes out the previous one.

The machine has a frequency response of from 150 to 4000 cps. Ordinarily a carbon microphone is provided, but for obtaining quality of reproduction, a magnetic-coil microphone is recommended.

"Infrared Negative as Applied to Special Effects Photography;" W. Hough and W. Leahy, *Pacific Coast Technical Division, Agfa Ansco Corporation,* Hollywood, Calif.

A new type of 35-mm. infrared negative is discussed, with special reference to the practical application of this type of film to certain phases of motion picture production. Sensitometric and general data are given comparing this type with existing panchromatic and infrared-sensitive emulsions.

"Two New Emulsions for Duplicating Work;" *Eastman Kodak Co.,* Hollywood, Calif.

Continued work on the process of making duplicate negatives has resulted in the production of two new emulsions by the use of which it is possible to make duplicates of excellent quality and graininess.

The duplicating positive material is a medium-contrast yellow-dyed emulsion of fine-grain characteristics, suitable for handling under positive printing room illumination. It requires more exposure than motion picture positive film but has sufficient speed for use under practical laboratory conditions. A developer of the *D*-76 type is found best for obtaining fine grain, good emulsion speed, and quality control.

For the duplicate negative a special panchromatic duplicating emulsion on gray support is used. The extended sensitivity of this material permits printing from the master positive of proper density and contrast with the printing equipment regularly used for duplicate negative printing. Development of the duplicate negative is to a lower contrast, but it requires the same developer as the master positive and approximately the same time of treatment. Detailed information on the control of quality and on the processing conditions are given.

It is anticipated that duplicate negatives made by the use of these materials may be used instead of the original negative for release printing.

"Laboratory Equipment for the Smaller Laboratory;" A. Reeves, Hollywood, Calif.

Although the technical problems faced by motion picture processing plants located away from the great centers of production are the same as those encountered in Hollywood, they are of a different order of magnitude, due to the smaller volume of work to be handled. For the same reasons, economic considerations, such as avoiding duplication of machinery, *etc.*, are of unusual importance. Notwithstanding this, the quality of the equipment used and of the work put out should adhere to the same high standards demanded in the finest major studio laboratories of any production center.

This paper describes laboratory equipment built to meet these needs, including a developing machine, so designed that it may be used interchangeably for processing negative and positive film, alternating these two types of service without requiring re-threading.

A light-tester of unusual accuracy and simplicity is also described. This instrument is built so that no fluctuations of current supply or other external factors can disturb the accuracy of its results, and is so designed that it may easily be matched to the light-settings of any printer. This same machine, by simply pressing a button, may be converted into an accurate sensitometer, thereby enabling any laboratory, regardless of its location with respect to the servicing facilities of the major film manufacturers, to utilize the important safeguard of sensitometric measurements in routine production.

"Present Aspects of the Development of 16-Mm. Sound;" A. Shapiro, *The Ampro Corporation*, Chicago, Ill.

A review of recent developments in 16-mm. sound, including technical advancements and perfections contributing to raising the standards of illumination and quality, and a discussion of the extent to which limitations of picture size and audience have been raised for large-audience performances.

Adoption of the 16-mm. sound-film for educational purposes is discussed. Its function as a medium for auditorium instruction for general education of an extracurricular nature and its use in the classroom as a corollary to textbook and oral instruction are treated. The use of sound-films for unusual or difficult experimentation is not practical in the ordinary school.

There has been an increasing use of 16-mm. sound for commercial and industrial purposes. An example is the extensive use made of such films by automobile manufacturers for sales exploitation. Picturizations of plant and manufacturing processes have been used as convincing evidence of quality and precision manufacture.

A gradual but slow increase of home users is noted. Rapid development of roadshows indicates a repetition of a cycle of the earlier history of the motion picture. Sources of entertainment film and features now available are outlined. Attitude of large producers toward supplying 16-mm. sound prints, and foreign sources of material are mentioned.

The relationship between 35-mm. and 16-mm. branches of the industry is discussed. Where is the legitimate domain of 16-mm.? Limitation of both types of film, the most effective fields for each, and the encroachment of 16-mm. in the entertainment field are brought out. The possible effect upon the general trend of type of entertainment pictures is indicated, and suggestions for the regulation of the 16-mm. industry are offered.

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

A summary is presented of correspondence conducted with the British Institute of Cinematography. The report of this organization is abstracted as follows: (*1*) A theoretical analysis of the light losses in a projector using direct illumination is made, showing that for every 100 lumens emitted by the lamp, only 2.43 lumens find their way through the projection lens; and (*2*) it is suggested that unit intensity be used as a method of comparison between one projector and another and that 1 foot-candle be regarded as an average value for home use and 4 foot-candle for small auditoriums.

Objection is taken by this Committee to the latter proposal, and the opinion is expressed that the suggested values are too low. A satisfactory intensity should cover projection of adequate quality.

Attention of the Society is directed to the matter of standardizing the procedure for the determination of total screen lumens.

Report of Standards Committee, E. K. Carver, *Chairman*.

Revised drawings for most of the standards, except those on sound sprockets, have been prepared and are to appear in a forthcoming issue of the JOURNAL.

There have been no fundamental changes except with regard to the sound-film. For 35-mm. film, the dimensions of the sound-track have been changed; and for 16-mm. sound-film, similar changes have been made and the distance between the picture and the corresponding sound has been changed to 26 frames.

Report of Sub-Committee on Perforations; J. A. Dubray, *Chairman*.

The Sub-Committee has investigated the possibility of adopting the SMPE standard perforation for negative film, and has come to the conclusion that various factors, especially the stock of background films, makes it impossible to use the SMPE standard perforation universally.

The Committee now proposes that the rectangular perforation proposed by Howell and Dubray in 1932 be adopted as the standard perforation for both negative and positive. This perforation would operate satisfactorily on all apparatus designed for the Bell & Howell perforation, and should give little or no trouble on apparatus designed for the SMPE standard perforation.

"Depue Combination Picture and Ultraviolet Non-Slip Continuous Automatic Sound Printer;" O. B. Depue, Chicago, Ill.

This printer has the following features: The picture-printing head gives a full-width picture, uses a standard aperture, and a sound aperture white light. The sound printing head is non-slip, uses ultraviolet light, has a rotary stabilizer, a generator supply for the light, and an automatic light-control board.

Both picture and sound-head are driven by separate 3-phase motors to assure steady film motion. The motors are mechanically tied to assure synchronism in starting and stopping, and are equipped with a compensating device allowing the motor to slip instantly into phase with bucking.

"Recent Advances in Recording Galvanometers;" G. L. Dimmick, *RCA Manufacturing Co., Inc.*, Camden, N. J.

Since the incorporation of the magnetic type of recording galvanometer in the high-fidelity recording system, a number of improvements have been made. The distortion and magnetic hysteresis have been reduced, the frequency characteristic has been improved, the effect of temperature upon the mirror has been eliminated, and the stability of the galvanometer has been increased.

The general theory of the galvanometer is discussed briefly. The method of damping is shown and described in detail, and a mathematical analysis of its operation is given.

The magnetic structure of the galvanometer now in use is made of silicon steel. A small amount of distortion results from the changing permeability with flux density. The use of nicaloi for both the pole-pieces and the armature has reduced this distortion to a negligible amount.

The complete characteristics of the present design and of the modified design are given. These include frequency, amplitude, and impedance characteristics. Curves showing the effect of direct current in the bias winding upon the wave-shape distortion are given.

In the modified design, certain mechanical improvements have been made. The difference in the coefficient of expansion of the duralumin mirror plate and the glass mirror has caused warping with changing temperature. A nickel-iron alloy, having nearly the same coefficient as glass, has been substituted for the duralumin. In the galvanometers now in service the mirror plate is fastened to the ribbon with cement. This was necessary because of the difficulty of soldering to duralumin. The nickle-iron alloy plate is now soldered to the phosphor-bronze ribbon, and this results in greater stability of the galvanometer in operation.

"Linear Decibel Scale Volume Indicator;" F. G. Albin, *United Artists Corporation*, Hollywood, Calif.

A volume indicator meter for use with recording systems is described, having the following salient features: (1) response proportional to the peak, amplitudes; (2) meter deflection proportional to level in decibels.

Both features are considered advantageous, first, because recording modulators are overloaded by peaks, for which reason the indicators should indicate peak levels. Second, the range of levels according to a decibel scale is considerably expanded over that with a linear amplitude scale. Furthermore, the ear recognizes sound level increments logarithmically, and therefore the response of the meter should also be logarithmic.

"An Automatic Sound-Track Editing Machine;" G. M. Best, *Warner Brothers Pictures, Inc.*, Burbank Calif.

The sound-track cutter requires a film reproducer in his daily routine work; a reproducer that can be threaded quickly and will not tear or damage the film, and will produce sound quality of sufficient excellence to judge splits or cut-outs in music recording.

Such a device has recently been developed, and its mechanical details and operation are described. By means of a geared motor drive and a series of friction rollers, the sound-track is fed past the light-beam of the reproducing system at standard speed, with a reversible feature that is automatic and instantaneous. No sprockets or clamp rollers are used, and the work of the cutter is speeded materially through its use.

"The RCA Recording System and Its Adaptation to Various Types of Sound-Track with Demonstration of Recent Recordings of the Class *A* Push-Pull Type;" G. L. Dimmick, *RCA Manufacturing Co., Inc.*, Camden, N. J.

The photographic recording of sound is accomplished by modulating a narrow beam of light and projecting this light upon a strip of moving film. There are three ways in which the amount of exposing light may be varied. A light-beam of fixed dimensions may have its intensity varied; a beam of constant intensity and length may have its width varied; or a beam of constant intensity and width may have its length varied. The first two types of modulation produce variable-density sound-tracks, while the third type produces variable-width tracks.

The RCA recording optical system can be made to modulate either the intensity or the length of the light-beam. The unit consists essentially of an incandescent lamp to produce the light, a system of lenses to direct the light, an aperture and slit to limit the light, and a reflecting mirror galvanometer to modulate the light. A magnetic shutter for ground-noise reduction is also part of the standard variable-width recording unit. The lens system is designed to have high optical efficiency, low stray light, and good definition of the images. A system of mirrors and lenses intercepts a small portion of the recording light and projects it upon an external card. This system magnifies the deflection of the galvanometer and shutter to such extent that the degree of modulation and the zero settings can be observed easily by the unaided eye. Facilities are provided for adjusting the lamp, the galvanometer, and the focus and placement of the recording light-beam.

Many different types of sound-track can be made with the recording optical system without sacrificing any of its advantages as a light modulator. By the use of the appropriate condenser and aperture assembly, the system will record standard bilateral variable-width track, standard variable-density track, push-pull class *B* variable-width track, push-pull class *A* variable-width density track, and push-pull class *A* variable-width track. The manner in which each of these systems functions is shown and described in detail.

The recording galvanometer is very rugged in design and stable in operation. The relatively large mirror is vibrated at substantially constant amplitude from zero to ten thousand cycles. Being of the magnetic type, the galvanometer is self-protected, and is reasonably free from damage due to overload. Damping of the galvanometer is accomplished in a way that eliminates any effects of the damping material at low frequencies and minimizes the effect of temperature upon the frequency characteristics. The details of construction, method of damping, and operating characteristics are shown and described.

"RCA Developments in Television;" R. R. Beal, *Radio Corporation of America*, New York, N. Y.

A brief review is given of the studies made of the several characteristics of television images and other factors that have been effective in establishing standards, in determining satisfactory performance, and in guiding the step-by-step development of the RCA electronic system of high-definition television.

The system employs the "Iconoscope," a cathode-ray tube for translating the visual image into electrical impulses, and the "Kinescope" for transforming the electrical impulses back into the variations of light-intensity to reproduce the image. The sensitivity and characteristics of the "Iconoscope" as a pick-up device are discussed.

The fundamentals of the RCA high-definition television system now under experimental field test in the New York area and the standards presently employed are reviewed. Photographs of the studios and other parts of the field-test facilities are included. A brief review is given to indicate the progress made and the results attained up to the present time in these field-tests.

The technic of formulating and presenting television programs is peculiar to the requirements of television. The development of the technic is presently related to programs employing artists in studios, outside pick-ups, and motion picture film. The requirements of program technic are discussed.

ERRATA

Kellogg, E. W. "The Quest for Constant speed;" April, 1937, p. 337.

In my paper *The Quest for Constant Speed* the system for averaging imperfections in the driving gear for a wax recorder is attributed to Messrs. Elmer and Blattner. This system was described in an S. M. P. E. paper by Elmer and Blattner, but mention should have been made that the fundamental patent, No. 1,747,866, is due to L. A. Elmer.

The damping arrangement shown in Fig. 8, employing a pair of metal bellows, is credited to H. Pfannenstiehl. I have since learned that while the reproducing machine in which this device was used was due to Pfannenstiehl and the paper describing the complete machine was published by him, the damping arrangement shown in Fig. 8 was due to Elmer, and was first disclosed in U. S. Patent No. 1,922,699.

Since the purpose of the paper was in part to give credit for some of the contributions that had not been adequately covered in previous publications, I am anxious to correct any wrong impressions that may have been given.

E. W. KELLOGG

Rayton, W. B., and Cook, A. A.: "The Effect of Aberrations upon Image Quality;" April, 1937, p. 377.

In line 15, on p. 384, the letter *B* should be read *D*.

SOCIETY ANNOUNCEMENTS

HOLLYWOOD CONVENTION

Complete details of the approaching Convention to be held at Hollywood, May 24th to 28th, inclusive, and the tentative program of the sessions will be found in the preceding section of this issue of the JOURNAL. Members of the Society are urged to make every effort to attend the Convention, as they will find it much to their advantage and pleasure. It is suggested that many may be able to arrange their vacations to accord with the dates of the Convention.

ATLANTIC COAST SECTION

At a meeting of the Section held on March 17th at the Hotel Pennsylvania, New York, N. Y., Mr. S. K. Wolf presented a paper on the subject of "Sound-Films for Teaching Physical Science." Supplementing the presentation, 16-mm. sound motion pictures were projected, dealing with the subjects of *Molecular Theory, Electrons, Electro-Chemistry,* and *Electrodynamics.*

The meeting was attended by approximately 200 persons, and a lively discussion followed the presentations.

MID-WEST SECTION

The regular monthly meeting of the Section was held on April 8th at the studios and laboratory of the Filmack Trailer Company in Chicago, Ill. A paper on the subject of *Making Special Trailers for Theaters* was presented by Mr. Mack and his technical staff, demonstrating the processes of animation, trick photography, and laboratory practice.

The meeting was well attended, and considerable interest was shown in the presentations. The next meeting of the Section was scheduled for May 13th.

EXCHANGE PRACTICE COMMITTEE

At a meeting held at the offices of the M. P. P. D. A. in New York on March 18th, further consideration was given to the various subjects initiated at the previous meeting. Among the subjects were those of splicing and rewinding, uniformity of printed matter distributed with films by exchanges, specifications for the ideal exchange, and the production of a demonstration film for use in exchanges.

By resolution of the Committee, the Secretary was instructed to write a letter to Mrs. J. P. Skelly, expressing the Committee's deep sorrow at the recent death of Mr. Skelly.

PROJECTION PRACTICE COMMITTEE

At a meeting of the Committee, held at the Paramount Building, New York, N. Y., on April 1st, further consideration was given to the subjects discussed at previous meetings, to be included in the report of the Committee now being prepared for presentation at the Hollywood Convention. The Committee plans to hold two more meetings in the interim.

It is with deep sorrow that the Committee learned of the death of one of its very active members, Rudolph Miehling, on April 7th. Mr. Miehling had long been active in the affairs of the Committee, and had been a member of the Society since 1924.

The Society regrets to announce the death of

RUDOLPH MIEHLING
April 6, 1937

ADMISSIONS COMMITTEE

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

ANDERSON, H.
Paramount Pictures, Inc.,
Paramount Bldg.,
New York, N. Y.

BELCHER, W. E.
150 Palm St.,
Rochester, N. Y

BORKENSTEIN, R. F.
Indiana State Police,
126 State House,
Indianapolis, Ind.

BULL, R.
39, Brooke Road West,
Waterloo, Liverpool,
England.

COHEN, M.
100 W. 59th St.,
New York, N. Y.

GILMARTIN, W. A.
21 Ingram St.,
Forest Hills Gardens,
Long Island, N. Y.

HAIZELDEN, A. W.
72, Scarsdale Villas,
Kensington,
London, W. 8, England.

HILL, C. G.
26 Peloubet St.,
Bloomfield, N. J.

HILLS, H. O.
Rialto Theater,
Kaiapoi, N. Z.

HUMPHREY, H. C.
97, Highlands Heath,
Putney, S. W. 15,
London, England.

JANKE, P.
316 S. 11th St.,
Newark, N. J.

POLLARD, A. E.
RCA Photophone, Ltd.,
Electra House,
Victoria Embankment,
London, England.

PÖSCHL, I. K. DE
Budafoki ut 8,
Budapest, Hungary.

ROGAL, W. E.
843 East Boulevard,
Weehawken, N. J.

SCHLOSBERG, R. T.
7074 Lanewood Ave.,
Hollywood, Calif.

Schreyer, C.
Bell & Howell Co.,
11 W. 42d St., New York, N. Y.

Seidel, C.
Cordoba 664,
Buenos Aires, Argentina.

Shepard, W. D.
Hotel De Soto,
Locust at 11th St.,
St. Louis, Mo.

Smith, R. C.
143 N. 14th St.,
East Orange, N. J.

Witt, R. E.
4306 Parker Ave.,
Chicago, Ill.

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SOME DATA REGARDING DIMENSIONS OF THE PICTURE IMAGE IN 16-MM. REDUCTION PRINTING*

G. FRIEDL, JR.**

Summary.—*With the increasing growth of the 16-mm. sound-film industry the question of standardizing the optical reduction ratio naturally arose. With the view of studying this problem, the author was requested by the SMPE Standards Committee to organize the information available and to present it so arranged to the Standards Committee for further study.*

The paper undertakes the study of the problem with regard to the requirements of optical reduction and to the areas available upon the film.

Optical reduction printing of 16-mm. positives from 35-mm. negatives is one of the popular methods of producing 16-mm. prints. In this process the size of the picture image printed upon the 16-mm. film is dependent mainly upon the size of the image on the 35-mm. film and the ratio of optical reduction. Our present standards for image size on 16-mm. film were established for regular camera exposure; they do not relate to optical reduction printing.

Because of the increasing popularity of optical reduction printing, Dr. E. K. Carver, Chairman of the Standards Committee, proposed that a preliminary study of the subject be made to determine whether or not some standard or recommended practice could be established for the guidance of the industry.

The data presented herewith are intended to set forth some of the dimensional considerations not readily apparent from a general review of the standards. It is intended that these data will assist in formulating some proposal for endorsement by the Society. Persons interested in the subject are invited to send their comments to the Standards Committee so that proper consideration may be given to their ideas during the present re-editing and revising of the Standards and Recommended Practices.

Information collected from a number of laboratories has shown

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differences of method, as might be expected in view of the fact that the conditions involved can easily be interpreted in various ways. Unfortunately, products are not uniform, with the result that when some of the prints are projected, titles are unbalanced and parts of the picture are cut off. In extreme cases, border lines are shown around the image upon the screen. Needless to say, such results are out of keeping with the exactness and precision that characterize modern showmanship. In many instances, the 35-mm. negative represents a considerable investment, and poor optical reduction printing of the 16-mm. voids much of the care and attention given to its production.

Requirements.—There are several factors that must be controlled in order to assure uniform, satisfactory results. The primary requirements are:

(*1*) The picture projected upon the screen by a 16-mm. projector should show the same image field as would be projected by a 35-mm. projector (assuming that the two prints were made from the same 35-mm. negative without shrinkage, weaving, *etc.*).

(*2*) The overlap of the projector aperture and the picture image should be sufficient to prevent showing white or black frame or border lines around the screen picture, for reasonable degrees of shrinkage and weaving.

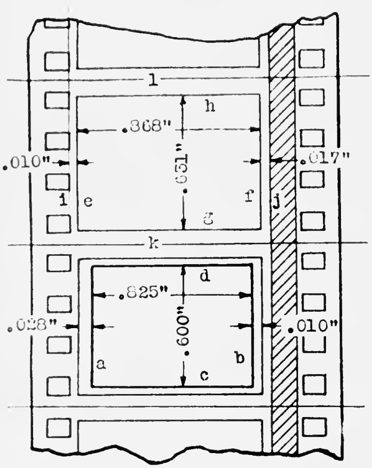

FIG. 1. Areas of 35-mm. images (*upper*) printed upon film, and (*lower*) projected upon screen.

For convenience, let us define certain terms that are used frequently in the following discussion:

Picture.—The area of the image actually projected upon the screen—the area exposed by the projector aperture (for 35-mm. film, the area within *a*, *b*, *c*, *d* of Fig. 1).

Picture Image.—The area of the image printed upon the film, not including frame or border lines—the area normally exposed by the camera aperture (for 35-mm. film, the area within *e*, *f*, *g*, *h* of Fig. 1).

Printed Image.—The area of the picture image, plus the black frame or border lines (for 35-mm. film, the area within *i*, *j*, *k*, *l*).

Ratio of Reduction.—Inasmuch as the first requirement relates to the picture projected upon the screen, the projector apertures will be used as the bases for establishing the optical reduction ratio.

The present projector aperture standards are 0.825 by 0.600 inch for 35-mm., and 0.380 by 0.284 inch for 16-mm. projectors, the ratios of height to width being 0.728 and 0.748, respectively. Both are well established standards, and in spite of the fact that it would be desirable that the ratios be alike, neither standard can be modified at present. Because of that it follows that a ratio of reduction based upon the widths of the 35-mm. and 16-mm. apertures will produce a different result from a ratio based upon the heights. It is therefore of interest to determine which of the two ratios is the better. As a matter of convenience, we shall refer to the ratio of reduction by widths as *Case 1*, and to the ratio of reduction by heights as *Case 2*. Thus, we find in the two cases:

Case 1 (ratio by widths—0.825 to 0.380).—The 0.600-inch height is reduced to 0.276 inch, meaning that the area upon the 16-mm. film equivalent to the 35-mm. picture is 0.380 by 0.276 inch.

Case 2 (ratio by heights—0.600 to 0.284).—The 0.825-inch width is reduced to 0.390 inch, meaning that the area upon the 16-mm. film equivalent to the 35-mm. picture is 0.390 by 0.284 inch.

Both these areas are different from the standard 0.380 by 0.284-inch projector aperture, and therefore for Case *1* a picture just as wide as the 35-mm. picture, but higher, would be projected; whereas for Case *2*, a picture just as high, but not as wide, would be projected.

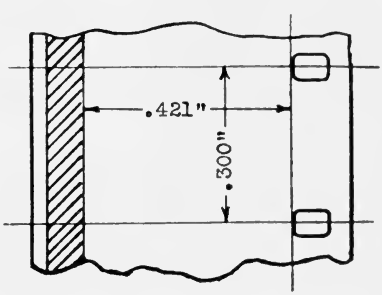

FIG. 2. Available picture area on 16-mm. film.

The increase of height for Case *1* is 0.008 inch of 16-mm. image, equivalent to 0.016 inch of 35-mm. image—approximately 3 per cent; and for Case *2* the reduction of width is 0.010 inch of 16-mm. image, equivalent to 0.022 inch of 35-mm. image—approximately 3.5 per cent. This infers a tentative conclusion immediately in favor of a reduction based upon widths, as no image is cut off; but before establishing a definite conclusion, let us investigate how other factors might affect the final result.

Space on 16-Mm. Film.—First, let us determine how the picture image fits into the space on the 16-mm. film; that is, into the area bounded by the center-lines of two consecutive perforations, the inner edge of the perforations, and the sound record, as shown in Fig. 2. The present standards specify that the picture image, as formed by the standard 16-mm. camera aperture, be printed up to the 0.096-inch "printed area" for variable-width recording. For reduction printing, however, we may assume that the width of the printed area need not be maintained as 0.096 inch and that it may be as small as 0.085 inch,

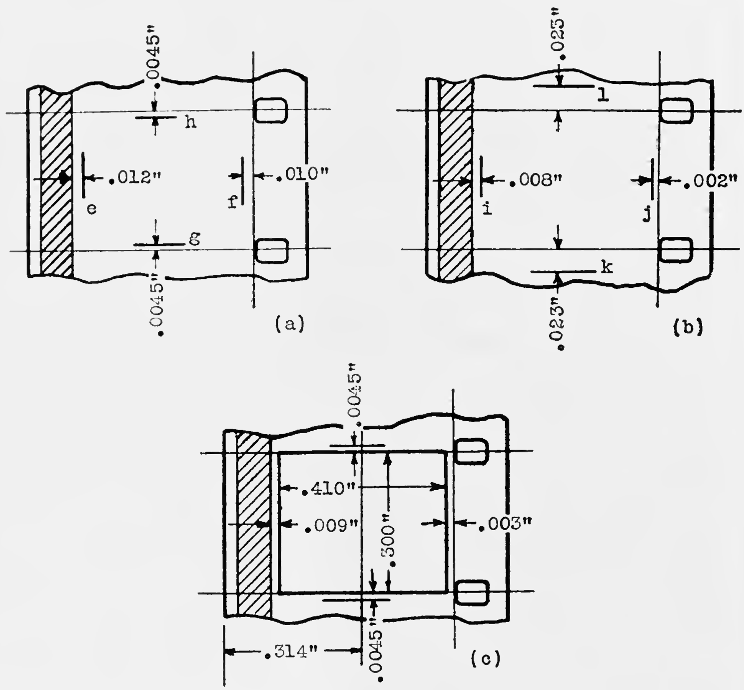

Fig. 3. Showing location of image on 16-mm. film, for Case *1*.

the same width as the variable-density record. Thus the area available for the picture image would be 0.421 by 0.300 inch.

Image Position on 16-Mm. Film.—To determine the position of the printed image, as printed from the 35-mm. upon the 16-mm. film, the 35-mm. negative and the 16-mm. positive must be aligned in such a manner that the center-lines of the picture areas coincide. Assuming that no masks are used, we find that for Case *1*, as shown in Fig. 3*a*, the edges of the picture image will be 0.0045 inch from the perforation center-lines at top and bottom, 0.010 inch from the edge of the perforations, and 0.012 inch from the 0.085-inch sound-track. Referring to Fig. 3*b*, the 35-mm. frame lines will extend beyond the available space on the film by approximately 0.023 inch at top and bottom, and 0.002 inch of the 35-mm. sound-track will extend inside the edge of the perforations at the right, whereas, at the left, the 35-mm. perforations will extend 0.008 inch inside the 0.085-inch sound-track.

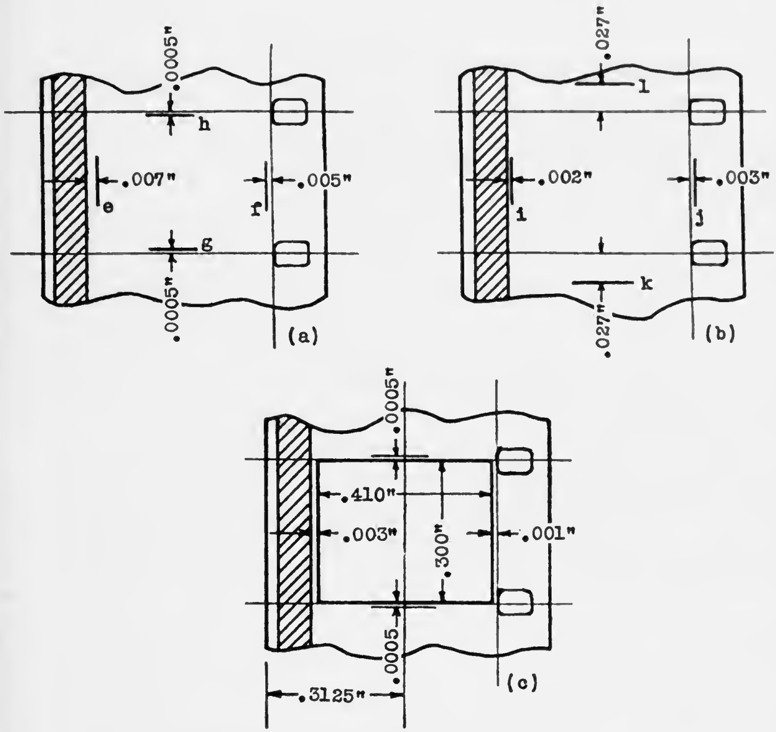

FIG. 4. Showing location of image on 16-mm. film, for Case *2*.

This means that the entire picture image will fall within the available space and that the sound-track, perforations, and frame and border lines (35-mm.) may be eliminated by suitable masking.

Similarly, for Case *2*, referring to Fig. 4*a*, the edges of the picture image will be 0.0005 inch from the perforation center-lines, top and bottom; 0.005 inch from the inner edge of the perforations; and 0.007 inch from the 0.085-inch sound-track. As shown in Fig. 4*b*, the frame lines will extend beyond the area by approximately 0.027

inch, top and bottom; the 35-mm. sound-track will extend 0.003 inch outside the edge of the perforations; and the 35-mm. perforations will be 0.002 inch inside the 0.085-inch sound-track. As in Case *1*, this means that the entire picture image will fall within the space, and that the sound-track, perforations, and frame and border lines may be eliminated by suitable masking.

Printer Aperture.—Having found that the picture image will fall within the space and that masking is desirable, we can now determine the most desirable size of printer aperture. The size could be made that of the actual picture, but that would limit the printed area and possibly result in white frame and border lines around the picture image.

In order to print black lines instead of white ones, an over-sized printer mask should be used. For Case *1*, referring to Fig. 3*c*, an aperture of dimensions 0.410 by $0.300^{+0.009}_{-0.000}$ inch, positioned with its center-line 0.314 inch from the guided edge of the film, will print an area that will be 0.003 inch inside the perforation edges and 0.009 inch inside the 0.085-inch sound-track, and the frame lines between adjacent images will be 0.009 inch. The allowance of +0.009 inch in the height of the aperture permits overlapping of the frame lines, but the upper limit of 0.309 inch is set to avoid overlapping of frame line and image area.

For Case *2*, as shown in Fig. 4*c*, an aperture of dimensions 0.410 by $0.300^{+0.0005}_{-0.0000}$ inch, positioned with its center-line 0.3125 inch from the guided edge, will print an area whose right edge will be 0.001 inch inside the perforation edges, and the left edge will be 0.003 inch inside the 0.085-inch sound-track. The frame line between adjacent images will be 0.001 inch. The close allowance of 0.0005 inch in the height of the aperture must be held if overlapping of the image is to be avoided. In this case it would not be serious to overlap some of the image and, therefore, a more practical allowance of 0.002 inch might be used.

Overlap of Projector Aperture.—The present 16-mm. standards for camera and projector apertures, 0.410 by 0.294 and 0.380 by 0.284 inch, respectively, provide overlaps in the projector of 0.015 inch on the right and left sides, and 0.005 inch at top and bottom. These tolerances permit variations in framing, weaving, and shrinkage without exposure upon the screen of anything but picture image. Using these figures as references, and referring to Fig. 5, we can compare the overlap for each of the two cases under discussion:

	Case *1*	Case *2*	Present Standard
Right Side	0.007	0.012	0.015
Left Side	0.013	0.018	0.015
Top and Bottom	0.0035	0.0075	0.005

It will be noted that all the overlaps for Case *2* are greater than those for Case *1*. Also, that in Case *1* the overlaps are generally smaller than those of the standard, whereas, in Case *2* they are greater.

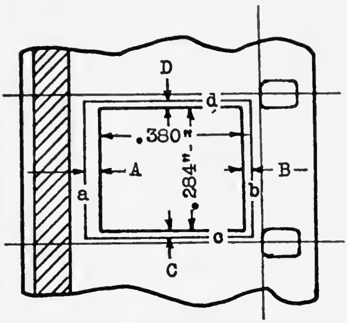

FIG. 5. Overlap of 16-mm. apertures.

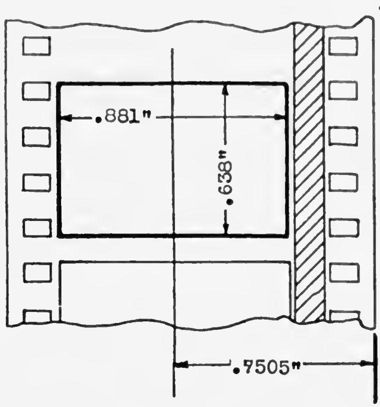

FIG. 6. Overlap of 35-mm. aperture.

Unless practice indicates that the present standards must be regarded as minimum, it might be assumed that Case *1* is satisfactory.

In the 35-mm. camera aperture, the center-lines are offset to provide greater margin of overlap on the side of the image farthest from the guided edge of the film (to be sure that the overlap on the left-hand side will be sufficient for high shrinkage). This unbalance reflects in the opposite direction upon the 16-mm. film because the guided edge is on the opposite side. Thus, the smaller overlap is on the side where the effect of shrinkage is greater.

Selection of Ratio.—A review of the comparative merits of Case *1* and Case *2* shows:

(*1*) Regarding the size of the picture shown upon the screen, Case *1* is better than Case *2*, as more height is shown, whereas in Case *2* the width is cut.

(*2*) Both reduction ratios, by widths or by heights, will reduce the 35-mm.

negative image so that it will fit within the available space on the 16-mm. film.

(*3*) Case *1* shows a slight advantage with respect to masking in the 16-mm. printer to utilize the maximum printed area on the film, as the height of the printer aperture need not be held to unreasonably close tolerances.

(*4*) The overlap of the projector aperture is more favorable in Case *2* than in Case *1*, although in the latter the overlap should be ample for normal conditions of shrinkage and weave.

From this we can see that the advantages for Case *1* slightly outweigh those for Case *2;* and although a compromise might be worked out, Case *1* can be regarded as the more satisfactory of the two.

Shrinkage.—Shrinkage of the 35-mm. negative should not be permitted to affect the size of the image upon the 16-mm. positive. Printers should therefore be arranged to compensate for any reduction of size of the 35-mm. image by adjustment of the optical system, in order that the 0.400 by 0.291-inch image is printed upon the 16-mm. positive with its center-line 0.412 inch from the guided edge. Shrinkage of the 16-mm. positive will have the greatest effect upon the projector aperture overlap on the side of the image farthest from the guided edge. Assuming that the maximum transverse shrinkage does not exceed 2 per cent, the maximum change of overlap would be about 0.001 inch. Thus, we might conclude that shrinkage of the positive will not affect projection.

35-Mm. Camera Aperture.—All previous discussions have been based upon the use of standard 35-mm. sound-film made with the 0.868 by 0.631-inch camera aperture. If film is made primarily for 16-mm. optical reduction printing, special attention to making the 35-mm. negative will improve the 16-mm. positive. For instance, in Case *1*, the 16-mm. available area is higher, proportionally, than the standard 35-mm. picture. Therefore, the 35-mm. camera aperture might be increased in height from 0.631 to 0.638 inch, and the field of action increased from 0.600 to 0.616 inch—about 2.7 per cent. Also, the width of the camera aperture could be increased from 0.868 to 0.881 inch to provide better overlap on the right side of the 16-mm. image in projection. The increase would be only on one side. The center-line of the camera aperture would be moved from 0.744 to 0.7505 inch from the guided edge, and a space of 0.004 inch would still separate the picture area from the sound-track. The width of the field of action should not be increased (Fig. 6).

These changes would be reflected in the 16-mm. print in the following manner: The overlap of the projector aperture on the right side would be increased from 0.007 to 0.013 inch. The effect of shrinkage in reducing the overlap of the projector aperture would be less serious—the frame line would be reduced from 0.009 to 0.006 inch, and the printer aperture height would be $0.300^{+0.006}_{-0.000}$ instead of $0.300^{+0.009}_{-0.000}$ inch.

SUMMARY

(*1*) Optical reduction prints should be made with special care to assure that the same picture field is projected from the 16-mm. film as from the 35-mm.

(*2*) The ratio of reduction should be established as a function of the width of the 35-mm. and 16-mm. projector apertures, namely, 2.14:1 (0.825 to 0.380).

(*3*) The 35-mm. and 16-mm. films should be guided in the reduction printer in such a manner that the center-lines of the picture areas (the areas normally exposed by the projector apertures) coincide.

(*4*) The present standard 16-mm. camera aperture dimensions and the 0.096-inch width of printed area for variable-width sound recordings need not be held in 16-mm. reduction printing.

(*5*) Shrinkage of the 35-mm. negative should be compensated for by retaining the 2.14:1 ratio and regulating the printer so that the image on the 16-mm. positive is 0.400 by 0.291 inch, located 0.412 inch from the guided edge.

(*6*) When 35-mm. negatives are made primarily for optical reduction printing to 16-mm. positives, it is desirable to modify the 35-mm. camera so that the aperture is 0.881 by 0.638 inch, with its center-line located 0.7505 inch from the guided edge. The field of action can be increased to an area of 0.825 by 0.616 inch, with the center-line located 0.744 inch from the guided edge.

THE MANUFACTURE OF MOTION PICTURE FILM*

E. K CARVER**

Summary.—*A brief account of some of the more important phases of manufacturing motion picture film, tracing the product through the plant from the raw materials through the Chemical, Roll Coating, Emulsion Coating, and finally the Finished Film Departments.*

The business of manufacturing photographic film is a peculiarly pleasant one for the technical man. There are three principal reasons for this. In the first place, most of the progress in this industry is based upon scientific research of a fundamental character. Second, there is a wide variety of technical problems, so that there is almost unlimited scope for technical skill. Third, due to the care required in handling all the materials involved, the type of workmen attracted to this industry is such that it is always a pleasure to be associated with them.

The subject may be discussed from several points of view, all interesting, and all broad enough to require many volumes for a complete discussion of their essential details. The different positions from which the manufacturer of motion picture film may be viewed is exemplified by the two expressions "film base" and "film support." Both these expressions mean the same thing, but we find that one of them is used chiefly by the emulsion makers, and the other chiefly by the support makers. To the emulsion maker, the film support is nothing more than its name implies—a transparent material upon which he may coat his carefully prepared emulsion. Among the makers of the support, however, this material is ordinarily referred to as the "base." They not only speak of it as the base, but they think of it as the basic material upon which is coated a thin layer of a creamy material before the base is ready for use. From the point of view of the emulsion coater, both the base and the emulsion are simply raw

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

materials, fairly simple in their properties, although one of them possesses the extremely annoying property of being sensitive to light, to abrasion, to high temperatures, to over-drying, to under-drying, and, in fact, to almost every possible variation in handling.

To the machine designer, motion picture film is made by machinery, the workmen merely feeding and tending the machines. To the workman, the film is manufactured in distinct steps, each step being a separate and distinct job in which he takes pride in being a specialist. From our point of view, then, motion picture film is manufactured by the coördinated efforts of a large number of separate units. This coördination implies coöperation, and it is this feature of the work especially that contributes most to the pleasure of working in the film industry. Nearly everyone enjoys team work—tennis players like to play doubles better than singles, baseball and football are fun because of team play, film manufacturing is interesting because of team play.

Among the many points of view from which the manufacture of motion picture film may be discussed, we shall adopt the point of view of the visitor at Kodak Park, discussing in turn the general layout of the plant, the organization, and the various steps through which the raw materials must go before emerging as finished motion picture film. Due to the fact that the problems faced by other manufacturers of motion picture films are the same as those faced at Kodak Park, we may assume that most of the things that apply here apply also to other manufacturers.

Kodak Park is devoted chiefly to the manufacture of photographic film, paper, and plates, although many other materials are also made here. Among these are adhesive tape, film cans, artificial leather, photographic chemicals, special organic chemicals, transparent sheeting, Kodapak, and many other materials, some of them apparently unrelated but all connected in some way to the production of photosensitive goods.

The oldest portion of the plant occupies about 75 acres and contains most of the manufacturing buildings. To the west of this portion lies another tract of about 63 acres containing the Distilling Plant, Solvent Storage, Nitric Acid Plant, one of the sulfuric acid plants, much of the dope making, and the Synthetic Chemicals Department. Still farther west lies the Gelatin Plant, in a newer tract of about 250 acres which still awaits development (Fig. 1).

The personnel attracted to the photographic industry is of varied types. Due partly to good management and partly to the interesting nature of the work, there is a very large number of the employes who have been with the Company for many years and who have developed extraordinary knowledge of the intricacies of their particular fields and a strong loyalty to the organization. A system of training groups, especially for leaders and supervisors, based largely upon discussion

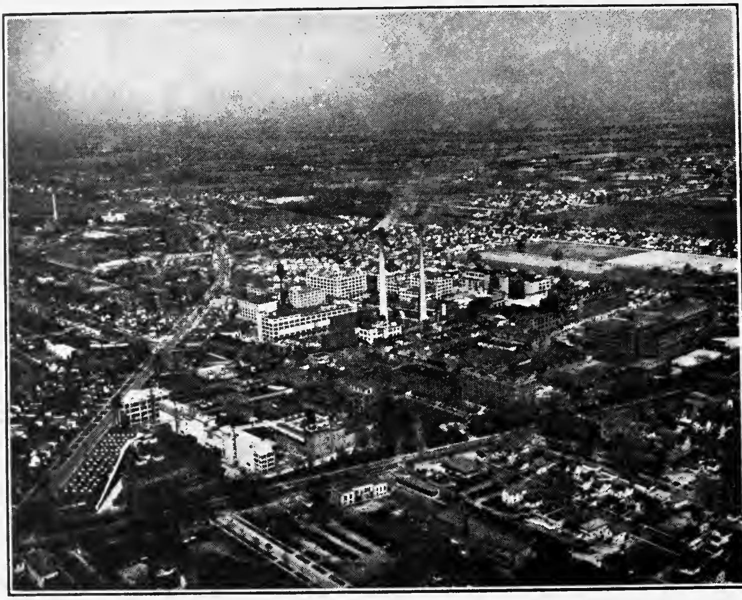

FIG. 1. Aerial view of Kodak Park, showing Kodak Park west in the left background.

and analysis of problems, has done much to keep them informed as to questions of administration, organization, and production. Within recent years there has been a large influx of technical men, made necessary by increasing manufacturing refinement and complexity and a need for further research development.

Film manufacturing, with which we are at present concerned, may be divided into two main phases. One has to do with emulsion making, which includes gelatin manufacturing and the preparation of the emulsions for coating. The other includes all other departments connected with the manufacture of the film, namely: the Chemical Plant, where the cotton is nitrated, the solvents distilled, and the dopes mixed; the Roll Coating Department, where the dope is coated into transparent sheets of film support; the Emulsion Coating Department, where the emulsion is coated upon the film base; and the Finished Film Department, where the film is slit, perforated, and packed ready for shipment. The raw materials used in the manufacture of nitrate film support are cotton linters, sulfur, sodium nitrate, camphor, and solvents. For safety support they are cotton linters, acetic anhydride, acetic acid, triphenyl phosphate, and solvents. For the emulsions they are hides, silver, nitric acid, potassium bromide, and sensitizing dyes.

The cotton linters used for the manufacture of cellulose nitrate are prepared from the short fibers of the cotton plant obtained by means of a special cutting machine from the cotton seeds after ginning. They are prepared for nitration at the various plants in the south by special treatment with caustic soda and hot water. Careful control of the treatments is necessary in order that the cellulose nitrate be suitable for nitration.

The Nitrating Plant is arranged to follow the gravity system. The linters, upon arrival, are taken to the top floor of the building. There they are put into a combined picking and drying machine, where the bales are torn apart by means of saw-teeth and brought to a uniform and low moisture content by means of controlled drying. From the drying bins the cotton is weighed out and placed into chutes, ready for immersion in a nitrating bath. These nitrating baths, or pots, are steel containers with special rotating stirrers which will quickly immerse the cotton beneath the surface of the acid contained in the pots. The acid is a specially controlled mixture of sulfuric acid and nitric acid containing definite amounts of water. The water content is the chief factor in controlling the percentage of nitrogen in the nitrocellulose, although, of course, the sulfuric acid and nitric acid also must be in the right proportions. After nitration for a definite length of time at controlled temperature, the nitrocellulose and acid are dumped through a pipe into a centrifuge on the floor below. Four nitrating pots will take care of one centrifuge. The centrifuge is made of stainless steel and is used to remove the acid from nitrocellulose. After as much acid as possible has been removed by centrifugal force, the operator opens the centrifuge, and by means of a long spatula, removes the cake of nitrocellulose from the sides of the basket and dumps it through the bottom into a rapid stream of running water which carries it into wash tanks. In these wooden wash tanks, the nitrocellulose, or "cotton" as it is generally called, is subjected to many changes of hot water to remove the residual acid. The stability of the nitrate depends to a large extent upon the thoroughness of this washing operation. The nitrocotton is stored in a wet condition until ready for use, when it is dehydrated by means of another centrifuge which removes most of the water by centrifugal force. By washing in this same centrifuge with butyl alcohol, the remainder of

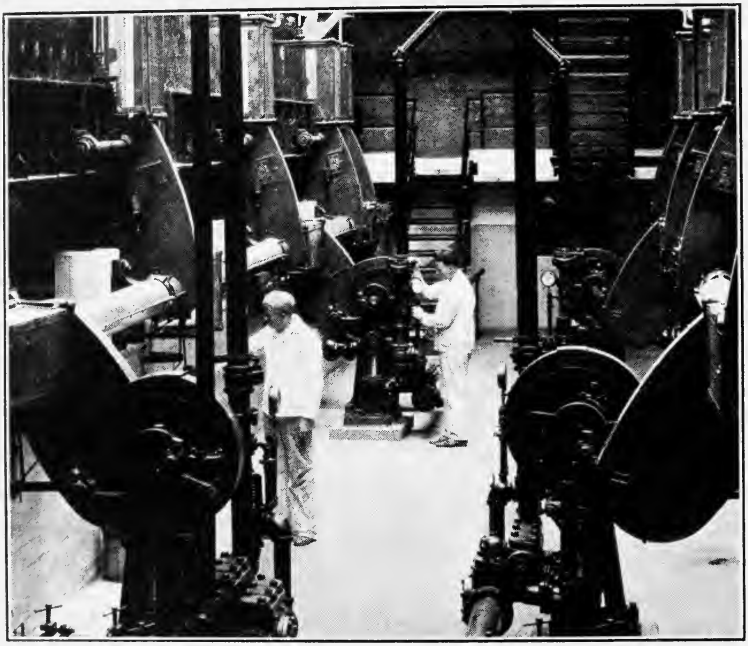

FIG. 2. Mixing and pumping the dope.

the water is removed. The dehydrated nitrocellulose is put into specially insulated metal cans and taken to the Dope Department, where it is mixed with solvent to form dope. The solvents most used for making nitrate films are methyl alcohol, ethyl alcohol, acetone, and sometimes alcohol and ether.

The dope mixers are large tanks equipped with paddles rotating in opposite directions and driven by powerful gears. Into these mixers the nitrocotton and solvents are placed, and the paddles rotated until a clear, uniform dope is obtained. From one mixer the dope is pumped through filters to other mixers for further mixing and filtration (Fig. 2). In these mixers camphor, or triphenyl phosphate in the case of cellulose acetate film, is blended with the dopes to plasticize and stabilize the finished film. The finished dope has much the appearance of clear, strained honey.

From the Dope Department, the solutions are pumped to the Roll Coating Department, where they are coated or cast into the form of film support (Fig. 3). In the roll coating machines, the dope is spread,

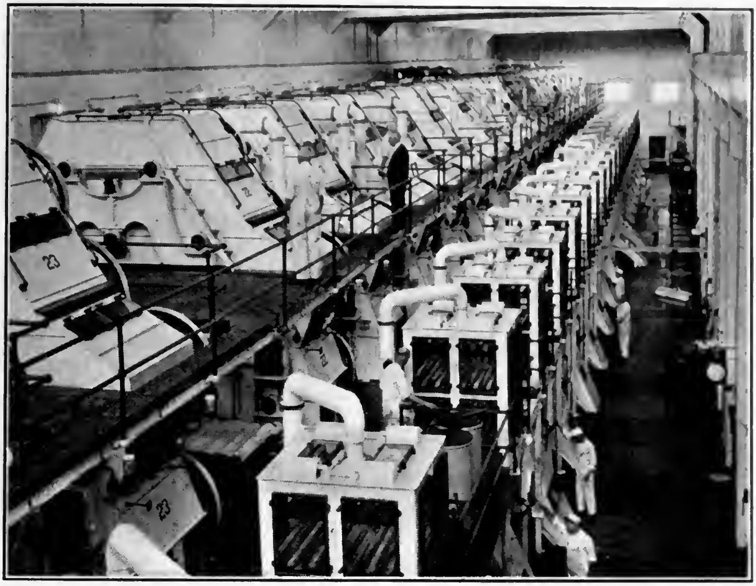

FIG. 3. Roll coating machines, in which the dope is cast upon large wheels for the preparation of film support.

by means of a hopper or trough having a narrow slit at the bottom, upon the upper surface of a large, slowly rotating polished wheel. These wheels vary from about 12 to 18 feet in diameter and from four to five feet in width. As they slowly rotate, a current of hot air is passed around their periphery, evaporating the solvents from the dope, so that by the time the dope has made almost one revolution, the coating is dry and is ready to be stripped from the wheel. After stripping, it passes over a long series of small rollers or drums, for the final curing operation. As it passes over these drums, various layers of other materials are usually applied. One of the applications which is almost universal in making photographic film, is a substratum of thin gelatin. This substratum is necessary in order to make the emulsion adhere firmly to the film support. For certain types of film, anti-halation backings or tints may also be required.

The air leaving the roll coating machine contains a certain amount of solvent which must be recovered if the process is to be economical. Of the various methods of solvent recovery used, water scrubbing,

Fig. 4. Storing the film support.

activated charcoal, and refrigeration are the most common, and refrigeration is generally regarded the most satisfactory, due to the fact that during refrigeration the air is also dehydrated and brought to a uniform condition. The finished film support is then wound into rolls, put into metal cans, and stored in cool rooms until ready to be coated with the emulsion (Fig. 4).

The principal raw material for emulsion making is silver, which comes in the form of ingots. These ingots are dissolved in nitric acid and the resulting silver nitrate is recrystallized several times in distilled water in large porcelain dishes (Fig. 5). Specially selected gelatin, chosen not only with regard to its physical properties, but also for its effect upon the photographic quality of emulsions made from it, is the other important raw material used in emulsion making. The silver nitrate is precipitated in the presence of gelatin, by means of potassium bromide, iodide, or chloride in a water-jacketed kettle provided with a stirrer. The gelatin is then set by being chilled in water and pressed out in the form of spaghetti in an emulsion press. These strips or rods of emulsion are soaked in distilled water to wash out the residual salts. After ripening and other special treatments,

FIG. 5. Crystallization of silver nitrate.

such as the addition of sensitizing dyes, the emulsion is ready for coating.

The emulsion coating operation is similar in many of its details to coating other fabrics, such as artificial leather, gummed paper, *etc.*, except for the requirements of cleanliness, uniformity, and the fact that the operation must be done in the dark. The operation is carried out by passing the film support, subbed side down, beneath a roller partly immersed in a pan of melted emulsion. The speed of travel and the temperature and viscosity of the emulsion govern the thickness of the coating. Immediately after the emulsion is applied it is chilled, to set it in place, and is then dried under carefully controlled humidity, temperature, and air velocity conditions, by passing the film in festoons through a long tunnel drier. The special devices for forming the loops or festoons are similar to those used in other coating industries. The relative humidity of air used for drying emulsions must be controlled within a very small range to obtain the best results, since the speed of emulsion is sensitive to changes in moisture content. The air that first strikes the emulsion must be conditioned so that the wet-bulb temperature is well below the melting point of the emulsion, in order to prevent the emulsion from running or forming streaks. For certain types of film, the emulsion-coating operation must be repeated several times. X-ray film and certain color-films have emulsion on both sides, while Kodachrome film requires at least five separate emulsion-coating operations. The coating operation is one in which great cleanliness is required and in which the work is carried out under difficulties, due to the fact, especially in the case of negative emulsions, that most of the work is carried out in almost total darkness.

Slitting and perforating motion picture film appear at first thought to be simple mechanical operations, but in actual practice they are extraordinarily complicated. The slitting is done by revolving knives equally spaced above and below the film. The upper knife has a keen razor edge, while the lower knife has a sharp square edge. Only the finest mechanics are used for maintaining these knives in their proper condition.

Perforating the film would be comparatively simple if it were not for the extreme accuracy required. The punches and dies are so accurately made that the punches can not be inserted into the dies by hand without injuring them, although when clamped in the machines they go in and out thousands of times without appreciable wear. Each punch consists of eight punching members and eight positioning members, or pilots, four of each on each side of the film. As the film passes through under the punch, four pairs of holes are made. A shuttle then moves the film four spaces forward, and the ram moves down again. This time the pilots, which have slightly tapered ends, enter the holes that have previously been punched, and finally position the film before the punches strike the new holes, so that each set of eight holes is accurately positioned by the previously punched set of holes. The tolerance ordinarily used in manufacturing the punches and dies is approximately 0.00002 inch.

We have now considered, in as much detail as space permits, the manufacture of motion picture film from the raw materials to the finished product. It is quite obvious that a very great mass of material has been omitted that would have to be presented if the complete story were to be told. Papers as long as the present one would be required to describe in detail merely the problems involved in manufacturing the cores used in the rolls of ciné film or of the black paper used in wrapping the film.

Twenty-five years ago there were but two types of motion picture film, negative and positive. In 1913, panchromatic film was supplied, and since then improvements and changes in emulsion, backings, tints, and the like have been introduced, so that at the present time there are manufactured sixty-two different types of motion picture film, including thirty-five different types of nitrate film and twenty-seven of safety film.

The problem of testing and controlling such a large variety of materials is a complicated one. In spite of the extreme care taken to keep each step in the preparation of each type of film entirely uniform, occasional variations creep in that are sometimes traced to extraordinarily insignificant causes. In order to check such variations, each department has its own testing facilities and laboratory, in which as many as possible of the qualities involved are tested. In addition, there is a general testing department, in which routine tests are made on all products, while occasional intensive studies are made by members of the research staff or other groups.

MICROPHONE MIXERS*

M. RETTINGER**

Summary.—The design of compensated microphone mixer circuits is discussed. The purpose of such circuits is to provide impedance matches for all the microphones in the circuits by means of so-called "compensating" or "building-out" resistors. General equations are obtained for the values of these resistors for multi-channel mixers of both the parallel and series-parallel type.

The purpose of this paper is to devise mixer circuits in which all the impedances are properly matched. As a result of this investigation three general equations were evolved that greatly facilitate the design of multi-channel mixers of the "series" type. By "series" type is meant the case where the "compensating" resistor is in series with the generator. For the sake of distinction one case of "parallel" type (two-channel mixer) will also be treated.

In addition, calculations were also made to determine the insertion loss of the various mixers in relation to the case where only one generator is properly matched to the line. In all these computations, no power losses were assumed in the transformer.

In order to make clearer the advisability of such an investigation, consider the conventional circuit for a two-channel mixer shown in Fig. 1. If R_i is a 250-ohm T pad, or the microphone itself, the impedance looking into R_i is $R_i + Z_o$. If Z_o is 500 ohms, as is usually the case, then the input channel is working into an impedance of 750 ohms instead of into an impedance of 250 ohms required for proper matching. In other words, looking into the circuit from the load side, the impedances are matched; but looking into the circuit from one of the input channels, there exists a mismatch of 1:3.

Consider now Fig. 2(A). The impedance looking into the circuit from one of the channels is given by

$$R_i = \frac{R_s[Z_o(R_i + R_s) + R_iR_s]}{R_s(2R_i + R_s) + Z_o(R_i + R_s)} \tag{1}$$

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* Received February 25, 1937.
** RCA Manufacturing Co., Hollywood, Calif.

Looking into the circuit from the load side, the impedance is

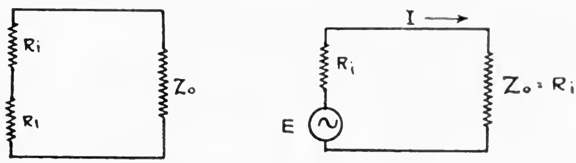
$$Z_o = \frac{2R_iR_s}{R_i + R_s} \tag{2}$$

Solving (*1*) and (*2*) simultaneously:

$$R_s = 2R_1$$
$$Z_o = (4/3)R_i$$

Similarly, for the circuit of Fig. 3:

$$R_i = R_s + \frac{(R_i + R_s)Z_o}{R_i + R_s + 2_o}$$
$$Z_o = \frac{R_i + R_s}{2}$$



(*A*) (*B*)

FIG. 1. Conventional circuit of two-channel mixer.

Simultaneous solution gives

$$R_s = \frac{R_i}{2}$$
$$Z_o = \frac{3}{4}R_i$$

In order to determine the insertion loss consider, first, Fig. 1(*A*). The power across Z_o is

$$P_1 = I^2Z_o$$
$$= \left(\frac{E}{2R_i}\right)^2 R_i$$
$$= \frac{E^2}{4R_i}$$

Let us next redraw Fig. 2(*A*) as shown by Fig. 2(*B*). The current through Z_o is

$$I = \frac{E/2}{(4/3)R_i + (2R_i^2)/3R_i}$$
$$= (E)/4R_i$$

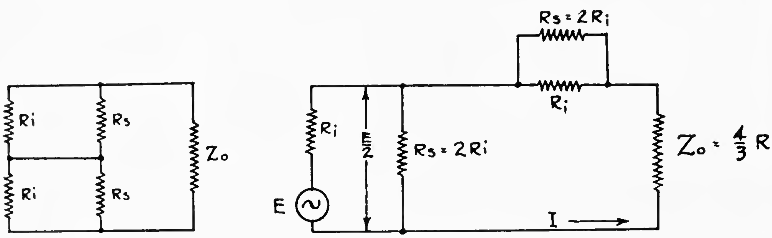
The power across Z_o is

$$P_2 = I^2 Z_o$$
$$= \left(\frac{E^2}{16R_i^2}\right)\frac{4}{3}R_i$$
$$= \frac{E^2}{12R_i}$$

Therefore the insertion loss is

$$DB = 10 \log \frac{P_1}{P_2} = 10 \log \left(\frac{E^2}{4R_i}\right) \Big/ \left(\frac{E^2}{12R_i}\right)$$
$$= 10 \log 3$$
$$= 4.7 \text{ db.}$$

The insertion loss of the circuit given by Fig. 3(*A*) can be calculated



(*A*) (*B*)

FIG. 2. Two channel mixer.

similarly by considering Fig. 3(*B*). This figure may be re-drawn to give Fig. 3(*C*). The current I is given by

$$I = \frac{E}{2R_i}$$

The voltage E' is given by

$$E' = (3/2)\, R_i\, (E)/2R_i$$
$$= (3/4)\, E$$

The power across Z_o is given by

$$P_2 = \frac{(E')^2}{Z_o} = \left(\frac{3}{4}E\right)^2 \Big/ \frac{3}{4}R_i$$
$$= \frac{3}{4}\frac{E^2}{R_i}$$

Hence the insertion loss is given by

$$DB = 10 \log \frac{P_1}{P_2} = 10 \log \left(\frac{E^2}{4R_i}\right) \Big/ \left(\frac{3}{4}\frac{E^2}{R_i}\right)$$

$$= 10 \log \frac{1}{3}$$

$$= -4.7 \text{ db.}$$

It is seen that for either two-channel mixer we have an insertion loss of 4.7 decibels, irrespective of what R_i is in either circuit.

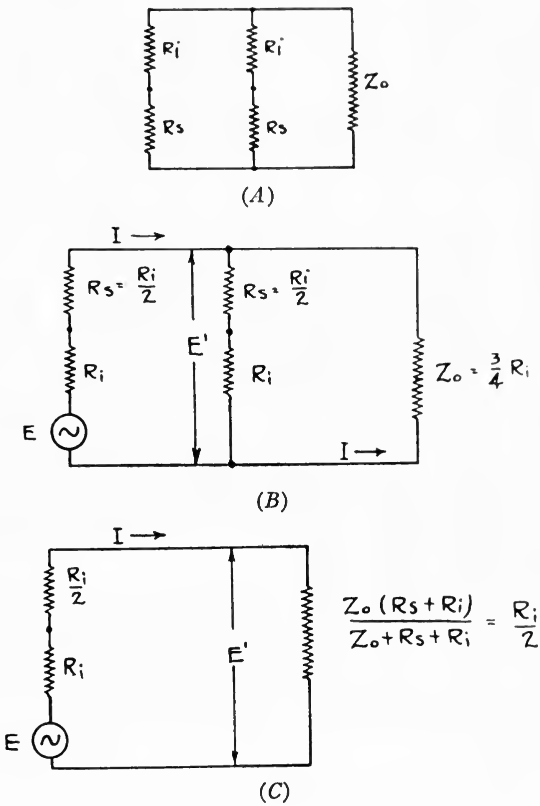


FIG. 3. Circuits for calculating insertion loss.

For a three-channel mixer, as shown by Fig. 4(A), we have

$$R_i = \frac{R_s(R_i + R_s + 2Z_o) + (R_i + R_s)Z_o}{R_i + R_s + 2Z_o}$$

$$Z_o = \frac{R_i + R_s}{3}$$

Simultaneous solution gives

$$R_s = \frac{2}{3} R_i$$

$$Z_o = \frac{5}{9} R_i$$

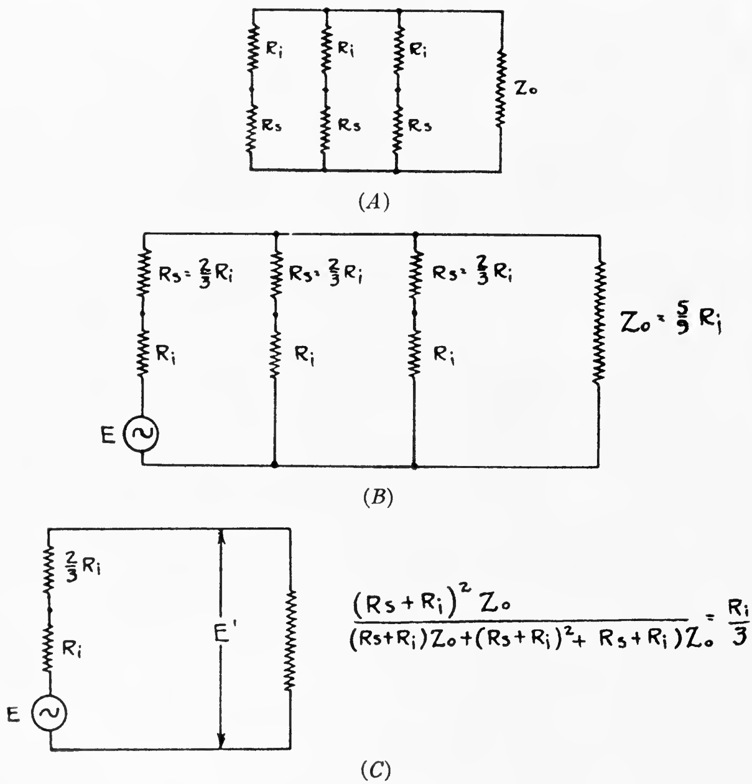


FIG. 4. Three-channel mixer.

To compute the insertion loss of this three-channel mixer, re-draw Fig. 4(*A*) to give Figs. 4(*B*) and 4(*C*). The current I is

$$I = \frac{E}{2R_i}$$

The voltage E' is

$$E' = \frac{5}{3} R_i \frac{E}{2R_i}$$

$$= \frac{5E}{6}$$

The power across Z_o is

$$P_2 = \frac{(E')^2}{Z_o} = \left(\frac{5}{6}E\right)^2 \bigg/ \frac{5}{9}R_i$$

$$= \frac{5}{4}\frac{E^2}{R_i}$$

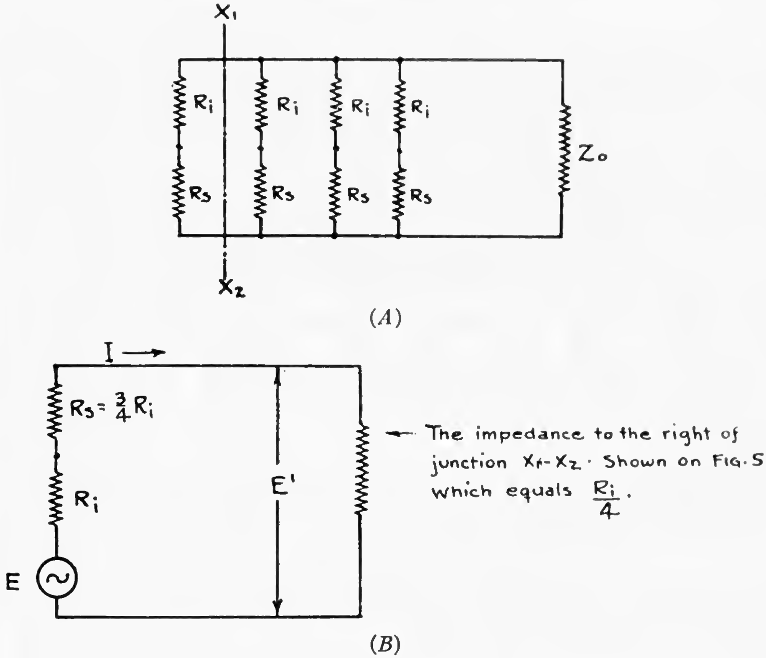


FIG. 5. Four-channel mixer.

Hence the insertion loss is

$$DB = 10 \log \frac{P_1}{P_2} = 10 \log \left(\frac{E^2}{4R_i}\right) \bigg/ \left(\frac{5}{4}\frac{E^2}{R_i}\right)$$

$$= 10 \log \frac{1}{5}$$

$$= 7 \text{ db.}$$

For a four-channel mixer as shown by Fig. 5(*A*),

$$R_i = R_s + \frac{(R_i + R_s)Z_o}{R_i + R_s + 3Z_o}$$

$$Z_o = \frac{R_i + R_s}{4}$$

Simultaneous solution gives

$$R_s = \frac{3}{4} R_i$$

$$Z_o = \frac{7}{16} R_i$$

To compute the insertion loss of this four-channel mixer, re-draw Fig. 5(*A*) to give Fig. 5(*B*). The current *I* is

$$I = \frac{E}{2R_1}$$

The voltage E' is

$$E' = \frac{7}{8} R_i \frac{E}{2R_i}$$

$$= \frac{7}{8} E$$

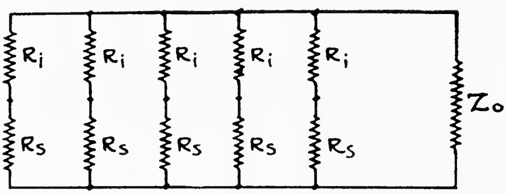


FIG. 6. Five-channel mixer.

The power across Z_o is

$$P_2 = \frac{(E')^2}{Z_o} = \left(\frac{7}{8} E\right)^2 \Big/ \frac{7}{16} R_1$$

$$= \frac{7}{4} \frac{E^2}{R_i}$$

Hence the insertion loss is

$$DB = 10 \log \frac{P_1}{P_2} = 10 \log \left(\frac{E^2}{4R_i}\right) \Big/ \left(\frac{7}{4} \frac{E^2}{R_i}\right)$$

$$= 10 \log \frac{1}{7}$$

$$= 8.4 \text{ db.}$$

For a five-channel mixer, as shown by Fig. 6,

$$R_i = R_s + \frac{(R_i + R_s)Z_o}{(R_i + R_s) + 4Z_o}$$

$$Z_o = \frac{R_i + R_s}{5}$$

Simultaneous solution gives

$$R_s = \frac{4}{5} R_i$$

$$Z_o = \frac{9}{25} R_i$$

The insertion loss can be calculated as before, resulting in

$$DB = 10 \log \frac{1}{9}$$

$$= 9.54 \text{ db.}$$

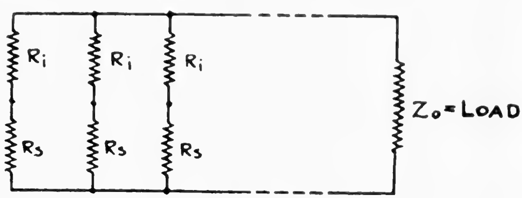


FIG. 7. Parallel type of mixer circuit. The values of the compensating resistances R_i and of the load-resistance Z_o can quickly be computed by the general equations at the end of this paper.

When the foregoing results are tabulated (excepting results for the circuit of Fig. 2), interesting conclusions can be drawn. Consider the following table:

	2-Channel	3-Channel	4-Channel	5-Channel
R_s	$\frac{R_i}{2}$	$\frac{2}{3} R_i$	$\frac{3}{4} R_i$	$\frac{4}{5} R_i$
Z_o	$\frac{3}{4} R_i$	$\frac{5}{9} R_i$	$\frac{7}{16} R_i$	$\frac{9}{25} R_i$
DB	$10 \log \frac{1}{3}$	$10 \log \frac{1}{5}$.	$10 \log \frac{1}{7}$	$10 \log \frac{1}{9}$

It is seen that R_i, Z_o, and DB can be expressed by the following equations, if we let n be the number of channels:

$$R_s = \frac{n-1}{n} R_i$$

$$Z_o = \frac{2n-1}{n^2} R_i$$

$$DB = 10 \log \frac{1}{(2n - 1)}$$

Thus a six-channel mixer has the following values:

$$R_s = \frac{5}{6} R_i$$

$$Z_o = \frac{11}{36} R_i$$

$$DB = 10 \log \frac{1}{11}$$

$$= 10.4 \text{ db.}$$

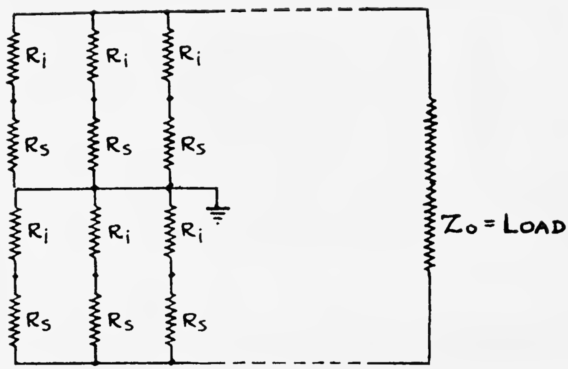


FIG. 8. Series-parallel type of mixer circuit for which all the important constants can easily be calculated by means of simple formulas found in the text.

SUMMARY

Parallel Type (Fig. 7).—If each generator R_i is to see its own impedance, and if n represents the number of R_i's in the mixer, then the value of the compensating resistors, R_s, is given by:

$$R_s = \frac{(n - 1)}{n} R_1$$

$$Z_o = \frac{(2n - 1)}{n^2} R_i$$

$$\text{Insertion Loss} = 10 \log (2n - 1)$$

Series-Parallel Type (Fig. 8).—If each generator R_i is to see its own impedance, and if n represents the *total* number of R_i's in the mixer, then the value of the compensating resistors, R_s, is given by:

$$R_s = \frac{(n - 3)}{n} R_i$$

$$Z_o = \frac{4(2n - 3)}{n^2} R_i$$

$$\text{Insertion Loss} = 10 \log (2n - 3)$$

In conclusion, the writer wishes to make due acknowledgment to Mr. W. S. Thompson for his valuable assistance in connection with the determination of the insertion losses.

SOFT X-RAY MOTION PICTURES OF SMALL BIOLOGICAL SPECIMENS*

H. F. SHERWOOD**

Summary.—*Soft x-rays have been used in radiographing leather, textiles, paper, biological specimens, etc. The most recent application is in recording soft x-ray motion pictures directly upon the film, using a special emulsion having a high sensitivity to soft x-rays. Radiographs were made at a speed of 16 frames per second.*

The camera used was a Universal model C with the lens removed and a piece of infrared gelatin filter covering the gate to protect the film from light, and, at the same time, to furnish a support for the subject. The camera shutter absorbs the soft x-rays from the tube during the short exposures between frames, thus allowing continuous operation of the tube.

A special form of x-ray tube fitted with an extremely thin window is required for the production of radiation suitable for radiographing thin subjects.

Soft x-ray motion pictures of the yellow meal worm show peristaltic waves, gas bells leaving the stomach through the mouth, and the effects of various anesthetic vapors on the internal movements.

Long-wavelength x-rays, known as "Grenz" or soft x-rays, have the low penetrating power that is best suited for the production of good radiographs of thin specimens. A special form of x-ray tube fitted with an extremely thin window is required for the production of this radiation. The voltages applied to the tube range from 5000 to 15,000 volts, which are quite low compared to those used in medical cineradiography.

It is not possible to focus x-rays with any sort of lens. The x-ray image is produced by passing the rays through the subject onto the film. A radiograph is a form of shadow image, in which the various parts of the subject are recorded in proportion to their transmission of the x-rays.

To produce an x-ray image of maximum sharpness and minimum distortion, the specimen is placed as near the film as possible, and the tube is spaced at the maximum feasible distance from the specimen.

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* Communication No. *520* from the Kodak Research Laboratories; received April 9, 1937. Presented at the Spring, 1937, Meeting at Hollywood, Calif.

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

An infrared gelatin filter (Wratten No. *87*) has been found most satisfactory for the protection of the film from light during its exposure to x-rays. Thin black paper affords an effective protection for the photographic material, but its use is impracticable in this work because its structure is recorded by the soft x-rays.

Fig. 1 shows the special tube and the specimen mounted close to the film. Soft x-rays have been successfully used in radiographing

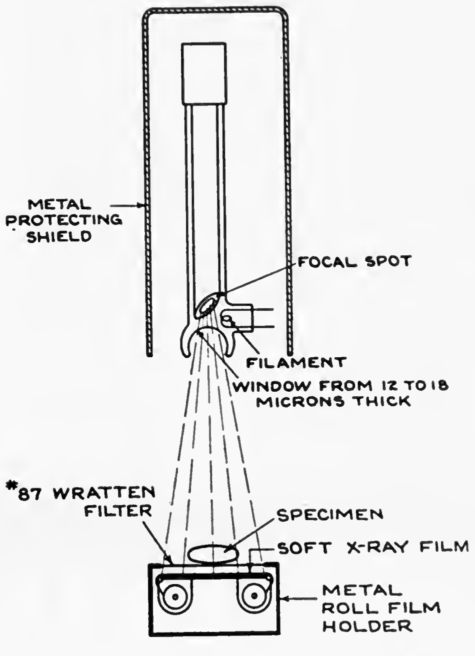

Fig. 1. Diagram of apparatus for soft x-ray radiography.

textiles, leather, paper, biological subjects, *etc.* The most recent application is in the recording of soft x-ray motion pictures directly upon the film. Using a special emulsion highly sensitive to soft x-rays, radiographs were made at a speed of 16 frames per second.

Fig. 2 shows the x-ray tube, camera, and driving mechanism. The camera is a Universal model *C*, with the lens removed. For the x-ray exposures, the camera is mounted with the film in a horizontal plane. A piece of infrared gelatin filter (Wratten No. *87*) covers the gate,

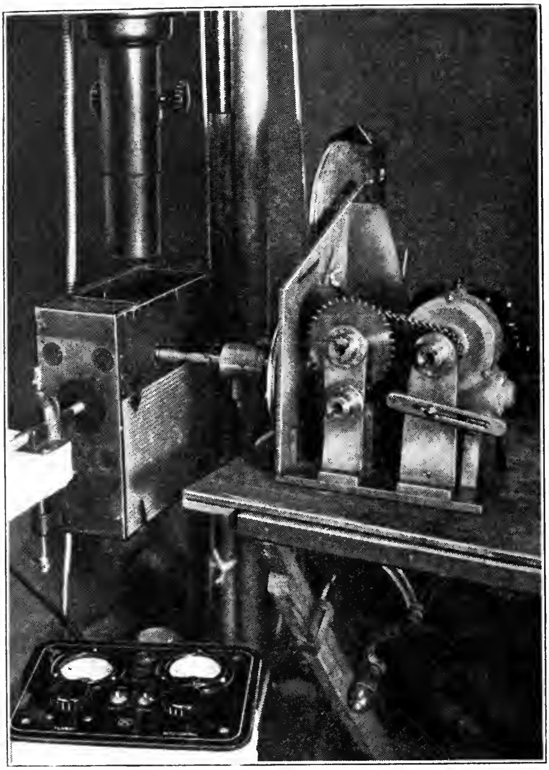

FIG. 2. X-ray tube, camera, and driving mechanism.

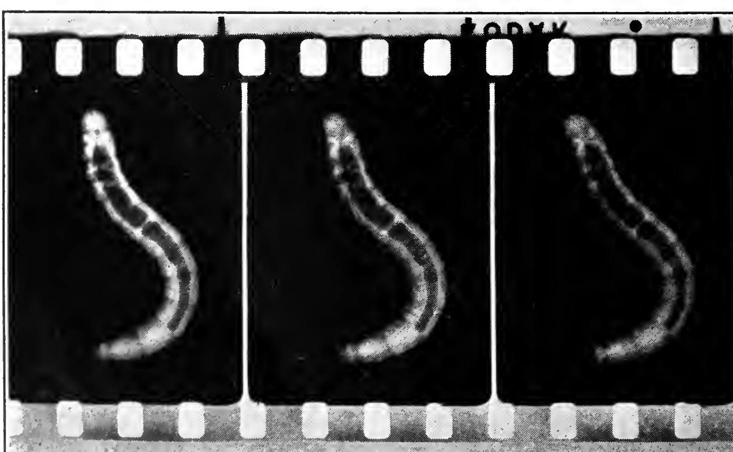

FIG. 3. Radiograph of a yellow meal worm.

thus protecting the film from light, and, at the same time, furnishing a support for the specimen. The camera shutter absorbs the radiation from the x-ray tube during the short exposure between frames, thereby allowing continuous operation of the tube.

Fig. 3 shows a yellow meal worm, taken at 16 frames per second on special "Grenz" ray film at 15,000 volts, 5-inch target-film distance, and 5 ma. This specimen was approximately 30 mm. long.

Subjects were selected upon the basis of length, shape, and thickness. Frequently it was found that two specimens of the same kind, with similar external appearance, showed marked differences both in the absorptive power for the radiation and in the amount of internal movement. These differences are probably due to the presence of varying amounts of fat and fluid in their bodies. The final selection from several specimens under consideration was made from fluoroscopic observations of the activity and opacity of each insect.

Fig. 4. Front view of camera.

It is necessary to view the motion pictures of specimens several times in order to observe carefully all the moving parts and to study their action. It was found that when a subject was anesthetized the peristaltic waves in the intestines increased in number per minute. The various anesthetic vapors tried, carbon tetrachloride, ether, and dry ice, all have the same effect upon the internal movements of the meal worm. The flow of gas bells from the stomach through the mouth formed a steady stream. The normal movements of peristaltic waves are quite slow and the passing of gas bells from the stomach proceeds at the rate of approximately once in every ten seconds.

Definite conclusions from such observations await further study by the entomologist and biologist. Insects that are transparent to infrared rays can be photographed by infrared light to show their internal structures. Since all insects, however, are transparent to x-rays, the x-ray method has a much wider application in this type of work than that using infrared radiation.

Unquestionably, soft x-ray motion pictures of living insects should prove useful for many research and educational purposes. They should prove a valuable aid in studying the variations accompanying the cycle of development and growth of insects. There is reason to believe that the radiographic method will be as useful in the basic biological sciences as it has been in medicine and industry.

PANORAMIC MOTION PICTURES*

C. J. POSEY**

Summary.—*A method of producing panoramic motion pictures, to be projected upon the interior of a cylindrical screen, is described. An unbroken panorama of 360 degrees is formed and the spectator may look in any direction he pleases.*

This paper describes a technic for the production of panoramic motion pictures that will represent, upon a continuous screen, the entire panoramic view about the point where the pictures are taken. The scheme of operation is entirely different from that used in present-day motion picture cameras and projectors. Instead of moving in a series of jerks, the film moves smoothly, at uniform speed. The pictures are projected upon the interior of a cylindrical screen, where they form an unbroken panorama of 360 degrees. The spectator may look in any direction that he chooses.

The general optical and mechanical design of the camera and projector has been worked out by the writer. Several variants of the scheme are possible. The essential elements are represented diagrammatically, in simplified form, in Figs. 1 and 2.

The camera is mounted upon a vertical axis about which it revolves in the manner of the familiar Cirkut camera, but at a faster rate, ordinarily sixteen times per second. The roll film travels in a horizontal arc at the same rate as the image formed by the lens. The exposure is made as the film passes a vertical slot in the back of the camera, the exposure time being governed by the width of the slot and the speed of rotation of the camera. The vertical axis of the camera does not need to remain stationary, but can be moved if a suitable transporter is provided.

In the projector, the process is reversed. A beam of light passes through the positive film and throws an image upon the inside of a cylindrical screen. The beam of light revolves around the inside of the screen at the speed of 16 revolutions per second. The width of

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* Received March 19, 1937.

** State University of Iowa.

film through which the light passes may be wider than the slit through which the exposure was made in the camera. If the throw is long, it may be necessary to provide more than one projection lens to ob-

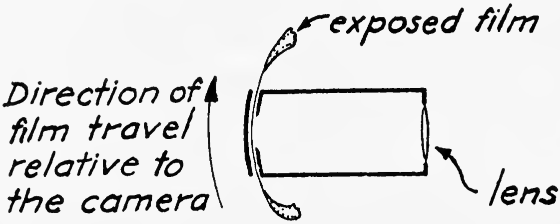

Fig. 1. Plan view of camera. Camera rotates counterclockwise about the vertical axis through the nodal point of the lens.

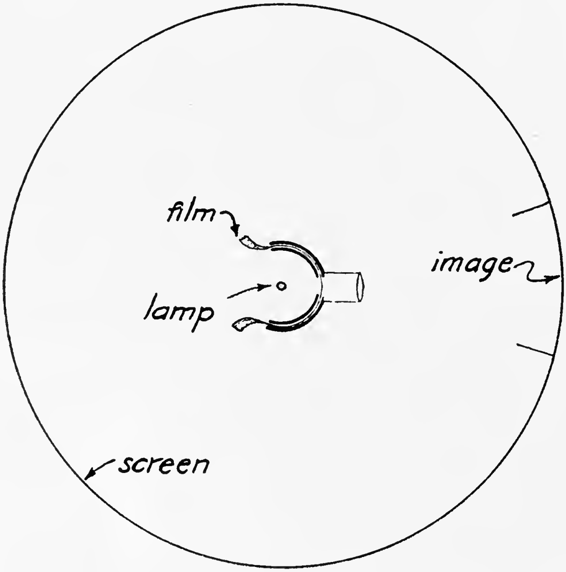

Fig. 2. Plan view of projector. Projector rotates clockwise, film counterclockwise relative to the projector, but stationary relative to the screen.

tain the required intensity of illumination. As stated before, the illustrations represent the general scheme in simplified form; certain obviously essential improvements in arrangement are omitted for the sake of clarity.

Making motion pictures panoramic would free them from the necessity of focusing attention within a certain space-angle. This very freedom, however, would require the development of an entirely new technic in dramatics. It is hard to imagine what would be the solution of some of the problems of dramatic representation, but certainly scenes of the following types could be handled without difficulty: travel pictures in scenic areas, slow-motion studies of clouds and mountain peaks, scenes at carnivals, rodeos, or expositions, and races upon circular or oval tracks.

The projection room will have to be circular, with the projector suspended from the center of the ceiling. The audience will sit in the area below the projector in revolving chairs that can be turned at will. These items alone will make panoramic motion pictures expensive. At first the theaters will be small, and the use restricted to travel advertising, in which field panoramic pictures will have great value due to the heightened realism and the enormous amount of publicity their appearance will bring. Panoramic motion pictures will probably never come into wide usage, but they should enjoy popularity at fairs and should find a permanent place in the larger cities.

A WIDE-RANGE, LINEAR-SCALE PHOTOELECTRIC CELL DENSITOMETER*

W. W. LINDSAY, JR.,** AND W. V. WOLFE†

Summary.—*A photoelectric cell densitometer is described that makes use of a modulated light-source, stable high-vacuum photoelectric cell, and an audio amplifier provided with a logarithmic potentiometer and multiplier supplying the desired linearity of calibration, the instrument being operated entirely by alternating current. Theoretical factors, density standards, and design problems of the instrument are also considered.*

The need for an instrument having a wide range of density and linearity of scale calibration has been recognized for some time. The more general types of instrument involve the balance of two illuminated spheres by visual observation, and therefore are to a large extent dependent upon the skill of the observer. Eye fatigue after many measurements tends to reduce the accuracy of the balance point. Various forms of photoelectric cell densitometers have also been constructed, and are in general use in most studios. The majority of these instruments utilize a meter with a scale calibrated in density or per cent transmission. Physical limitations impose a scale calibration becoming rapidly congested as the higher density end is approached. Instability, also, is a limiting factor as well as the amount of light that can be used without burning the film under measurement. There are, of course, other theoretical problems of density measurement that appear to be fundamental in nature, and therefore apply to nearly all types of densitometers.

With the above-mentioned limitations in mind, the writers undertook the construction of a densitometer along slightly different lines, involving the use of a modulated light-source;[1] a stable photocell of the high-vacuum type; an amplifier having essentially constant gain, in conjunction with a precision attenuator having a linear relation

* Received April 23, 1937; presented at the Spring, 1937, Meeting at Hollywood, Calif. Original ms. prepared June 1, 1935.

** General Service Studios, Inc., Hollywood, Calif.

† RCA Manufacturing Co., Hollywood, Calif.

between decibels attenuation and angular rotation; and a multiplier. The amplifier is designed with band-pass characteristics so that harmonics of the light-modulator are suppressed as well as the lower power supply frequencies. A simple and rugged indicating instrument of the copper-oxide rectifier type completes the picture. The requirement that the instrument be operated from the alternating current mains, either 50 or 60 cycles, imposed other problems that will be described in detail later.

Briefly, the instrument would operate as follows: The power switch is turned on and amplifier put into operation; the photocell is placed in the operating position; the gain of the amplifier is adjusted so that the zero density point on the potentiometer scale reads reference meter deflection; then the unknown density is inserted; and the amplifier gain adjusted to read the reference meter deflection again. By suitable calibration, the gain of the amplifier may be interpreted in terms of density.

THEORETICAL POINTS OF INTEREST

The accurate measurement of density involves a great many factors which in a practical operating instrument can not be entirely realized.

(*1*) In particular, we must assume that the light reaching the film under measurement is completely diffused; otherwise our readings will be somewhere between totally diffuse and specular density.

(*2*) Also, even though the light reaching the film is completely diffused, it may not be practicable to provide a photocell housing that will permit all the scattered light passing through the film to reach the photocell cathode.

Sensitivity considerations, and the fact that the maximum amount of light that can be employed is limited by the danger of film burn, the first requirement can be only approximated. The approximate condition applies to the position of the photocell with respect to the film, and while we attempt to collect upon the photocell cathode all the scattered light transmitted through the film, the condition is still far from ideal.

(*3*) There is a further difficulty, which is probably more obscure than the first two, commonly referred to as the "color coefficient," or stain effect. While practical use of the instrument has not shown any serious discrepancies that we felt could be attributed to color stain of the film samples being tested, theory indicates that in view of the spectral characteristics of the exciting lamp and photocell, there is ample room for error to occur. In the measurement of negative density, we are interested in the density that would be seen by the positive emulsion, since this is the usual print stock. The exciting lamp gives very little emission in the blue range, compared to the red, and the caesium photocell is even worse in this respect. In the experiments we tried several photocells, sensitive in the blue region, but the densities read on the samples we had, showed little, if any, difference. The use of a suitable filter would be desirable, but is difficult to obtain with the correct attenuation characteristics.

FIG. 1. Exterior view of densitometer.

For the measurement of the positive, or print, densities, a much more favorable condition exists, since in actual reproduction a filament type of lamp and caesium cell are used. The error then is due chiefly to the amount of diffusion in the instrument, and the fact that no optical lens system is used in our instrument.

(4) An examination of the calibration of the instrument will show a nearly perfect linear relation between gain in decibels and dial rotation (Figs. 1 and 6A). This should hold for density also, if all theoretical requirements could be realized. The (slight) curvature noticeable as higher densities are measured, can be explained

with reference to points *1* and *2* by Callier's Q.[2] There may be some other factors which we have not considered, as well.

(*5*) By calibration from standard densities, measured in terms of total visual diffuse values for the particular emulsions being used, very satisfactory results may be obtained, provided that the negative color coefficient remains reasonably constant.

Density Standards.—In attempting to calibrate the instrument accurately, it became very apparent that the instruments that were available for checking standard film tablets were in themselves very inaccurate. It was only after making several hundred checks that we felt at all sure that the calibration was satisfactory.

The need of the industry for better standards or methods of measuring sub-standards, is keenly felt.

Light-Source.—A small lamp of standard form, readily available, is of course desirable. The usual methods of using a storage battery, rheostat, and ammeter to keep the illumination constant did not appeal to us. Various types of light-source were tried, and since it was desirable from an economic standpoint to use certain equipment that was available, we decided upon a double-filament automobile head-lamp bulb, using both filaments.

Method of Modulating Light-Source.—Various methods of modulating the light-source were tried. The simple one of supplying the lamp filaments with alternating current proved unsatisfactory for several reasons, chiefly because of the low percentage of light modulation achieved and the problem of shielding the amplifier from the low frequency fields. Alternating current was also tried on the photoelectric cell, but the results were not gratifying. The classical method of using an oscillator to provide audio-frequency variation of cell sensitivity was not attempted, since we rapidly concluded that the simple and time-tried method of using a disk provided with light apertures and rotated so as to interrupt the light striking the cell, would prove to be the most satisfactory one to use. A small motor of the induction type was found whose speed of rotation depended chiefly upon the frequency of the supply mains rather than upon the voltage. A light aluminum disk was mounted upon the motor shaft and provided with circular holes equally spaced near the periphery. The number of holes was chosen to produce an audible frequency of about 910 cps. when running on a 50-cycle supply, and 1090 cps. on a 60-cycle supply. This imposed a rather severe requirement upon the amplifier, the solution of which will be treated in detail later. The photographs of the instrument, opened (Figs. 2 and 3), illustrate the arrangement of motor, disk, and illuminating lamp.

Photoelectric Cell.—Various cells were tried, and while the photronic type had considerable appeal, it was discarded due to its lack of linear response over the wide ranges of light intensity we proposed using,

FIG. 2. Interior of densitometer, showing arrangement of motor disk, and illuminating lamp.

corresponding to a density range of zero to three. Gas-filled cells were also tried, since their output is greater and would require less gain in the audio amplifier. We finally chose a high-vacuum cell, which was found to be entirely linear, with gas ionization effects practically absent. The stability was found to be sufficiently superior to that of the gas type, so that the additional amplifier gain that was necessary was warranted.

Light-Source and Photoelectric Cell.—Before going further, it is appropriate to make some mention of the position of the photocell with respect to the light-source, and since we are attempting to measure totally diffuse density, it is important that the light-source be well diffused. The rotating disk produces some diffusion, but we found it necessary to use as thick a piece of pot-opal glass as the

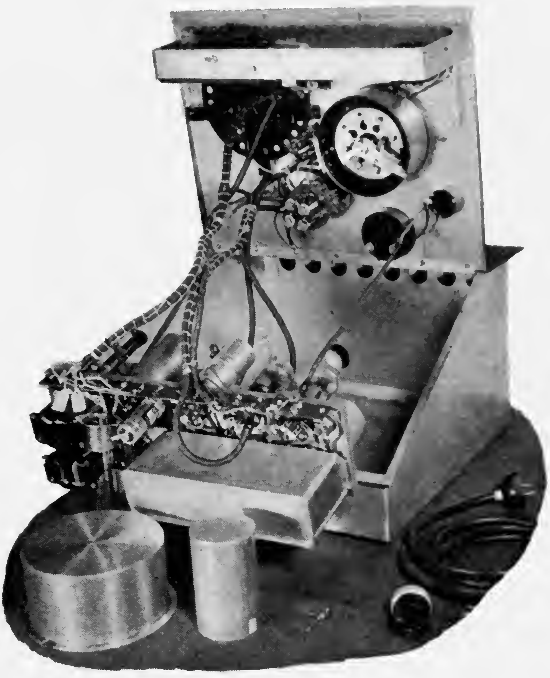

FIG. 3. View of the interior, showing the disk, potentiometer, illuminating lamp, and method of mounting the parts.

sensitivity and range of the amplifier would permit. It is so placed as to be practically in contact with the film under measurement—this is the most desirable condition.[3] The photocell is mounted in a circular housing, which, in turn, is pivoted so that with a little pressure of the hand it may be brought down upon the film. A spring serves to raise the cell housing up out of contact with the film and the light-source. This is a very useful feature, since it serves partially to protect the amplifier and indicating instrument from overload (Fig. 1).

POWER SUPPLY, AMPLIFIER, ATTENUATOR, AND INDICATING INSTRUMENT

Naturally, with the various tests of different photocells and light-modulating arrangements, the amplifier assumed various forms.[4] The final choice of the high-vacuum cell required a complete revision of its component parts and circuit. The schematic circuit of the complete instrument (Fig. 4) indicates the final form chosen. Briefly, we start with a conventional power supply circuit, the power transformer being used to supply the exciting lamp (light-source) and tube heaters. The rectified direct current is used to provide B and C

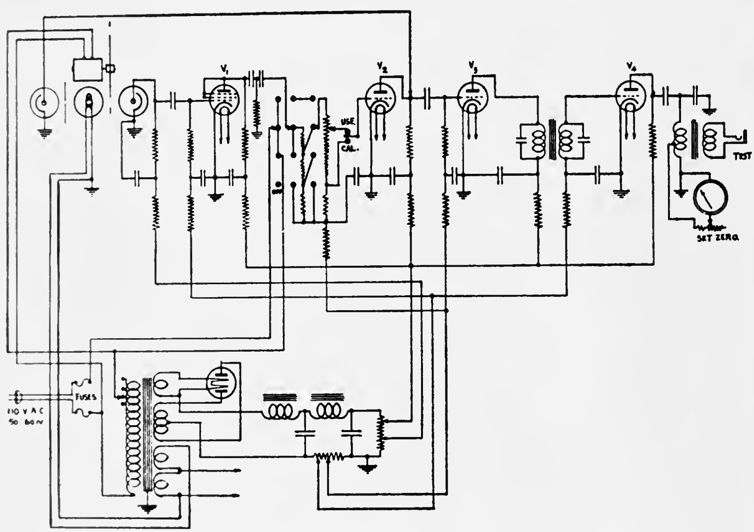

FIG. 4. Circuit of densitometer (V_2 and V_3 are in the same bulb).

potentials for the amplifier proper. The photocell receives its polarizing voltage from a tap on the bleeder resistance. The photocell is resistance-capacity coupled to the grid of the first tube, which is a pentode connected for triode operation. This provides high insulation resistance, since the control grid appears at the top of the glass bulb. The plate circuit of this tube is, in turn, resistance-capacity coupled to the input of the multiplier and logarithmic potentiometer. A special guard leak and double capacity serve to prevent any spurious direct current from affecting the bias on the grid of the tube fed from the logarithmic potentiometer. The multiplier changes the gain in steps of 20 decibels, and the range of the logarithmic potentiometer has been adjusted to have about the same range. This means that only the potentiometer is used for the highest density range (highest amplifier gain), and the multiplier serves to reduce the gain in additional steps of 20 decibels each. A range of 0–1.0 in density requires a 20-db. change in gain, and since we measure about 0–3.0 in density, the range of multiplier and potentiometer is effectively 60 decibels. For reasons discussed previously we actually do not reach 3.0 in density, but are limited to 2.74. The movable contact on the logarithmic potentiometer feeds the audio voltage to the grid of the next tube, which is of the double triode type, in one glass

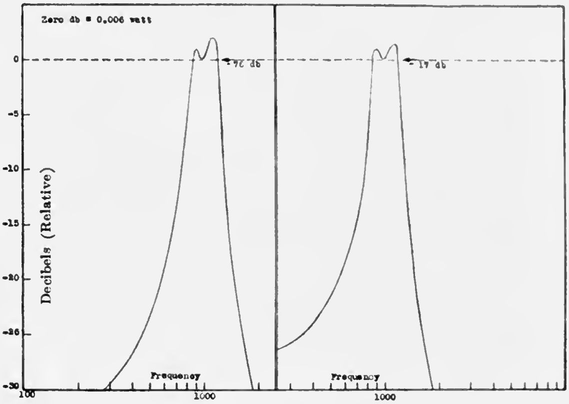

FIG. 5. Gain-frequency characteristic of densitometer amplifier, with two signal amplitudes.

bulb. From the plate of the first triode unit, the signal is resistance-capacity coupled to the grid of the second triode unit. The plate of this second unit is connected to a tuned circuit which is critically coupled to another tuned circuit, the degree of coupling being so chosen that a double-peak response occurs. The reason for this double peak is to take care of the change of frequency of the signal when the motor operating the light-modulating disk is used on either 50- or 60-cycle supply circuits. One peak occurs at 910 cps. and the other at 1140 (Fig. 5). The response is almost identical for both signal amplitudes and the band widths are similar. The second tuned circuit supplies the signal to the grid of a conventional triode, the plate of which is connected by means of a resistance-capacity coupling to the output transformer. This alters the tube plate impedance to a more suitable value for operating the indicating meter. The meter has an adjustable series resistance, providing a convenient means of setting the *calibrate* or zero density point, on the logarithmic potentiometer, to the correct reference point on the scale of the meter itself. The meter is a simple copper-oxide rectifier type with a d-c. sensitivity of 500 microamperes. The linearity of the calibration may be seen in Figs. 6 and 6*A*.

Before passing to the subject of stability and a means of partly correcting the large changes in light resulting from small lamp current changes, stress must be placed upon the use of circuit elements having essentially no temperature coefficient. Since this is actually

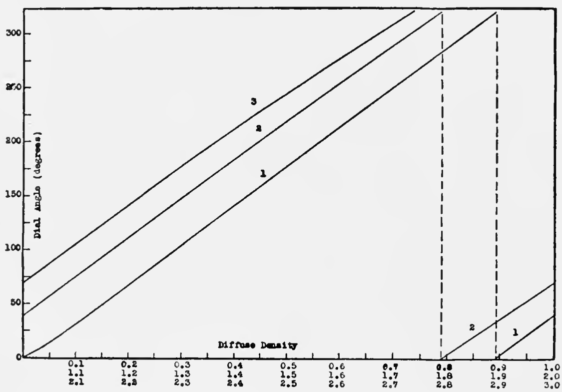

FIG. 6. Densitometer calibration.

not possible, the entire instrument shows a slight temperature effect, necessitating a minor increase in the *Set Zero* dial, which means that the overall sensitivity decreases with increase of temperature. All interstage coupling condensers are of the compressed mica type, and were selected for high insulation resistance. Their size in connection with the value of leak used in the grid circuits was so chosen as to provide additional discrimination against power supply frequencies. This also applies to the output transformer and its associated series capacity.

All circuits are resistance-capacity filtered to provide adequate isolation and prevent feedback effects. The use of the large 50-μf capacity between the low-potential end of the logarithmic potentiometer and ground was found to be very important.

The original circuit provided individual cathode biasing but we found that better results were attained by grounding all the cathodes (this is particularly true of the double triode tube) and obtaining the required negative bias from the total current flowing through a resistor in the negative lead of the power supply unit. This resistor is provided with adjustable taps so that the optimal bias for stability may be obtained. The use of this adjustment provides an overall gain essentially independent of line voltage changes (±0.5 decibel for ±5.0-volt line fluctuation).

Although reasonable amplifier stability has been attained there remains the photocell, and since its sensivity is practically independent of the applied d-c voltage, we are faced with the large change

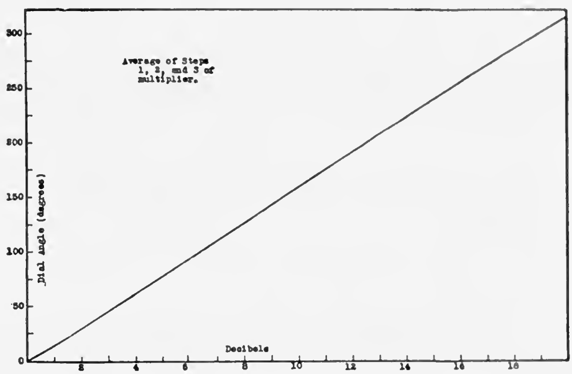

FIG. 6A. Decibel calibration of densitometer potentiometer.

of light intensity resulting from a small change of current through the exciting lamp filament—a 1-per cent current change effecting a light change of from 6 to 8 per cent. This is by far the greatest effect, and without elaborate voltage regulating devices, the most difficult to overcome. In this connection, one of the writers had previously made use of photocells as gain control devices in amplifier circuits. The idea therefore occurred to him to use another photocell as a coupling impedance of the amplifier, and by illuminating the cell from the exciting lamp directly (without modulation), any variation in light would in turn be reflected as a change of amplifier gain, and it might be possible, by a suitable adjustment of the coupling arrangements, to compensate for the bad effects mentioned above. In actual practice this requires considerable care in order to get the correct effect. The circuit arrangement is included in the complete circuit diagram of the instrument (Fig. 4).

ACKNOWLEDGMENTS

The writers wish to thank Mr. T. K. Glennan, *Vice-President,* and Mr. J. R. Whitney, *Sound Director,* of General Service Studios, Inc., through whose coöperation this development was possible. They also wish to express their appreciation for the coöperation of the Eastman Kodak Company in supplying standard density tablets, and to Dr. O. Sandvik for the discussion of several theoretical points.

Considerable credit is due Mr. John McCall for the mechanical arrangements, and workmanship, and thanks are due to Mr. Frank O'Grady whose untiring efforts in the practical use of the instrument have resulted in a far better device than had been originally anticipated.

REFERENCES

[1] FERRIE, G., JOAUST, R., AND MESNY, R.: "Amplification of Weak Currents and Their Application to Photoelectric Cells," *Proc. I. R. E.* (Aug., 1925), No. 8, p. 461.

[2] JONES, L. A.: "Photographic Sensitometry," *J. Soc. Mot. Pict. Eng.*, **XVII** (Nov., 1931), No. 5, p. 713. *Eastman Kodak Co., reprint,* pp. 58 and 60.

[3] *Ibid.*, **XVII** (Nov., 1931), No. 5, pp. 727–729; *Eastman reprint,* pp. 72–74.

[4] MILLER, C. W.: "A Linear Photoelectric Densitometer," *Rev. Sci. Instr.* (April, 1935), p. 125.

ADDENDUM

(*1*) The following papers having a definite bearing on the subject of density measurement have been published subsequently to June 1, 1935. It is believed that they will contribute to a more complete understanding of the problem:

HIATT, B. C., AND TUTTLE, C.: "Note on the Measurement of Photographic Densities with a Barrier Type of Photocell," *J. Soc. Mot. Pict. Eng.*, **XXVI** (Feb., 1936), No. 2, p. 195.

TUTTLE, C.: "A Recording Physical Densitometer," *J. Opt. Soc. Amer.*, **2** (July, 1936), No. 7.

FOGLE, M. E.: "New Color Corrected Photronic Cells for Accurate Light Measurements," *Trans. Illum. Eng. Soc.*, **XXXI** (Sept., 1936), p. 773.

(*2*) The photocell method of light-change compensation has been described for the sake of interest. However, it did not prove very practicable in operation, and has been removed. The use of a synchronous motor and saturated-core voltage-regulator has proved to be the best means of reducing the effect of line-voltage fluctuation, and have been added to the instrument during the past year.

NEW MOTION PICTURE APPARATUS

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

A NEON TYPE VOLUME INDICATOR*

S. READ, JR.**

Some reduction in volume range is usually desirable, and in most cases quite necessary, whenever original sound is reproduced or recorded, later to be reproduced. None of the systems is capable of reproducing the full range from the existing acoustic noise level to the maximum sound intensity that may be encountered, since most systems do not have sufficient power output; and even if they did, their inherent noise level would be objectionable for weak sound intensities.

Volume is usually controlled manually. Automatic volume control systems have not been satisfactory, except in very special cases, for controlling the amplitude of the audio-frequency voltage obtained from original sound.

A wide variety of volume indicators, devices for measuring this audio-frequency voltage, has been employed to assist the operator in judging the result of "monitoring"; that is, of reducing the electrical output during periods of high sound intensities and increasing it during periods of low intensity. It is the purpose of this paper to describe an improved type of neon volume indicator.

REQUIREMENTS

Before describing the unit, let us consider some of the requirements of a volume indicator:

Peak Amplitudes.—First, in order properly to limit the range of intensities so as not to exceed the maximum that can be accommodated by the equipment, it is desirable to have some indication of the peak intensities that occur. In the case of variable-width film recording, the width of the space provided for the sound-track limits the peak amplitudes that may be recorded. From this consideration it is obviously very desirable to have the volume indicator respond to peak amplitudes of the a-c. voltage.

Power Level.—Second, it is necessary to maintain such a ratio of intensities between different sounds as to produce a pleasing effect, especially when the recording is made over a long period and then reproduced continuously, as is done in

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* Presented at the Fall, 1936, Meeting at Rochester, N. Y.; received April 9, 1937.

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

the process of recording and reproducing commercial motion pictures. Although extremely loud sounds and extremely weak ones can not be reproduced in accordance with the original ratio of intensities, it is quite necessary that the range be compressed uniformly so that a given reproduced sound will not be greater than another when the reverse is true of the original sounds. Also it would not be realistic to reproduce sounds at equal intensities when the original values are appreciably different. This involves measuring the energy in the respective sounds. Since the energy in an alternating-current wave is proportional to the rms. value of the wave, it is obvious that the rms. value should be indicated over a number of cycles of the sound in question.

Wave-Form.—There are a number of difficulties involved in meeting the two requirements just mentioned. Calibration is generally made with a sine-wave voltage, whereas the actual voltage to be measured is extremely complex as to wave-form. Instead of perfect sine-wave voltages with their peak values approximately 40 per cent greater than the rms. value, the peak values may considerably exceed the rms. values.

Frequency.—The frequency of the signal voltage presents a problem that is somewhat different when measuring peak amplitudes from that of measuring power levels.

Different sound systems differ greatly with frequency as to their peak carrying abilities. Constant-velocity devices such as loud speakers and disk recorders can usually handle much higher peaks at the high frequencies; whereas constant-amplitude devices, such as film recorders, permit essentially the same amplitude throughout the audio range. The allowable percentage modulation of a high-grade transmitter is practically uniform over the audio band.

Then for use with film recording or with broadcast speech input equipment, a uniform peak indication over the audio range of frequency is required; whereas for disk recording a closer approach to the permissible amplitude of the recording stylus is worth while. If the actual powers in the signal voltages are to be noted, then the rms. response *vs.* frequency should be constant. However, if the indication is to be proportional to how loud the reproduction sounds to an observer, the solution becomes extremely difficult. Even neglecting the variations in characteristics of the various reproducing equipments, the response of the human ear varies with frequency and intensity of the sound as shown by Fletcher.[1] Although a correlation of the rms. response *vs.* frequency characteristic with these variables may be worth while, a linear response-frequency correlation greatly simplifies the problem, especially if one indicator is to be used for denoting both peak and rms. values.

Transients.—Even if the difficulty of wave-form and frequency response is met it is still essential that the peak and rms. indications be as independent of transients as possible. Since the signal voltage is not only complex as to wave-form and frequency but is continually changing both in magnitude and wave-shape, the response should be such as to respond faithfully to sudden changes. Any inertia of the system may cause the indication either to fall short of the correct value or to indicate excessively high amplitudes due to overswing.

Scale Range and Proportionality.—The audio waves encountered in original sound have a tremendous range of amplitude, from extremely loud sounds to very weak ones. Even after monitoring, the range of intensity may still be of the order of 40 or 50 decibels in standard recording or broadcast speech input channels. Also this change of level may take place over relatively short periods of time, making it quite desirable that the indicator respond to at least this range without any assistance from the operator in the way of changing the multiplication factor of the scale or otherwise modifying the range of the instrument. It is desirable that the proportionality of output amplitude to scale indication be such as to obtain as accurate an indication as needed at any portion of the scale. Particularly at low levels is it necessary to expand the scale so as to be able to detect changes over the lower 25 decibels of the range. A logarithmic relation should be quite satisfactory.

It is often desirable for one reason or another to exaggerate some portion of the scale. For example, the part of the scale near the maximum permissible amplitude could be expanded so as to guard against overmodulating. An essentially logarithmic scale that can be modified easily over any portion of its range should be quite satisfactory.

Ease of Observation.—Even if the indicating device is capable of responding accurately to the sudden changes and wide range of amplitude encountered, it is still necessary to transfer the information to the mind of the operator so that he in turn may properly control the output volume level. Since it is not possible for him to note the changes at the rapidity with which they take place, some form of delay, either in the electrical circuit or as a result of the operator's persistence of vision, must be relied upon. At the same time, the device should be capable of responding to any increase that may take place during the delay. Also the return to normal should be sufficiently rapid to afford a reasonably accurate indication of the changes of volume taking place over short periods of time.

Summary of Requirements.—The desired characteristics may now be summarized as follows:

(*1*) Peak amplitudes as well as an approximation of the power level should be indicated, even though the wave-form be complex. The response should be uniform over the audio-frequency range.

(*2*) The usable range of intensities, 40 to 50 decibels, should be covered by one scale, arranged to indicate the voltage as accurately as may be necessary at any portion of the scale. A convenient means for modifying this proportionality should be provided.

(*3*) The indicating means should easily permit the operator to observe the peak values as well as the approximate power levels.

PREVIOUS TYPES

Some of the existing types of volume indicator are: a d-c. meter in conjunction with a rectifier, such as a biased detector or a copper-oxide rectifier; a cathode-ray oscillograph; an oscillating-mirror galvanometer for deflecting a beam of light across a scale; a neon tube in which the length of the column increases with applied voltage; and a group of neon lamps so arranged that an increasingly greater number of them glows as the impressed voltage is increased.

The meter and rectifier types usually indicate rms. or average values of the voltage wave, although circuits of the type shown in an earlier paper[2] may be used to indicate peak values. The transient response is not particularly accurate, due to over- or underswinging of the needle, depending upon the damping and inertia of the moving element. Their frequency characteristics are usually quite uniform over the major part of the audio-frequency spectrum. The useful range of the scale is generally limited to about 14 decibels, thereby requiring some means of changing the sensitivity in order to cover the desired range. The indication is roughly proportional to the square of the voltage. A circuit for obtaining a logarithmic response has been shown by Hunt.[3] With the meter type, the indications are somewhat difficult to observe, due to the small size of the scale and pointer which moves rapidly.

The cathode-ray oscillograph, oscillating-mirror galvanometer, and neon column type all indicate the peak of the voltage wave. The frequency characteristic is or can be made linear over the audio-frequency range. The scale is linear, and therefore requires some form of multiplier or special amplifier to extend its range. The response to transients is satisfactory. The indications are easier to observe than those of the meter type units. However, the weakly illuminated portion

FIG. 1. Neon volume indicator.

corresponding to the peak values is somewhat difficult to see due to its proximity to the brighter portion of the column.

The ability of the cathode-ray oscillograph to show the amplitude along one axis, and some other parameter, such as time, carrier frequency, *etc.*, at right angles, has many desirable applications.

An earlier type[4] of volume indicator employing a group of neon lamps, as shown by Bjornson, has several disadvantages. Several lamps are operated from a single amplifier tube, so that the more sensitive lamps may become quite brilliant by the time the voltage is sufficient to cause the more insensitive lamps to glow, or the insensitive ones may glow quite faintly at the time of initial ionization. Considerable audio power is wasted in series resistors, and considerable difficulty is encountered in obtaining uniform response at low frequencies due to the direct current flowing in the transformer. If condensers are used to block the direct current, transient disturbances are encountered. If d-c. bias is applied to the lamps so as to reduce the audio power required, the normally slight changes in ionization voltage of the lamps may be greatly exaggerated as regards the percentage variation in the a-c. voltage required.

NEON VOLUME INDICATOR

Fig. 1 is a front view of a neon type volume indicator designed to approximate the aforementioned characteristics, and primarily intended for sound recording although it is quite applicable to radio broadcasting. As may be seen, the device consists of thirteen neon lamps arranged in a row, with suitable means for causing an increasing number of the lamps to glow as the sound intensity is increased. The *O* calibration marking represents 100 per cent amplitude of the sound-track. The other lamps are calibrated in decibels, plus or minus, from this reference point. The lamp at the extreme left, marked *−45*, represents the lowest signal intensity to which the device will respond. As the level is increased above this value more and more of the neon lamps ionize and begin to glow.

Peak Amplitudes.—The ionization is practically instantaneous, and therefore the peak value is represented by the lamp that is lighted farthest to the right. There is some delay in the extinction of the lamps as the signal intensity is decreased, due to two causes: namely, the deionization time of the lamp, which is of the order of 0.01 second, and the fact that the voltage at which a neon lamp ceases to glow is somewhat below that at which the glow begins. This difference is not a serious detriment, as successive increases in peak amplitude are always indicated. The lower extinguishing voltage is not serious as the wave passes through zero once in every cycle, and the maximum time during which the lamps

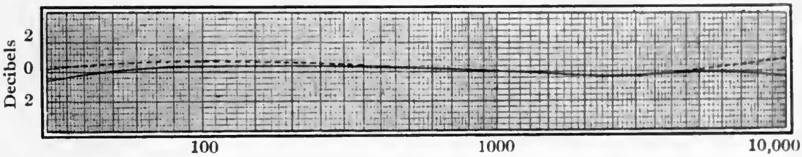

FIG. 2. Response characteristic; neon volume indicator *PB132A1*. Broken curve, *0*-db. lamp; solid curve, −45-db. lamp.

remain illuminated is determined by the frequency of the wave or the definite deionizing time just mentioned. In any case, it will never be longer than half a wavelength at the low frequencies.

Power Level.—Two methods are possible for roughly noting the rms. value for a number of cycles composing the sound. The indicator is capable of responding to only one-half of the audio wave; that is, either to the positive half or that corresponding to sound pressures, or to the negative half or that corresponding to sound rarefactions. It will usually be found that one side of the sound-wave generally that corresponding to pressure, will possess the greater amplitude and consequently will be more peaked than the other half of the sound-wave. If the indicator is connected so as to respond to the low-amplitude half of the wave, the peak amplitudes will approach the rms. values sufficiently closely to assist in matching sound levels over an extended period of time. If it is desired to connect the unit to respond to the other half of the wave, so as to denote the maximum peak amplitudes, the difference in intensity of illumination of the lamps may be used to estimate the energy level, due to the fact that the lamps actuated by the peak voltages are illuminated during only a small portion of time and consequently do not appear as bright as those illuminated over a greater period of time. Then the right-hand end of the illuminated column represents the maximum peak amplitudes. Some point farther to the left, as determined by somewhat brighter illuminations, approximates the energy level or rms. value.

Wave-Form.—The wave-form is not a particular problem, since this type of device is capable of indicating both the rms. and the peak values of the wave. The only noticeable result is the variation of the ratio of peak to rms. value as the wave-form varies.

Frequency.—The frequency response is uniform over the audio range from 30 to 10,000 cps. as demonstrated by Fig. 2. Response curves of only two of the lamps are shown; however, they are quite similar to those of the remaining eleven lamps.

Transients.—The response to transients is exceptionally accurate, because as has been previously pointed out, the ionization of the neon lamps is practically instantaneous. Accordingly, we do not have the over- or underswing as usually occurs in the meter type of volume indicator. As has been previously mentioned,

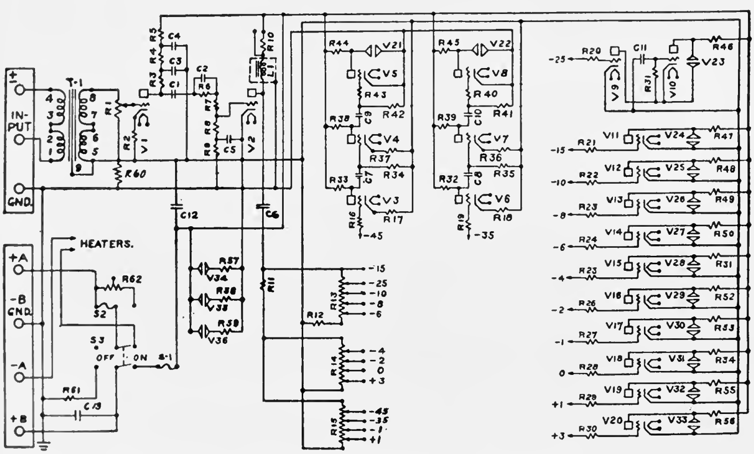

FIG. 3. Schematic diagram of neon volume indicators *MI-3175* and *MI-3176*.

the deionization time of 0.01 second merely causes the lamps to glow for that length of time longer than the indicated voltage exists, but does not prevent a lamp indicating a higher level from starting to glow.

Scale Range and Proportionality.—As may be seen from Fig. 1, the indicator is calibrated to cover a range of 48 decibels; that is, 45 below 100 per cent amplitude and 3 above. Thus, in addition to giving a warning before overshooting occurs, this indicator points out how nearly the weak sounds approach the noise level of the system. At the low levels of amplitude the steps are 10 decibels apart, decreasing to 2 decibels per step over the remainder of the scale. Two additional lamps, *−1* and *+1*, are included so as to denote accurately the amplitude near the overshooting point. Smaller increments of indication near the low end might be more desirable, but it was felt that the additional size and complication was not warranted, as this portion of the range, although quite necessary, is not used as frequently as the portion representing somewhat higher levels. However, as will be shown later the scale may be easily modified if desired.

Ease of Observation.—Several features of the neon volume indicator combine to assist the operator to note quickly and easily the amplitudes resulting from the sound-waves. The delay in extinction of the lamps, as well as the persistence of vision of the operator, facilitate reading peak amplitudes. Since the lamps are arranged to indicate in steps rather than continuously, it is much easier to note the maximum amplitude; a weak light in a dark space provides greater contrast than the same amount of illumination adjacent to a more brightly illuminated portion of the scale. In addition, a flashing type of illumination seems to be eaiser for the eyes than one of which the illuminated portion is increased and decreased in length.

The actual light intensity of each lamp remains approximately constant from

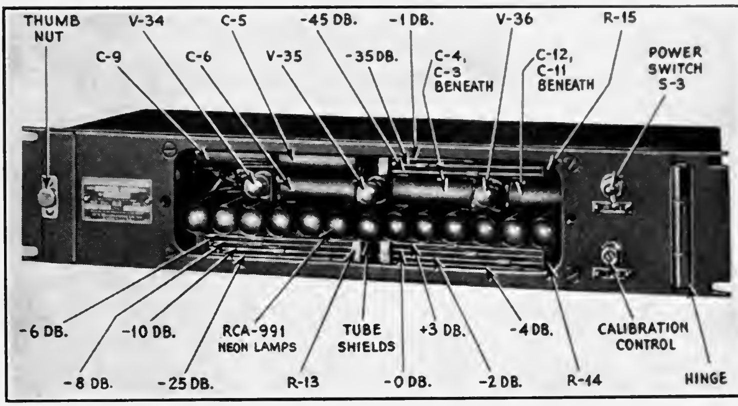

FIG. 4. Front view of neon volume indicator, with cover removed.

the ionization point to maximum brilliancy; the apparent illumination changes as a function of the time the lamp remains glowing. This prevents any of the lamps from being sufficiently brilliant to reduce the visibility of the others.

The effect of the surrounding lighting is not as serious as it is with many other types of indicators. The characteristic color of the neon lamps and the directly visible electrodes make the indication easily visible in a moderately lighted room. The markers indicating the levels are so illuminated as to provide for easy observation even in a moderately lighted room or in total darkness. In addition, the scale has been divided into several sections, according to amplitude, by making three of the markers brighter than the others, and making it unnecessary to note the actual markings on the scale once the operator has become acquainted with the significance of the divisions. These brightly illuminated markings are zero db. (or 100 per cent amplitude), −6 db. (50 per cent amplitude), and −25 db. (approx. $5^1/_2$ per cent amplitude). The illumination of the markers, as well as that of all the others, is obtained from neon lamps and is diffused so as to provide contrast between these lamps and the indicating lamps. The exceptionally long scale makes observation easier and the changing of sensitivity unnecessary.

Circuit.—Fig. 3 is a schematic circuit diagram of the *MI-3175* and *MI-3176* neon volume indicators. The circuit includes a two-stage amplifier composed of two *RCA-955* radiotrons, V_1 and V_2, and the input transformer T_1 which reflects a 30,000-ohm load to the source of audio frequencies and has a flat response for any source impedance from 0 to 30,000 ohms. The output of this amplifier is fed into the potentiometers R_{13}, R_{14}, and R_{15} to which the thirteen indicating lamps *RCA-991* and associated amplifiers are connected. The amplification of each circuit is such as to give the required sensitivity, at the same time maintaining the

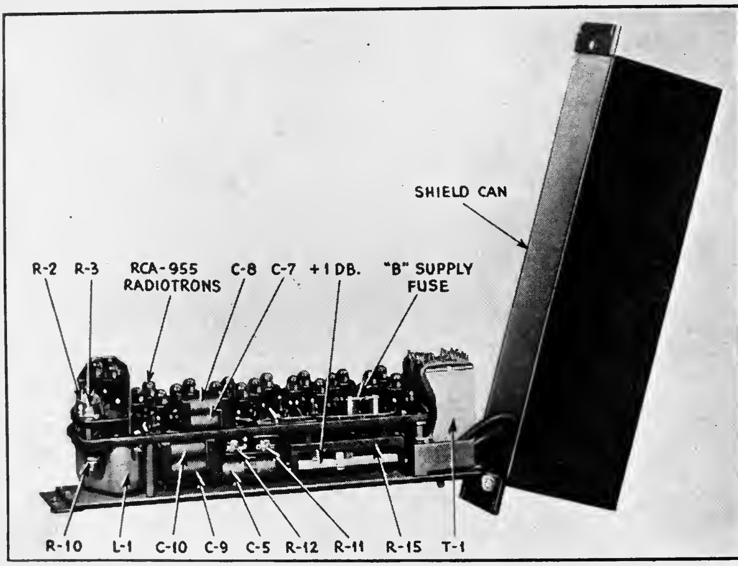

FIG. 5. Top view of neon volume indicator, with panel swung out of shield.

same overall phase rotation. The ratio of the voltages applied to the various circuits is such as to cause the lamps to glow in the order and relation indicated by the calibration marks on the scale. Adjustment is provided by the sliders shown in Fig. 4; the arrows pointing to these controls are designated by the decibel calibration of the associated lamps. The −15-db. lamp is used as a reference for adjusting the sensitivity of the remaining lamps. R_1 provides for overall calibration.

The cycle of operation of the neon lamps will now be described, beginning at the time when the *RCA-955* radiotrons, V_5, V_8, V_{10}, and V_{11} to V_{20}, inclusive, are drawing sufficient plate current so that the voltage across their respective neon lamps V_{21} to V_{33}, inclusive, is insufficient for ionization of the neon. Such a condition exists when no signal is applied to the input terminals.

For simplicity the operation of the +3 lamp, V_{33}, will be described. As the grid of the amplifier V_{20} is made more negative, the drop through the plate resistor R_{56} is reduced until the voltage across the neon lamp, V_{33}, reaches the ionization point, approximately 70 volts. At this point, the lamp begins to glow, and continues to glow as long as the grid is sufficiently negative. As the grid voltage approaches zero, the plate current in V_{20} increases, and accordingly the voltage across V_{33} decreases. When this voltage becomes less than approximately 55 volts, the lamp ceases to glow. Thus it is apparent that the lamps indicate only during the negative half-cycle of the a-c. voltage applied to the grids of the final amplifier stages.

Phasing of the other amplifier stages is such that the glowing takes place during the half-cycle that the plus-minus terminal of the input transformer is negative. This plus-minus marking agrees with markings on the other units of the standard film recording equipment, thereby assuring proper phasing.

The use of a separate, directly coupled, low-power amplifier for each neon lamp limits the total range of power supplied to each lamp. Accordingly, the illumination does not vary greatly from the point of ionization to the point of plate cut-off. Neon lamps are used to illuminate the calibration markers located above the individual neon lamps.

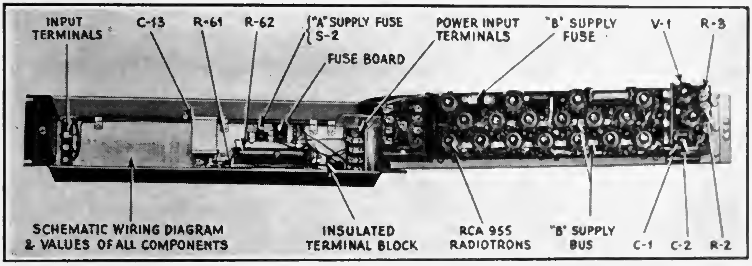

FIG. 6. Rear interior view of neon volume indicator.

Power.—The power requirements are: 180 volts d-c. at 20 milliamperes, or 275 volts d-c. at 30 milliamperes, for plate current; 6–8 volts d-c. or 6.3 volts a-c. at 3.2 amperes, for heater current. The filament circuit may be grounded as required.

Resistor, R_{10}, is included in the plate circuit of V_2 when a 275-volt plate supply is used; that is, when this voltage is obtained from the bridging amplifier of the recording system. It is short-circuited when the indicator is supplied by a 180-volt source. The other stages have sufficiently high plate resistors to make a change in the circuit unnecessary when changing from one voltage to the other. Resistor R_{61} is provided to simulate the load furnished by the neon indicator when plate voltage is supplied from the *MI-3223* bridging amplifier of the recording channel. This resistor is open-circuited when other sources of plate supply are used.

Mechanical.—Figs. 1, 4, 5, and 6 show the mechanical construction of the neon volume indicator. The *MI-3175* and *3176* indicators are essentially the same. The principal difference is in the appearance of the front surface. The *MI-3175* is intended for rack mounting, and the *MI-3176* for mounting in the standard recording mixer consoles, *MI-3114* and *MI-3117*. The panel of the neon indicator is hinged at the right edge so that the entire amplifier may be swung open for service or inspection. This gives access to the *RCA-955* radiotrons, whereas the *991* neon lamps may be reached by removing the cover plate from the front panel.

The assembly of the unit has been made very compact so as to require relatively small space, which is usually at a premium near the mixing equipment. However, every effort has been made to facilitate servicing the unit. The sockets for the *RCA-955* radiotrons are made from bakelite cylinders, with the associated circuit resistors of each radiotron mounted thereon and connected to terminals on the inside diameters of the sockets. Connection to the plate supply is made through metal strips to which the appropriate terminals of the sockets are screwed, thereby providing both electrical connection and mechanical mounting. The neon lamps fit into automobile type sockets which are mounted by means of screws extending through the bakelite sub-panel from the rear. These screws provide for electrical connection as well as the mounting. Such assembly facilitates the replacement of any of these parts.

The overall dimensions of the indicator are 19 inches wide by $3^1/_4$ high by $5^3/_8$ deep, and the weight with tubes is 18 pounds.

APPLICATIONS

A few of the applications for which this type of neon volume indicator may be employed are:

(1) Film Recording.

(2) Radio Broadcasting.

(3) Disk Recording. (One rather desirable usage is the indication of the peak amplitudes of the recording stylus; a suitable wave-filter is required.)

(4) Investigating the composition of sounds as to peak amplitudes. (For example, a neon volume indicator and means for making a continuous photographic record of the indicating lamps could be used to replace the peak amplitude recording device used by Sivian, Dunn, and White[5].)

REFERENCES

[1] FLETCHER, H.: "Speech and Hearing," *D. Van Nostrand Co.* (New York, N. Y.), 1929, p. 230.

FLETCHER, H., AND MUNSON, W. A.: "Loudness, Its Definition, Measurement and Calculation," *Bell Sys. Tech. J.*, **XII** (Oct., 1933), p. 377.

[2] READ, S., Jr.: "RCA Victor High-Fidelity Film Recording Equipment," *J. Soc. Mot. Pict. Eng.*, **XX** (May, 1933), No. 5, p. 396.

[3] HUNT, F. V.: "Voltmeter-Vacuum Tube with Logarithmic Response," *Rev. Sci. Inst.*, **IX** (Dec., 1933), p. 672.

[4] BJORNSON, B. G.: U. S. Pat. 1,759,604.

[5] SIVIAN, L. J., DUNN, H. K., AND WHITE ,S. D.: "Absolute Amplitudes and Spectra of Certain Musical Instruments and Orchestras," *J. Acous. Soc.*, **II** (Jan., 1931), p. 330.

REPRODUCING EQUIPMENT FOR MOTION PICTURE THEATERS*

M. C. BATSEL AND C. N. REIFSTECK**

Equipment for reproduction of sound motion pictures is located in two places in every theater. The loud speaking or reproducer equipment is on the stage behind the sound screen, and the sound head and amplifiers are in the projection room, usually located at the rear of the theater.

The main elements for successful reproduction of sound accompanying a picture are:

(*1*) A sound head used for translation of the photographic sound record into minute electrical energy.

(*2*) Amplifying equipment to increase the minute electrical energy from the sound head to a value that will operate the loud speakers at the required volume.

(*3*) Loud speaking equipment which translates electrical energy to acoustical energy or sound.

In addition to these three major elements, there are other associated parts used as part of the complete equipment to insure proper performance in the theater. Some of these are: change-over switching systems to transfer the amplifier from one machine to another for continuous performance; a monitor speaker for the projectionist; and, in some installations, a remote volume control located in the auditorium.

(A) THE SOUND HEAD

The sound reproducing attachment or sound head is used in conjunction with a standard motion picture projector. It contains all the optical, electrical, and mechanical equipment necessary to convert the variations in opacity of the photographic sound record into electrical currents.

A recent high-fidelity sound head, known as the rotary stabilizer type, is shown in Fig. 1. This designation refers to the system employed for imparting a steady motion to the film at the point where the translation takes place. This type of sound head is considered a decided improvement over previous types used.

The first types of sound heads employed fixed sound gates consisting of stationary guide plates and pressure shoes for holding the film in the position where it was pulled by a sprocket past the translation point. Experience demonstrated that these gates required almost constant attention to prevent the accumulation of wax and emulsion upon the polished surfaces of the film guides and pressure shoes to prevent the film from chattering or being scratched, which would result in noisy reproduction of the sound. The frictional resistance to the film passage resulted in wear of the guides and pulling sprockets.

A major problem in the first types of sound heads was the achievement of a constant speed of the film at the translation point. Many attempts were made to

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

make the pulling sprocket directly below the gate revolve at a uniform velocity by the use of elaborate mechanical filters between the driving motor and the sprocket. In the best of these systems some ripple was present in the sound reproduction from the film, due to uneven motion of the film resulting from imperfect mechanical parts. A serious flutter or rapid variation in the motion resulted from the use of a sprocket to pull the film through the gate by means of the perforations in the film.

The rotary stabilizer type of sound head was designed to eliminate all the objections of the gate type. This was accomplished by the use of a rotating drum to

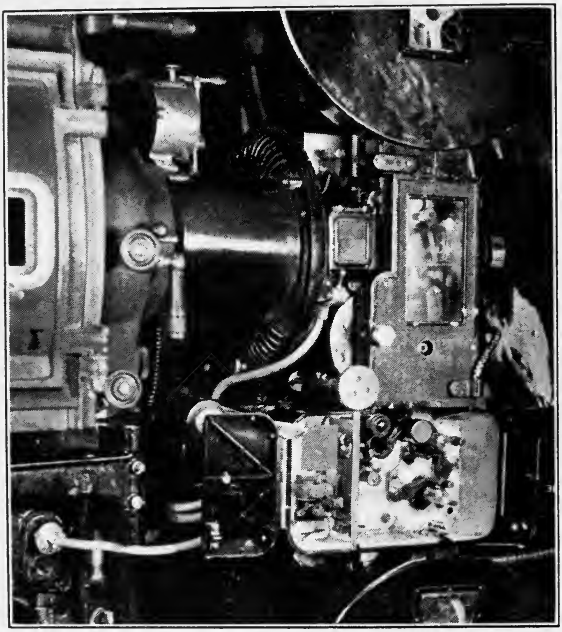

FIG. 1. Rotary stabilizer type of sound head.

which is attached the rotary stabilizer elements. Special care was taken to see that the film as it passes through the sound head is bent into as wide a curve as possible, insuring that it would lie flat and all points of the sound-track would be in focus. The free-running sound drum shaft is mounted in ball bearings so that the friction is reduced to such a small amount that it is possible for the film to drive this drum without appreciable tension. This tension is so light that the film is never pulled taut except at the start. The film being in contact with the drum, rotates with it. This prevents any possibility of film scratching. The film assumes a curved path after leaving the sound drum. The stiffness of the film serves as a compliance which, in conjunction with the mass of the rotating elements, acts as a filter to eliminate variation in the motion of the film at the translation point.

The best known expedient for uniform rotation is the fixed flywheel on a shaft. This, however, is unsatisfactory for control of the drum shaft because the flywheel would continually hunt or oscillate with the springy film loop in the same manner that a weight suspended from a coiled spring would oscillate under the slightest disturbance.

The theory of the rotary stabilizer principle was discovered several years ago and was later further elaborated and expanded. This work led to a device for controlling the drum speed that fulfilled the conditions required for a satisfactory reproducer, namely that the system be damped so as to prevent oscillation of the mass of the rotating system when propelled by a spring for absorbing irregularities in the motion of the driving mechanism. The practical form of this reproducer sound head consists of a light case constructed as a short cylindrical casing firmly

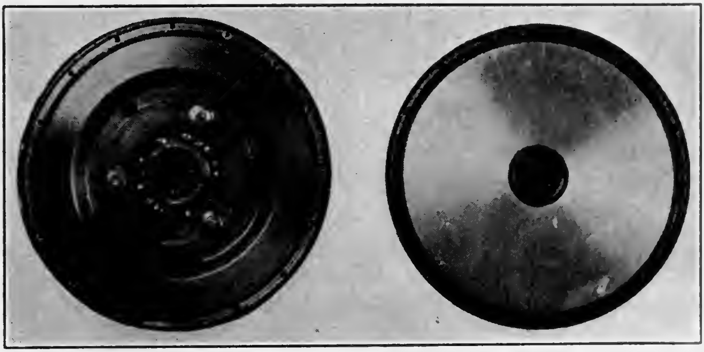

FIG. 2. Rotary stabilizer.

fastened to the drum shaft. Inside the casing upon a hub forming part of the case, a heavy free-floating flywheel is carried on a ball bearing. (Fig. 2.) A light oil fills the remaining space inside the case. The oil acts as a viscous driving medium between the heavy flywheel and the case. The case is sealed so as to be oil-tight. Any tendency for oscillation between the stabilizer assembly and the film loop is prevented, due to the fact that the energy of the disturbance is dissipated in the oil when there is relative motion between the casing and the flywheel, which does not follow rapid changes in the motion of the casing because of its inertia. The relative moments of inertia of the casing and flywheel are approximately one to eight.

To keep the film in proper position upon the drum, it passes between two flanged rollers mounted directly above the drum. To accommodate film of various degrees of shrinkage, one flange is movable. The fixed flange is on the sound-track side, and is known as the guiding roller. The flange assembly is also adjustable within limits so that the sound-track may be adjusted to the correct position for being scanned by the light-beam passed through it to a photocell.

The light-beam is approximately 0.001 by 0.084 inch. It is obtained by focusing an image of a slit in a diaphragm (five times as large) upon the film. The diaphragm in which the slit is put is illuminated by a 10-volt, 5-amp. lamp and a condensing lens. A small collector lens is mounted in the drum over which the film passes. This directs the light to a photoelectric cell. The cell is connected through a transformer of suitable impedance ratio for connecting to a 500-ohm line to the amplifier.

To eliminate possible noise due to vibration of the lamps or photocell, the motor is mounted upon rubber, and the rotating sound drum, optical system, photocell, photocell transformer, and exciter lamp are also mounted upon one plate and resiliantly mounted to the main case of the unit.

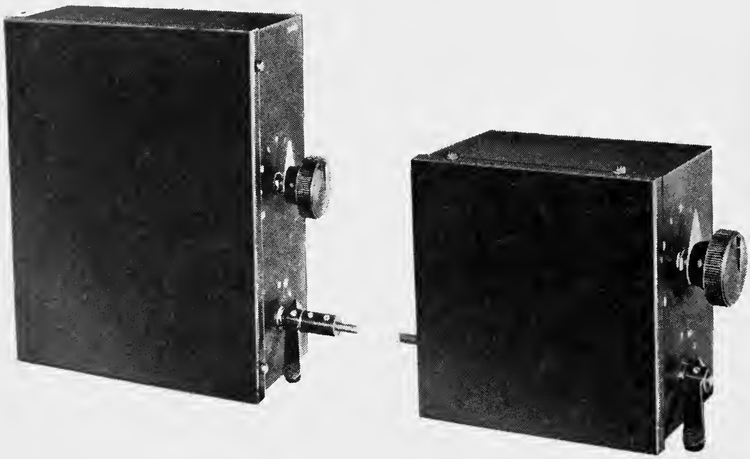

FIG. 3. Fader box.

(B) AMPLIFYING EQUIPMENT

A current type of amplifying equipment consists essentially of a fader box (Fig. 3) mounted upon the front wall of the projection room at each projector; a main amplifier (Fig. 4); a monitor speaker amplifier; a monitor speaker (Fig. 5); and an exciter lamp and loud speaker field supply unit (Fig. 6).

The fader system is used to connect the sound head to the amplifier at the time the picture changes from one reel to another. It consists of a switch for exciter lamp change-over and a 20-db. variable attenuator pad. This pad serves to preset the volume from the machine to a predetermined level, or to eliminate changes in volume at the change-over due to different sound level on the film. By this means the projectionist need not leave his position at the projector to make adjustments of volume after the change-over.

The main amplifier in Fig. 4 is the type used in the larger theaters. It is so constructed that all parts can be removed from the front for ease of service. It consists of a voltage amplifier and one or two power amplifiers. The equipment is,

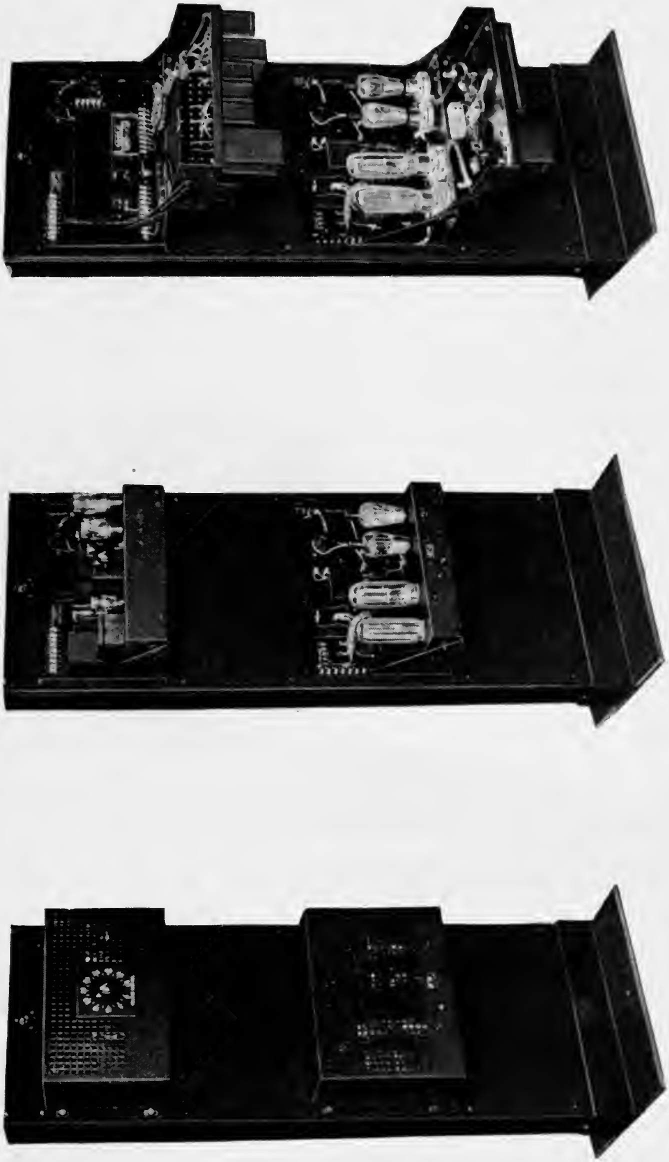

FIG. 4. Main amplifier.

completely a-c. operated and self-contained. Each amplifier is complete in itself including its own rectifiers for power supply. The voltage amplifier has sufficient voltage amplification to drive the power amplifiers when the input terminals are connected to the line from the photocell transformer. Both voltage and power amplifiers are novel in construction. Each amplifier consists essentially of three parts; namely, a vertical panel, a base proper, and a base support. On the vertical panel attached to the rear of the rack are mounted the heavy power supply parts, such as power transformers, filter reactors, *etc.*, and the base support. On the base support are mounted very few parts, as its main function is that of sup-

FIG. 5. Monitor speaker.

porting the main base and the inter-panel cabling. On the main base are mounted the main amplifier parts and the tubes. This main base is so constructed that it can be hinged down for inspection and service. It can also be completely removed without the use of a soldering iron, as all connections are made to the vertical panel through screw terminals. In the circuits employing large capacitors these are segregated into sections in parallel. Important sections of capacitors and points of the circuit are fused against possible trouble. Failure of a section of the filter capacitor that is fused will permit the program to continue until the end or until such time as repairs can conveniently be made.

An indicator of the neon lamp type is placed in the plate circuit of the amplifiers to indicate that the circuit is functioning properly. The lamp is lighted at all times; failure to light indicates no plate current to the tubes. The trend in recent years in electrical equipment has been to eliminate all unnecessary controls and meters. Alternating-current operated amplifiers and modern amplifier tubes do not require tube controls or meters for adjustment. Only one manual control is found on the main amplifier. This is the master volume control, which can be preset and need not be changed for the entire performance. Experience of projectionists (who are occupied in keeping the show going) with this type of amplifier in the past years indicates that the design is practicable and capable of meeting the requirements for uninterrupted service.

The monitor amplifier is self-contained with its power supply, and is mounted

FIG. 6. Exciter lamp and loud speaker field supply unit.

in some convenient location upon the projection room wall. It is made to bridge the speech circuit to the stage. It has a separate volume control to permit adjustment for noise conditions encountered in a projection booth. Its output is sufficient to drive the monitor speaker (Fig. 5) to give adequate sound at each projector station. Monitor speakers are primarily used to indicate that the speech circuit to the stage is functioning properly, and to give the operator the proper sound cue for change-over from one machine to another.

The exciter lamp and loud speaker field supply rectifier and filter unit (Fig. 6) supplies power for the exciter lamp in the sound head (10 volts at 5 amp.), and 18 watts at 12 volts for each of the loud speakers. Change-over from one machine to another is accomplished by means of a relay controlled by the control switch at each projector station.

(C) LOUD SPEAKER EQUIPMENT

A recent design of loud speaker (Fig. 7) equipment to be installed on the stage consists of two separate speakers, one of which reproduces the frequency range below 300 cps. and the other above 300 cps. A dividing network or filter serves to divide the electrical output of the amplifier accordingly.

The low-frequency speaker is made up of two folded exponential horns, each 40 inches high by 80 inches wide, mounted one above the other. Each horn has

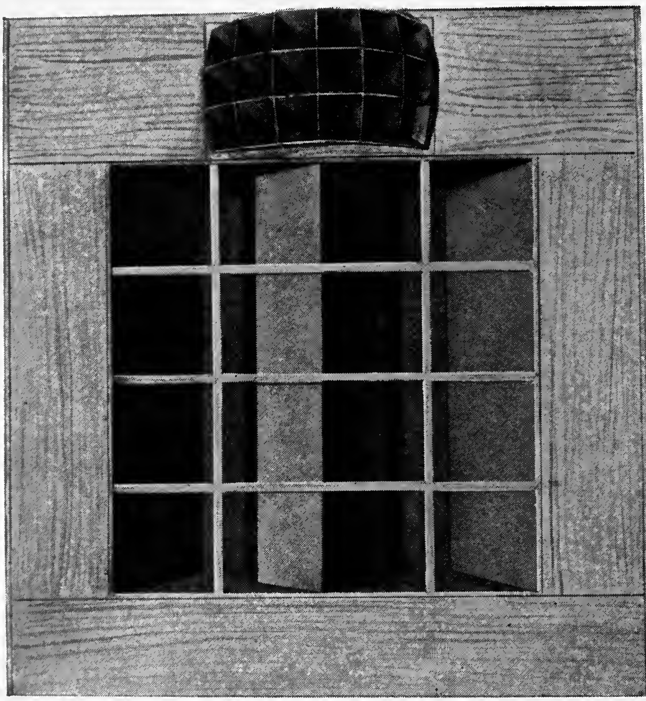

FIG. 7. Multiple section loud speaker.

two 14-inch cone type driver units. The frequency range is from 40 to 300 cps. as used with the dividing network.

The high-frequency speaker is of the exponential type. It consists of a number of small exponential horns, each measuring at the bell opening approximately 7 × 7 inches. These small horns are assembled into clusters, forming the equivalent of a large horn with partitions dividing it into sections. All sections are driven by two speaker mechanisms through a *Y* throat.

A plain exponential horn has a directional characteristic that varies with frequency. The higher the frequency the more narrow the beam becomes. A single exponential horn mounted in place of the multiple-section horn shown in

Fig. 7 would give a resultant "bassy" reproduction to that portion of the audience in seats located well off the axis, and the reverse would be true for those directly upon the axis.

This effect is eliminated if a cluster of small exponential horns is used. The mouth opening formed by the cluster is spherical in shape. Four sizes are used for various types of theaters, each three layers of the small horns in height, and varying in angle from approximately 52$^1/_2$ to 105 degrees, in clusters of nine, twelve, fifteen, and eighteen of the small horns. The width of the theater and the acoustical properties of the side walls determine the angle used. The high-frequency speaker operates over a frequency range from 300 to 10,000 cps. The 300-cycle

FIG. 8. Low-frequency speaker.

crossover was selected as a compromise on high-frequency horn length. Moving it to a higher frequency is a disadvantage from the standpoint of division of primary speech sounds. The limitation in depth of the speaker assembly is brought about by the necessity of flying the speakers on theater stages where stage presentations are given and the loss of lines for scenery drops is a problem.

The low-frequency driver mechanism (Fig. 8) is a high-efficiency cone type dynamic speaker. Four of these are used per installation. The high-frequency driver mechanism (Fig. 9) is a cone type unit. The cone is molded from a fiber sheet and has no seams. It is treated to make it moisture proof. It has been determined that the strength per unit weight or mass of the diaphragm for this fiber is greater than can be obtained with other materials.

The size of the auditorium and its acoustic properties have a very definite influence upon the size of the equipment to be installed, and frequently the acoustical characteristics of the auditorium require that the characteristics of the equipment be adjusted to compensate for undesirable effects. It may be necessary, due to high absorption of the low frequencies, to supply additional energy to the low-frequency speakers and *vice versa.*

FIG. 9. High-frequency loud speaker driving mechanism.

It is customary to rate equipment according to theater seating capacity and volume of the auditorium. Experience has shown that the following classification of theaters as to size results in a commercially satisfactory arrangement of equipment:

	Cubical contents in cu. ft.
Up to 500 seats	75,000
500 to 800 seats	120,000
800 to 1400 seats	200,000
1400 to 3000 seats	720,000
3000 up—Special custom equipment	

The type of sound head used is not dependent upon the size of the theater. For economic reasons the types and sizes of amplifiers and speaker complements are selected as required for the seating capacity and size of the theater. It is desirable that all equipment be installed under the supervision of factory trained installation engineers who make the final tests and adjustments of the installation.

CURRENT LITERATURE OF INTEREST TO THE MOTION PICTURE ENGINEER

The editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic copies may be obtained from the Library of Congress, Washington, D. C., or from the New York Public Library, New York, N. Y. Micro copies of articles in those magazines that are available may be obtained from the Library of the U. S Department of Agriculture, Washington, D. C.

American Cinematographer

18 (March, 1937), No. 3.

They Make Pictures in India (p. 90).	P. Perry
Production Night-Effects with Agfa's Fundamentally New Type of Infrared Film (p. 96).	A. F. Edouart
Coaching an Olympic Team with 16-Mm. Movies (p. 112).	J. R. Hubbard
If You Make Movies, Amateur or Professional, You Just Can't Help Doing These Transition Things (p. 114).	W. Stull
Background *vs.* Foreground Lighting (p. 118).	F. B. Good

British Journal of Photography

84 (Feb. 12, 1937), No. 4006.

Small Motion Picture Cameras (p. 102).

84 (Feb. 19, 1937), No. 4007.

Amplifiers in Small Sound Projectors (p. 114).	T. F. Langlands

84 (Feb. 26, 1937), No. 4008.

Practical Considerations Concerning the E. S. S. Density Meter (p. 130).	G. C. Cato

Electronics

10 (March, 1937), No. 3.

Philco Shows 441-Line Television (p. 9).

Filmtechnik

13 (Feb. 27, 1937), No. 4.

A Model Sound-Film Studio (Ein Modernes Tonfilmatelier) (p. 29).	
A New Means of Sound-on-disk (Nadelton auf neuen Wegen) (p. 34).	P. Hatschek
A New Modulation Indicator (Ein neuer Aussteuerungsanzeiger) (p. 36).	H. Neumann

International Projectionist

12 (Feb., 1937), No. 2.

Types of Shutters and Their Effect upon Projection II (p. 7). — A. C. SCHROEDER
What is the Present Position of Color Cinematography? (p. 12). — D. A. SPENCER
Commutators: A Little Care Saves Big Repair Bills (p. 16). — L. E. MILLER
Constructional Changes in Some Sound System Components (p. 17). — L. CHADBOURNE
Eye-Strain: A Definite Occupational Hazard for Projectionists (p. 24). — C. R. UNDERHILL, JR.

12 (March, 1937), No. 3.

The Simplex Shutter and Its Adjustment (p. 7). — A. C. SCHROEDER
What Is the Present Position of Color Photography? (p. 11). — D. A. SPENCER
The New Super-Simplex Pedestal (p. 16).
A New Projection Tool: The Cathode-Ray Oscilloscope (p. 17). — L. P. WORK
The Right and Wrong Use of Sound Equipment Testing Units (p. 24). — L. CHADBOURNE

International Photographer

9 (March, 1937), No. 2.

Making History with Cinecolor (p. 4). — H. C. BROWN
Duplex Super Camera (p. 7).
Talkies on 16-Mm. Film—A Success (*I*) (p. 18). — A. P. HOLLIS

Journal of the Acoustical Society of America

8 (April, 1937), No. 4.

Transposition of Speech Sounds (p. 217). — E. BARANY
Sound Analysis (p. 257). — H. H. HALL

Journal of the Association of Cine Technicians

2 (Dec., 1936–Jan., 1937), No. 7.

Some Recent Developments in Sound Recording Equipment (p. 86). — W. H. CLARKE
Otto Kanturek on British Chemicolour (p. 106).

Journal of the Optical Society of America

27 (March, 1937), No. 3.

Graininess of Photographic Materials in Objective Absolute Measure (p. 100). — A. VAN KREVELD, J. C. SCHEFFER
Photometric Discrimination with a Diffuse Boundary (p. 112). — W. E. K. MIDDLETON
On the Precision of Photometric Observations (p. 120). — A. H. HOLWAY
A Further Search for the Ideal Color System. (I) A New Mechanico-Graphical Method (p. 124). — R. H. SINDEN

A Brightness Meter (p. 132). — M. LUCKIESH, A. H. TAYLOR

Kinotechnik

19 (Feb., 1937), No. 3.

New Work in the Sound Recording Field (Neuere Arbeiten auf dem Gebiete der Tonaufnahme) (p. 39). — H. WARNCKE

Fine-Grain Emulsions, Fine-Grain Development, and Sensitivity (Feinkornschichten, Feinkornentwicklung und Empfindlichkeit) (p. 51). — G. SCHWARZ

Motion Picture Herald (Better Theaters Section)

126 (March 6, 1937), No. 10.

What Makes the Most Efficient Theater Air-Conditioning System? (p. 15).

Recent Developments in Stage Lighting Methods (p. 20). — H. KLIEGL

127 (April 3, 1937), No. 1.

Getting the Most out of Modern Sound Equipment (p. 31). — A. NADELL

Movie Makers

12 (March, 1937), No. 3.

The Double System for Sound (p. 122). — J. A. MAURER

Photographic Journal

77 (March, 1937).

The Photographic Latent Image Considered from the Standpoint of the Quantum Mechanics Model of Crystals (p. 142). — J. H. WEBB

Search for Causes of Graininess (p. 161). — D. A. SPENCER

Sub-Standard and Professional Apparatus (p. 164).

Photographische Industrie

35 (Feb. 24, 1937), No. 8.

Type B and C Projectors Permitted in Germany (Die in Deutschland zugelassenen Bildwerfer der Typenklasses B and C) (p. 263).

35 (Mar. 3, 1937), No. 9.

The Preparation of Black-and-White Enlargements from Agfacolorfilm (Die Herstellung von Schwarz-Weiss-Vergrosserungsbildern von Agfacolorfilm) (p. 281). — A. SCHILLING

Comparison of the Quality of Sound Records (Zum Qualitatsvergleich von Tonschriften) (p. 298).

Proceedings of the Institute of Radio Engineers

25 (March, 1937), No. 3.

Automatic Tuning, Simplified Circuits, and Design Practice (p. 289). — D. E. FOSTER, S. W. SEELY

A Graphical Design of an Intermediate-Frequency Transformer with Variable Selectivity (p. 340). C. BARANOVSKY
A. JENKINS

Science et industries photographiques

8 (Feb., 1937), No. 2, Series 2.

Carotinoids: A New Series of Photographic Sensitizers (Les Carotenoides: Une nouvelle serie de sensibilisateurs photographiques) (p. 33). E. CALZAVARA

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SOCIETY ANNOUNCEMENTS

HOLLYWOOD CONVENTION

As the Hollywood Convention will be in progress at the time this issue of the JOURNAL goes to press, further details will be published in the succeeding issue. The tentative program and abstracts of many of the papers will be found in the May issue, and in the July issue will be published a description of the highlights of the Convention, together with the final program as actually followed.

ATLANTIC COAST SECTION

At a meeting held on April 21st at the Studios of RCA Photophone, Inc., New York, N. Y., Dr. V. K. Zworykin, *Director*, Electronic Research Laboratory of RCA Manufacturing Company, Camden, N. J., presented a paper on television. The meeting was well attended and considerable interest was shown in the discussion that followed the presentation. The material presented by Dr. Zworykin is contained in large part in an article published by him in the May issue of the JOURNAL, supplemented by a rather complete description of the television installations in the Empire State Building and Radio City, New York.

PACIFIC COAST SECTION

At a meeting held at the Hollywood-Roosevelt Hotel on April 15th, Mr. G. F. Rackett presented a discussion of the production activities of the various motion picture producers in England, and compared their activities with relation to those in Hollywood. Following Mr. Rackett, Mr. A. E. F. MacInerny, who has been connected with studio and theater installations in Great Britain and Japan, elaborated further on the operation of the British studios and the markets for British and American-made films.

Mr. Jack Okey, who has also been connected with the construction of British studios, continued the discussion further, with regard to the local conditions governing studio construction, and Messrs. C. Rosher, A. Gilks, and R. Rennahan, who had all taken part as cameramen in the production of various British pictures, discussed some of the problems facing the cameramen in British studios.

JOURNAL AWARD AND PROGRESS MEDAL

The following regulations pertaining to the Journal Award and the Progress Medal of the Society of Motion Picture Engineers are published in accordance with the provisions for such publication contained therein. Members of the Society who wish to nominate recipients for either or both the Awards should communicate their nominations to the General Office of the Society as promptly as possible.

JOURNAL AWARD

The Journal Award Committee shall consist of five Fellows or Active members of the Society who shall be appointed by the President and confirmed by the Board of Governors. The Chairman of the Committee shall be designated by the President.

A cash award ($50, or other sum as may be appropriated by the Board of Governors) shall be made at the Fall Convention of the Society to the author or authors of the most outstanding paper which is originally published in the JOURNAL of the Society during the preceding calendar year. This Award shall be known as the Journal Award. An appropriate certificate shall be presented to the author or to each of the authors, as the case may be.

A list of five other papers shall also be recommended for honorable mention by the Committee.

A majority vote of the entire Committee shall be required for the election to the Award. Absent members may vote in writing.

The Committee shall be required to make its report to the Board of Governors for ratification at least one month prior to the Fall Meeting of the Society.

These regulations, a list of the names of those who have received the Journal Award, the year of each award, and the titles of the papers shall be published annually in the JOURNAL of the Society. In addition, the list of five papers selected for honorable mention shall be published in the JOURNAL of the Society during the year current with the Award.

The Journal Award Committee for the current year is as follows:

E. A. WILLIFORD, *Chairman*

A. C. HARDY E. HUSE G. F. RACKETT

The Awards in previous years have been as follows:

1934—Peter Andrew Snell, for his paper entitled "An Introduction to the Experimental Study of Visual Fatigue." (*Published May, 1933*)

1935—Loyd Ancile Jones and Julian Hale Webb, for their paper entitled "Reciprocity Law Failure in Photographic Exposure." (*Published September, 1934*)

1936—E. W. Kellogg, for his paper entitled "A Comparsion of Variable-Density and Variable-Width Systems." (*Published September, 1935*)

PROGRESS MEDAL

The Progress Award Committee shall consist of five Fellows or Active members of the Society, who shall be appointed by the President and confirmed by the Board of Governors. The Chairman of the Committee shall be designated by the President.

The Progress Medal shall be awarded each year to an individual in recognition of any invention, research, or development which in the opinion of the Committee, shall have resulted in a significant advance in the development of motion picture technology.

Any member of the Society of Motion Picture Engineers may recommend persons deemed worthy of the award. The recommendation in each case shall be in writing and in detail as to the accomplishments which are thought to justify consideration. The recommendation shall be seconded in writing by any two Fellows or Active members of the Society, who shall set forth their knowledge of the accomplishments of the candidate which, in their opinion justify consideration.

The Committee shall meet during the month of July. Notice of the meeting of the Committee held for the purpose of considering the award of the Progress Medal shall appear in the June issue of the JOURNAL. All proposals shall reach the Chairman not later than June 20th.

A majority vote of the entire Committee shall be required to constitute an award of the Progress Medal. Absent members may vote in writing.

The report of the Committee shall be presented to the Board of Governors for ratification at least one month before the Fall Meeting of the Society.

The recipient of the Progress Medal shall be asked to present a photograph of himself to the Society, and, at the discretion of the Committee, may be asked to prepare a paper for publication in the JOURNAL of the Society.

The regulations, a list of the names of those who have received the medal, the year of each award, and a statement of the reason for the awards shall be published annually in the JOURNAL of the Society.

The Progress Medal Award Committee for the current year is as follows:

A. N. GOLDSMITH, *Chairman*

M. C. BATSEL J. I. CRABTREE R. M. EVANS

The 1935 Award was made to Edward Christopher Wente, for his work in the field of sound recording and reproduction (*cf. issue of December, 1935*).

The 1936 Award was made to Charles Edward Kenneth Mees for his work in photography (*cf. issue of December, 1936*).

The meeting of the Committee will be held July 6th.

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MOTION PICTURE ENGINEERS

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